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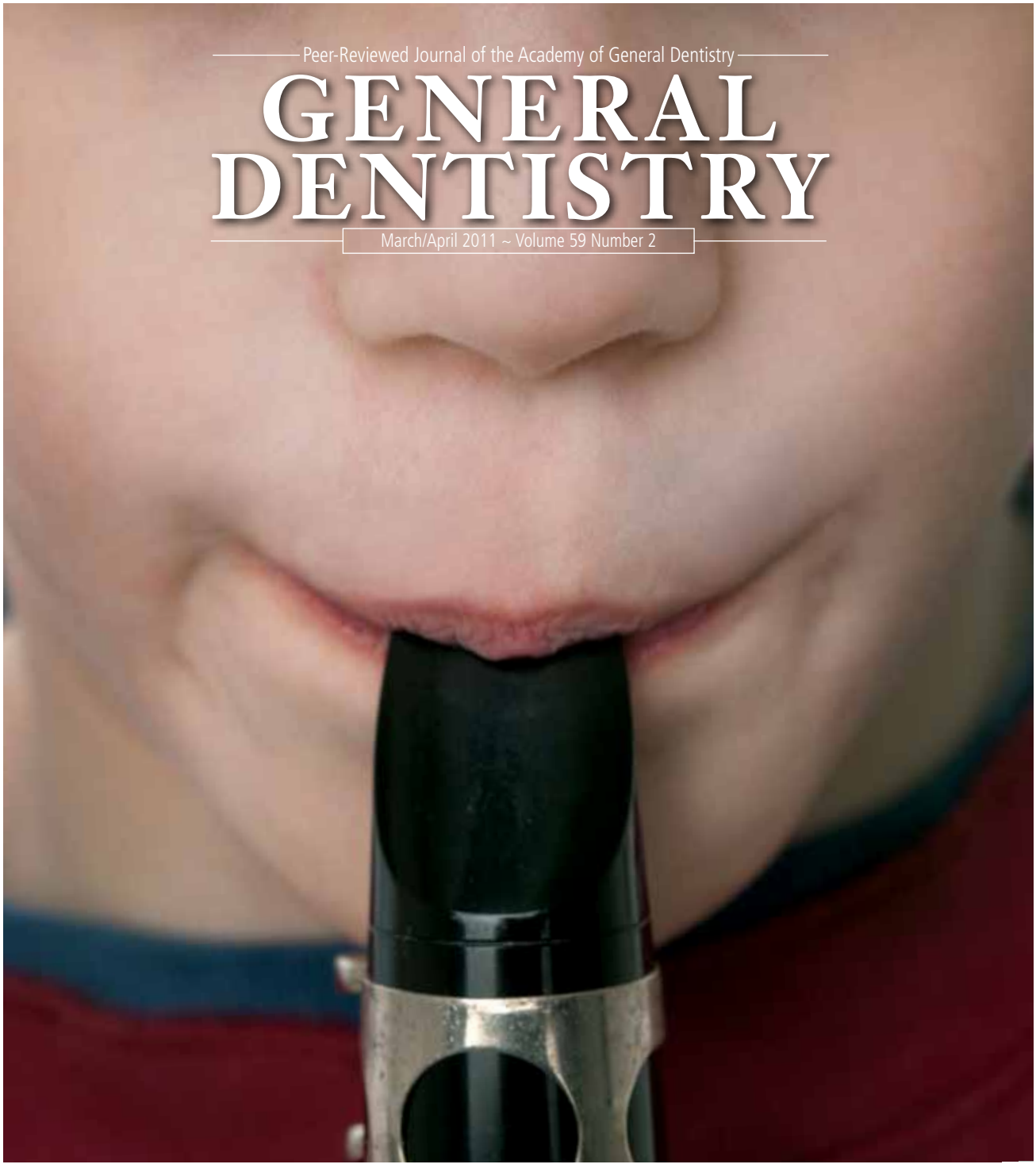

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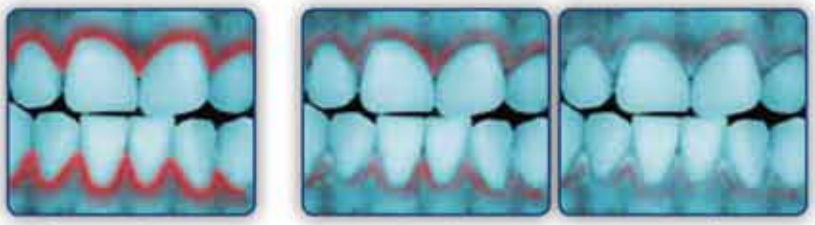

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Advisory Board

Follow the money

I want to start this editorial by reiterating that this is my opinion and not that of the Academy of General Dentistry (AGD), although I'm sure that some of our members will agree with some of my thoughts.

To paraphrase Deep Throat's advice during the Watergate investigation, "If you want to find the answers to today's intrigue, follow the money!" It seems that everything boils down to money these days, and unfortunately that applies to all areas of health care, including dentistry. I'm afraid that the government is discovering that it can't afford to pay for dental care any more than it can afford to pay for medical care, and the answer seems to be to destroy dentistry as a profession and reduce it to a trade with lower standards of care.

Imagine being a new dentist, eager to begin pursuing your profession after graduation despite facing at least $250,000 of debt, only to be told that a sizeable portion of your job will be supervising staffers who have only two years of dental training but are allowed to perform the same procedures you do. Even worse for the profession, these mid-level providers might be supervised by hygienists or corporate managers *or receive no supervision at all.*

Some dental educators believe that it is acceptable to train mid-level providers with money from grants. Why, then, should I pay dues, give donations, support endowments, or contribute to any dental school alumni fund or organization when the school's purpose has been reduced to training independent mid-level providers who will decrease my patient pool, putting me and my future colleagues out of business?

Even with that said, and contrary to what you may have heard from some quarters, this issue isn't about competition; it's about being forced to accept and even support the provision of substandard care, and I for one can't do it. I believe that allowing less competent individuals to deliver surgical and irreversible dental care borders on criminal. In addition, the implementation of independent mid-level providers will foist a two-tiered dental system onto the public, increasing and ensuring discrimination against the poor and uninsured.

Some dentists feel that lowering our standards of care to treat more patients is better than providing the best dental care in the world. This view is refuted by no less an authority than the National Dental Association (NDA). The NDA believes that all citizens are entitled to equal protection and health care under the law. The NDA also believes that a two-tiered system which operates under the premise that "something is better than nothing" is unacceptable. The NDA considers it critical that the highest quality and standards of care are always maintained in meeting the needs of the underserved community. All of these positions are supported by the AGD.

I have written before that the love of money is the root of all evil, and now that statement has a corollary: "The lack of money is the root of all medical and dental evil." Government officials seem to think that our objection to the independent mid-level provider position is simply the whining of a bunch of rich dentists. They don't recognize that dentists have for years accepted—at a loss—below-market-value payments in order to prop up a continually underfunded welfare system, while still providing the highest level of dental care possible.

There is more to success than making money, and one way for us to succeed is to preserve our current high standards of care. I encourage you to read the AGD White Paper, titled "Increasing Access to and Utilization of Oral Health Care Services" (available at *www.agd.org/files/webuser/website/advocacy/accesstocarewhitepaper.pdf*), to get the facts about this issue and to contact the AGD Advocacy department to find out how you can get involved. We need to show those who would destroy our noble profession that we will not go down silently or without a fight.

Roger D. Winland, DDS, MS, MAGD
Editor

COMMENT

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Botulinum toxin (Botox, Dysport, and Myobloc): Pharmacology 101

Richard L. Wynn, PhD

Botox is the brand name of Allergan's purified protein-botulinum toxin type A, derived from anaerobic bacterium *Clostridium botulinum.* Type A is one of seven distinct botulinum toxins (identified as types A–G) produced by different strains of the *Clostridia* bacterium. Each botulinum type produces a different immunologic response and is made by a different manufacturing process. Botulinum toxin exists as three commercial products on the U.S. market: onabotulinumtoxinA (Botox, Botox Cosmetic), abobotulinumtoxinA (Dysport, Medicis Aesthetics Inc.), and rimabotulinumtoxinB (Myobloc, Solstice Neurosciences, LLC). As of this writing, no other antigenic toxins are available for therapeutic use.

Botulinum toxin has been assessed as being the most poisonous substance known to man.[1] One gram of a crystalline form of the toxin, if milled into proper size for inhalation and dispersed evenly, would kill more than 1 million people. Technically, however, it has been impossible to crystallize that much of the toxin for such dissemination. Food-borne botulinum toxin would kill far fewer people but could be used as a terrorist attack.

Approved and unlabeled uses

The U.S. FDA-approved uses and unlabeled/investigational uses for botulinum toxin are listed below.

OnabotulinumtoxinA (Botox; Botox Cosmetic)

Approved uses include treatment of strabismus and blepharospasm associated with dystonia (including benign essential blepharospasm or VII nerve disorders) in patients at least 12 years of age; treatment of cervical dystonia (spasmodic torticollis) in patients at least 16 years of age; temporary improvement in the appearance of lines/wrinkles of the face (moderate to severe glabellar lines associated with corrugator and/or procerus muscle activity) in adult patients up to age 65; treatment of severe primary axillary hyperhidrosis in adults not adequately controlled with topical treatments; and treatment of focal spasticity (specifically upper limb spasticity) in adults.[2]

Unlabeled/investigational uses include treatment of oromandibular dystonia, spasmodic dysphonia (laryngeal dystonia), and other dystonias (for example, writer's cramp, focal task-specific dystonias); migraine treatment and prophylaxis; and treatment of dynamic muscle contracture in pediatric patients with cerebral palsy.[2]

AbobotulinumtoxinA (Dysport)

Approved uses include treatment of cervical dystonia in both toxin-naive and previously treated patients; temporary improvement in the appearance of moderate to severe glabellar lines associated with procerus, and treatment of corrugator muscle activity.[3]

No unlabeled/investigational uses have been suggested for Dysport.

RimabotulinumtoxinB (Myobloc)

Approved uses include treatment of cervical dystonia.[4]

Unlabeled/investigational uses include treatment of cervical dystonia in patients who have developed resistance to Botox, Botox Cosmetic, or Dysport.[4]

More on Botox

Botox has been approved in more than 75 countries to treat 20 different neurological disorders. In addition to its cosmetic application, Botox has been used in the U.S. for nearly 15 years for a range of therapeutic applications, including treatment of crossed eyes and excessive sweating.[1] Botox ranked as the number one minimally invasive cosmetic procedure in the U.S. in 2005.

Botulinum toxin was developed in the 1940s by the U.S. and other countries as a biological weapon. At much lower doses, it can temporarily alleviate neurological disorders, and in this capacity it was the first biological toxin licensed for the treatment of human diseases.

The toxin acts by preventing the release of the neurotransmitter acetylcholine from vesicles at the neuromuscular junction. Chemically, the toxin is known as a *proteinase* and is able to cleave one or more of the fusion proteins by which the neuronal vesicles release acetylcholine. In the absence of acetylcholine, muscle contraction

or gland activity is temporarily shut down. When used to treat medical disorders, minute amounts of the toxin are injected directly into the targeted muscle or gland. The shutdown of muscle or glandular activity lasts from one to six months, depending on the medical indication. Eventually, the nerve endings recover and revert to normal acetylcholine release. To maintain the therapeutic effect, another injection may be needed.

In addition to its cosmetic uses, Botox has been indicated by the FDA for the treatment of serious medical disorders; the first of these was in 1989 for uncontrolled eye blinking (blepharospasm) and treatment of crossed eyes (strabismus). In 2000, Botox gained FDA approval for *cervical dystonia,* defined as involuntary neck and muscle spasms that can cause abnormal postures of the head. In 2002, Botox gained FDA approval for cosmetic use that included treatment to improve the appearance of lines/wrinkles of the face (moderate to severe glabellar lines associated with corrugator and/or procerus muscle activity). Finally, in 2004, the FDA approved the use of Botox as a treatment for excessive underarm sweating (hyperhidrosis) that cannot be managed with topical agents.

Outside the U.S., Botox is approved for the treatment of juvenile cerebral palsy and adult spasticity. In the U.S., it is used for off-label indications including migraine headache, chronic lower back pain, stroke, traumatic brain injury, and cerebral palsy.

History

An outbreak of botulism among people who had eaten uncooked blood sausage in southern Germany in 1815 led a physician named Kerner to publish a precise description of botulism symptoms, from blurred vision to progressive muscle weakness and culminating in respiratory failure.[1] He postulated that minute quantities of this disease-producing substance might be able to treat disorders of the central nervous system. In 1897, a Belgian professor of bacteriology named van Ermengem discovered the bacterium responsible for producing the toxin and renamed the disease from *Kerner's disease* to *botulism*, from the Latin *botulus* (sausage).

Botulinum toxin was isolated from the *Clostridium botulinum* organism in the early 1920s. Later that decade, scientists at the University of California, San Francisco, first isolated botulinum toxin type A, while scientists at the University of Wisconsin purified the botulinum type A toxin in crystalline form in 1946.

Botox warning

Complete information on Botox, including administration, dosing, and adverse effects, is available both in print and online.[2] Meanwhile a serious black-box warning label has been issued for Botox by the FDA. **This warning reads as follows:**

Distant spread of botulinum toxin beyond the site of injection has been reported; dysphagia and breathing difficulties have occurred and may be life threatening; other symptoms reported include blurred vision, diplopia, dysarthria, dysphonia, generalized muscle weakness, ptosis, and urinary incontinence which may develop within hours or weeks following injection. Risk likely greatest in children treated for the unapproved use of spasticity. Systemic effects have occurred following approved and unapproved uses, including low doses. Immediate medical attention required if respiratory, speech, or swallowing difficulties appear.[5]

Specific reports on adverse events associated with use of botulinum toxin

Ihde and Konstantinovic reviewed three trials that used botulinum toxin type B to treat cervical dystonia and one trial that used botulinum toxin type A to treat chronic facial pain.[6] From the cervical dystonia studies, the adverse drug reactions (ADRs) were mild and transient, with numbers needed to harm ranging from 12–17. (Numbers needed to harm represents the number of patients treated before observing an adverse event.) Dystonia, injection site reactions, and general reactions such as flu-like symptoms, nausea, and headache were some of the events reported. Dry mouth was reported in 3–33% of patients, while dysphagia ranged from 0–27% of patients.

From the chronic facial pain study, using botulinum toxin type A, the rate of ADRs was less than 1%. The ADRs were relatively mild and transient and included dry mouth, bruising at the injection site, and itching at the injection site. Dysphagia and temporary paralysis of the muscles affecting expression occurred in one patient ($N = 90$).

Cote *et al* reviewed all of the serious ADRs reported to the FDA since botulinum toxin type A was licensed and the nonserious ADRs reported from December 2001 to November 2002 following botulinum toxin type A administration.[7] There were a total of 1,437 ADR reports, with 406 occurring with therapeutic uses and 1,031 occurring with cosmetic uses. Therapeutic uses included treatment of severe primary axillary hyperhidrosis and treatment of strabismus and blepharospasm associated with dystonia, cervical dystonia, and focal spasticity. Cosmetic uses included temporary improvement in the appearance of lines/wrinkles in the face

(moderate to severe glabellar lines associated with corrugators and/or procerus muscle activity).

Of the 406 reports of ADRs after therapeutic uses, 217 met the FDA definition of serious while 189 were nonserious. The serious ADRs included 28 deaths and 17 seizures. The deaths were attributed to heart attacks, cerebrovascular accidents, pulmonary emboli, pneumonia, or unknown causes. Most of the serious ADRs corresponded to the risks described in FDA-approved labeling, such as dysphagia, muscle weakness, allergic reactions, flu-like syndromes, and injection site trauma.

Of the 1,031 ADRs after cosmetic uses, 36 were of a serious nature and 995 were nonserious. No deaths were reported in this group. The serious ADRs included focal facial paralysis, muscle weakness, dysphagia, flu-like symptoms, and allergic reactions. The most commonly noted nonserious ADRs included lack of affect (63%), injection site reaction (19%), and ptosis (11%.)

In a published commentary, Batra *et al* observed that of the ADRs reported in the study by Cote *et al* after therapeutic use of botulinum toxin type A, 47% were classified as serious, compared to 3.5% of serious ADRs reported after cosmetic uses.[7,8] In addition, the proportion of serious ADRs from December 2001 through November 2002 was 33-fold higher for patients given botulinum toxin type A for therapeutic uses than for those receiving it for cosmetic uses (19.5% vs 0.6%).

In contrast to the Cote *et al* study that reviewed only those ADRs reported to the FDA, Naumann and Jankovic reviewed the ADRs described and reported in randomized controlled trials of botulinum toxin type A.[7,9] They reviewed 36 studies involving 2,309 subjects through searches of online databases, including MEDLINE, for the years 1966–2003. Of the 2,309 subjects, 1,425 received botulinum toxin type A treatment. No study reported any severe adverse events. The reporting of any mild to moderate adverse event showed a rate of approximately 25% in the groups treated with botulinum toxin type A, compared to 15% in control groups. Focal weakness was the only adverse event that occurred significantly more often with botulinum toxin type A than in the control. Some of the mild to moderate ADRs reported in both treatment groups and control groups included injection site reactions, headache, ptosis, and neck pain. The authors concluded that the results of their meta-analysis and experience from long-term, open-label investigations demonstrated that botulinum toxin type A has a favorable safety and tolerability profile across a broad spectrum of therapeutic uses.[9]

Author information

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COMMENT

Pre-prosthetic orthodontics for esthetics and function in restorative dentistry

Bruce W. Small, DMD, MAGD

Predictable restorative dentistry can be challenging for many reasons. Difficult clinical procedures, restorative choices, periodontal problems, occlusion, and laboratory work are just a few of the problems that get in the way of long-lasting dentistry. Tooth position prior to restorative work is another factor that can be changed if necessary, making a case a little easier. Also, changing the position of teeth can improve function and esthetics for the patient.

This column presents cases of orthodontic movement of teeth for both pre-prosthetic and esthetic reasons. The cases were completed with traditional orthodontic therapy or successive clear polymer aligners.

Case report No. 1

A 55-year-old woman was referred to the office from an oral surgeon. She originally was referred to the surgeon by her previous dentist for extraction of both maxillary central incisors (Fig. 1–3) and placement of a six-unit bridge. She had two ill-fitting crowns with posts attached, which had come loose several times. The oral surgeon (who had practiced as a general dentist for six years) and the patient discussed the possibility of saving the teeth.

The patient was informed that several therapeutic options options were available:

- Extraction of both central incisors and placement of a six-unit bridge, which could cause an unnatural-looking pontic space at the gingival level.
- Extraction of the central incisors and placement of two implants, which probably would leave an open gingival embrasure.
- Attempting to restore the mouth with new posts and cores. However, part of the preparations would be below the gingival margin, and creating a ferrule would be difficult, if not impossible. Hygiene also could be a problem.
- Placement of new posts and cores, followed by orthodontic extrusion and periodontal surgery.

The patient chose the fourth option, which had been suggested as the ideal treatment for this case. In consultation with the orthodontist, only 3.0 or 4.0 mm of movement would be necessary to create a proper crown:root ratio.

New posts were placed and three TMS pins (Coltene/Whaledent, Inc.) were added to each tooth for additional retention to the composite cores. Two pins were placed in the occlusal portion (Fig. 4 and 5) and one was placed

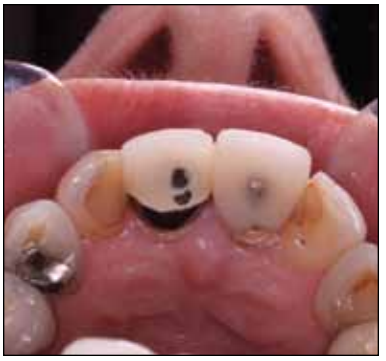

Fig. 1. Occlusal view of the old crowns on central incisors with faulty margins.

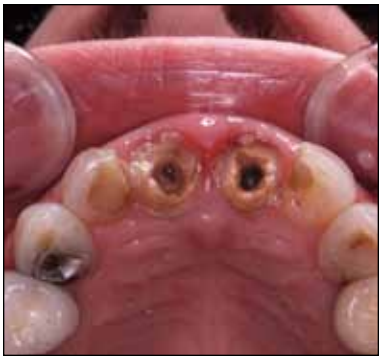

Fig. 2. Preoperative occlusal view of the incisors without posts and crowns.

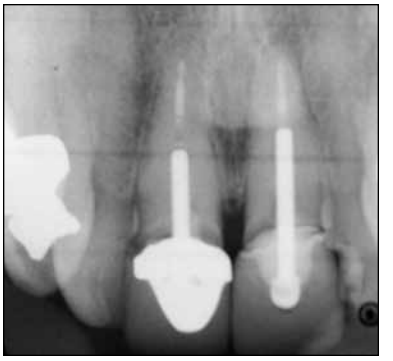

Fig. 3. Preoperative radiograph of the old crowns.

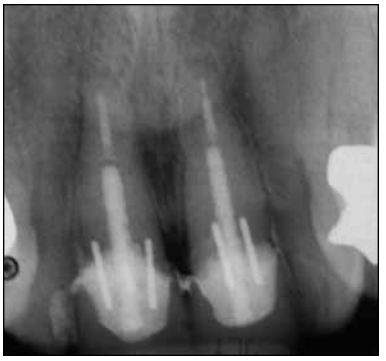

Fig. 4. Radiograph of new posts, TMS pins, and composite buildups.

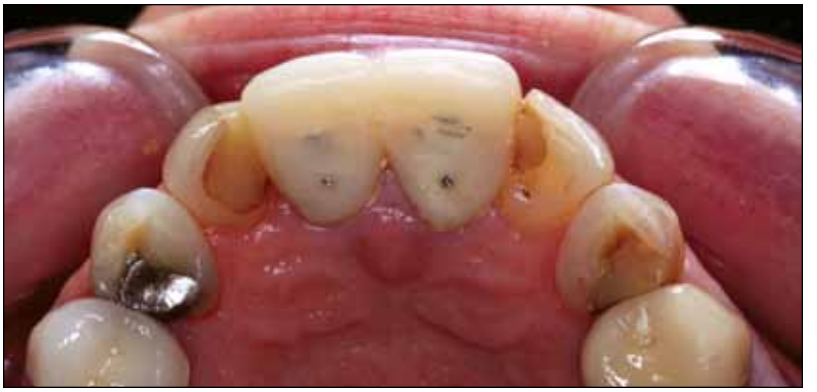

Fig. 5. Lingual occlusal view of provisional crowns with TMS pins on the lingual aspect.

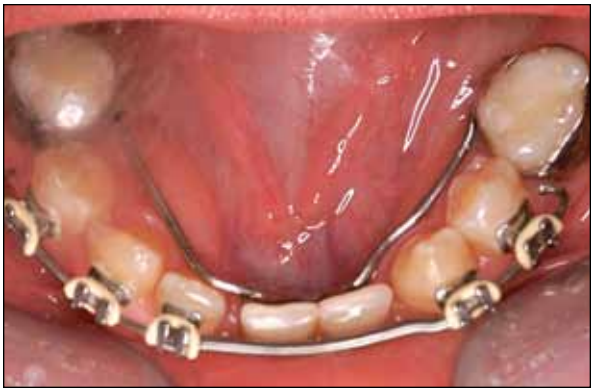

Fig. 6. Mandibular occlusal view of a 13-year-old girl with anodontia.

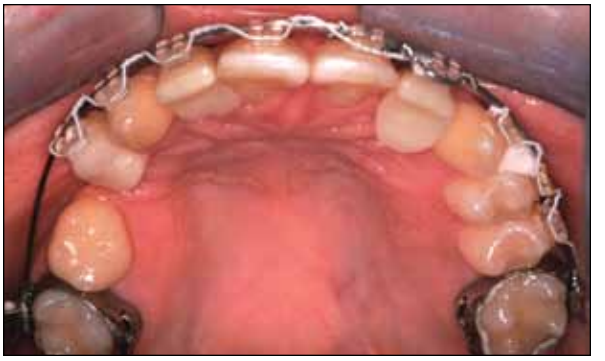

Fig. 7. Maxillary view of the patient in Fig. 6 with orthodontic appliances prior to implant placement.

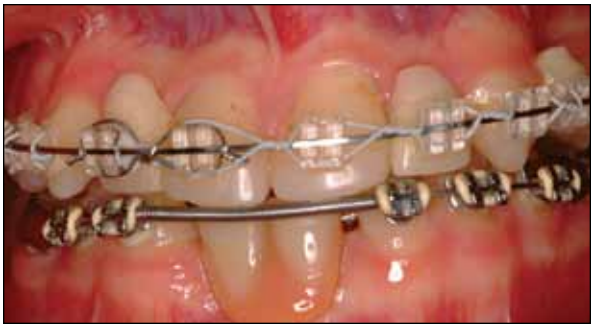

Fig. 8. Retracted anterior view of the patient in Fig. 6.

through the lingual portion of the provisional crowns to help prevent dislodgement during orthodontics. As the teeth move, occlusal adjustments will be made to create room for the movement.

Following completion of the orthodontics, a periodontist will restore the biologic width and create an ideal esthetic environment that can be easily maintained by the patient, prior to final placement of the crowns for teeth No. 6–11.

Case report No. 2

A 13-year-old girl was referred to the office for a consultation regarding implants. She had anodontia with many teeth congenitally missing. Orthodontics was completed, making room for implant placement as ideal as possible (Fig. 6–9).

One compromise was made: Site No. 12 was unavailable for implant placement, so tooth No. 11 was used as an abutment for a three-unit bridge with the implant in site No. 13 (Fig. 10). Chee and Mordohai have recommended not connecting natural teeth to implants, but there was no viable alternative in this case.[1] The patient and parents were informed of possible intrusion of the canine and a bridge was created. The case was completed and the patient was very happy to have a

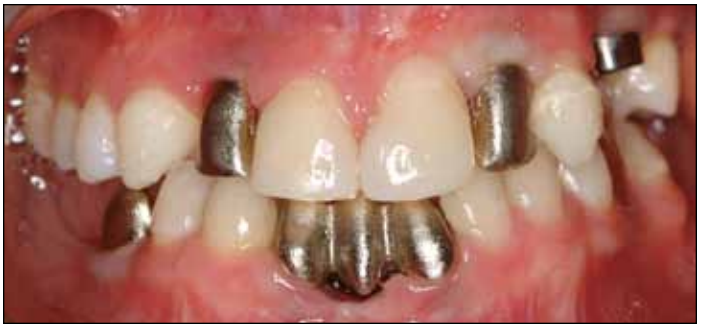

Fig. 9. Anterior view of the patient in Fig. 6, with implant abutments and metal copings at try-in.

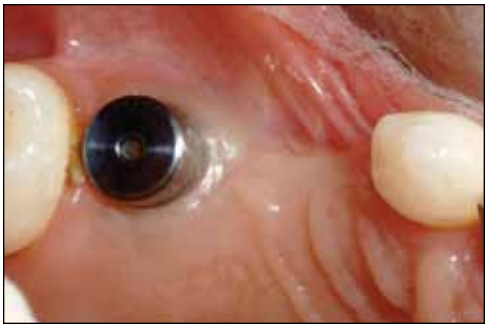

Fig. 10. Maxillary view of the maxillary left side, showing implant abutments and virgin tooth No. 11.

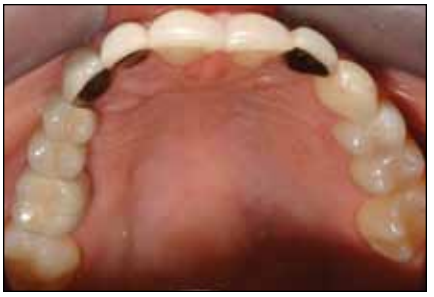

Fig. 11. Maxillary occlusal view of the completed case.

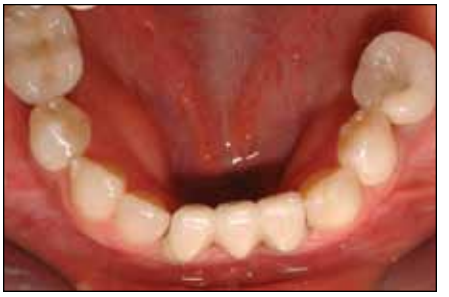

Fig. 12. Mandibular occlusal view of the completed case.

Fig. 13. Facial view of the completed case.

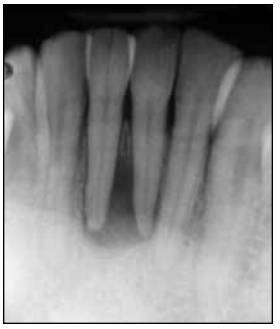

Fig. 14. Preoperative radiograph of an endodontic lesion in the anterior mandible.

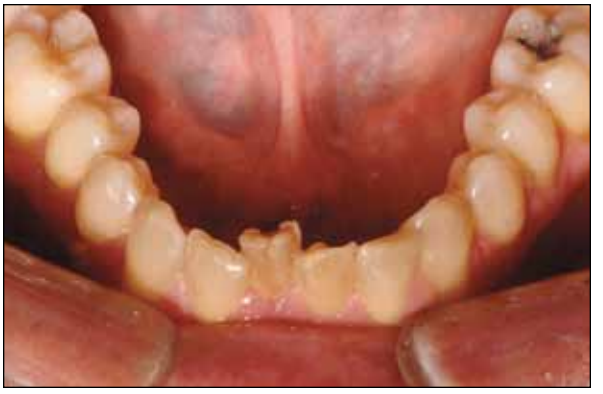

Fig. 15. Preoperative clinical view of misaligned mandibular incisors.

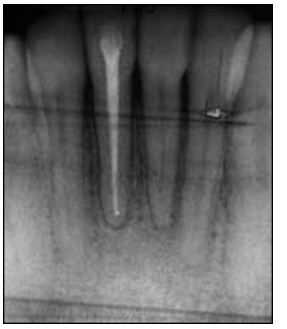

Fig. 16. Postoperative radiograph of completed endodontics and the healed periapical area.

full complement of teeth for the first time in her life at age 17 (Fig. 11–13).

Case report No. 3

A 62-year-old man complained of pain and swelling in the anterior mandible (Fig. 14). Tooth No. 24 was chipped and in traumatic occlusion (Fig. 15). It was suggested that endodontic therapy be performed and that clear plastic aligners be used to move the tooth into a better occlusal relationship. The patient accepted the treatment plan and the endodontist treated the case successfully (Fig. 16). After five months of movement using successive computer-generated aligners, the tooth was brought into a more ideal position (Fig. 17). After the completion of orthodontics, four all-ceramic crowns were constructed, seated, and bonded using a self-etching resin cement (Fig. 18–20).

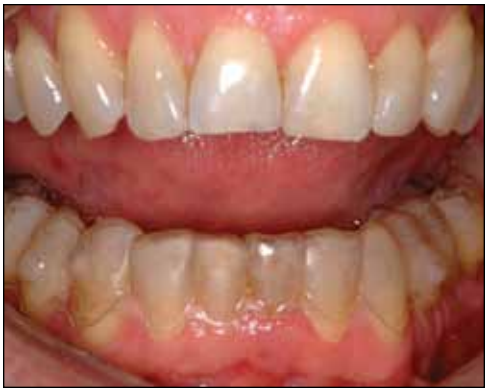

Fig. 17. Aligner in place with composite buttons on teeth.

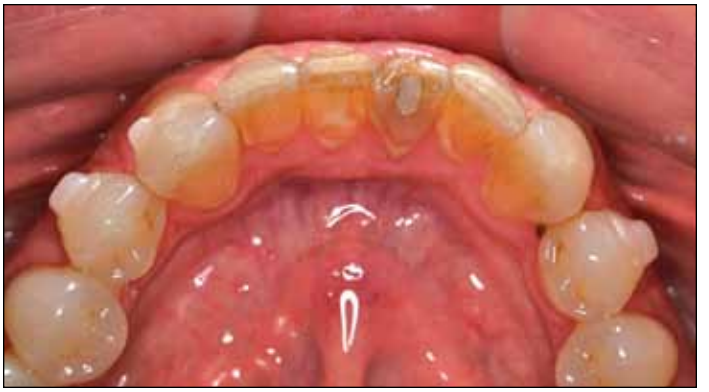

Fig. 18. Postoperative view of completed orthodontics.

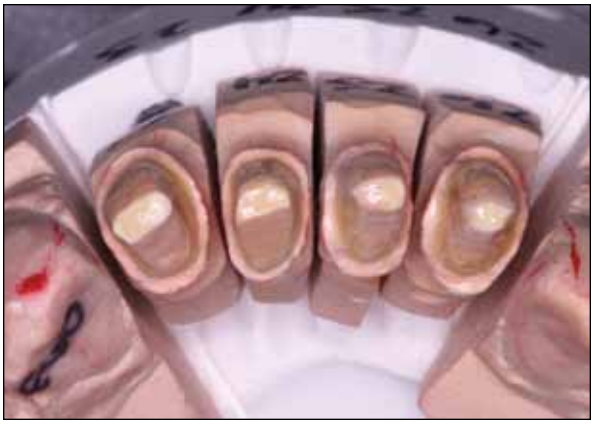

Fig. 19. Die model illustrating preparations for all-ceramic crowns.

Fig. 20. Anterior view of the completed case.

Discussion

The three cases presented here demonstrate the use of orthodontics for prosthetic reasons. Oftentimes, restorative treatment can be simplified and made easier for both dentist and patient by moving the teeth into more ideal positions, sometimes minimizing the need for additional prosthetics.

Tooth movement can be accomplished via traditional brackets and wires or the newer aligner therapy, with excellent results obtained from both methods. It is important to know the limits of both treatment modalities and to be able to address any problems that occur during treatment. It is highly recommended that general dentists be properly trained in diagnosis and treatment using aligner therapy before attempting this new method of orthodontics. A close association with a board-certified orthodontist is always an advantage.

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Latest innovations in flowable composites

Michael B. Miller, DDS

Photocured flowable composites were introduced to the dental profession in 1995 with Revolution (Kerr Corporation). The original manufacturer (E & D Dental Products) recommended that the product could be used for Class III, IV, and V restorations, porcelain veneer cementation, porcelain and marginal defect repairs, sealants, and core buildups. Surprisingly, one of the most popular contemporary uses of flowable composites—the first increment at the bottom of the proximal box for a Class II preparation—was not even mentioned initially as a use for Revolution.

While Revolution was (and still is) essentially a modified resin cement, new flowables have branched into three new directions: low-stress, self-adhesive, and high strength/low wear.

Low-stress

Conventional flowable composites have comparatively higher shrinkage than sculptable composites, likely due to the lower filler load and higher resin percentage of flowables. Because it is the resin that shrinks, it is quite logical to assume that flowables will shrink more, causing increased stresses on the developing bond; however, the resin in the new low-stress flowables presumably has been modified to minimize this stress despite the material still shrinking more than sculptable composites.

The big advantage with low-stress flowables is that they can be placed in relatively thick layers (about 4.0 mm), which can speed up the procedure, a goal that most dental practitioners want anyway. But shrinkage stress is only one part of the equation: If you place any composite in thicknesses greater than 2.0 mm, the ability to cure it thoroughly comes into question.

So what do we really know about these products? The REALITY Research Lab (RRL) has studied the depth of cure of two recently introduced products, Venus Bulk Fill (Heraeus Dental North America) and SureFil SDR flow (Dentsply Caulk). This was done by comparing the surface hardness to that at the bottom of the proximal box, even if the thickness was 4.0 mm. The results showed that both products can exceed the 80% cure goal; however, to achieve this goal, the materials must be cured for 40 seconds, not the 20 seconds recommended by the respective manufacturers.

But what about the claim of lower curing stress? The RRL found that both Venus Bulk Fill and SureFil SDR flow had significantly less shrinkage stress compared to a conventional flowable (Filtek Supreme Plus Flowable, 3M ESPE). Further, this shrinkage stress was statistically the same as that of a glass ionomer base (Fuji IX GP Extra, GC America Inc.).

The unanswered question, of course, is what does this lower shrinkage stress mean when it comes to tooth integrity and restoration stability over time? A laboratory study cannot provide that answer, but at least some peace of mind comes from not putting undue stresses on a tooth, because glass ionomers like Fuji IX have been used successfully for many years.

Nevertheless, if you fill a proximal box with 4.0 mm of flowable composite, there is a good likelihood that this flowable increment will be sufficiently occlusal to form all or part of the contact area. However, the question remains as to whether any flowable, low-stress or not, resists wear well enough to use in restoring contacts. Therefore, I still believe that it would be prudent to continue restoring contacts with a more heavily filled, sculptable composite.

Self-adhesive

Cements were the first resin-based materials to bear the self-adhesive label, and because cements and flowables can be used interchangeably in many respects, it is not suprising that flowables were next. Similar to what happened with low-stress flowables, two products, Vertise Flow (Kerr Corporation) and Fusio (Pentron Clinical), kick-started the self-adhesive trend.

From a clinical standpoint, a self-adhesive flowable has great appeal, since it eliminates the need for a bonding agent. However, even though the application procedure is not difficult, it is quite specific, meaning that you cannot simply syringe these materials into preparations, as you would with a conventional flowable.

With Vertise Flow, for example, the first increment is injected in a thin layer (less than 0.5 mm) after the tooth has been cleaned and dried. This thin layer is necessary because it acts, in effect, as a self-etching

adhesive. Next, this layer is agitated aggressively, using the disposable brushes that come with the kit. Once this first increment has been placed, you can add another layer to finish restoring a small Class I restoration or switch to a more conventional composite in the case of a larger preparation.

To complicate matters, the technique for Fusio has important differences from that for Vertise Flow. The preparation is not dried after cleaning, because Fusio bonds better to a glistening wet tooth surface. Also, a rubbing technique for the initial layer is used instead of the agitation method for Vertise Flow. These technique variances point out that the application protocols for these products are material-specific, which means that there is a learning curve if you switch from one product to the other.

The jury is still out on the bond stability of self-adhesive flowables.

Another difference between these products is their indications for use. Fusio is described as being "liquid dentin," which would seem to imply that it should be used only as a base or liner, but instead it is recommended for definitive small Class I, III, and V restorations. Meanwhile, Kerr Corporation is taking a more conservative stance with Vertise Flow by restricting its indications (at this time) to small Class I restorations, pit and fissure sealants, and liners/bases under larger restorations. In other words, using it for other types of definitive restorations such as Class V or core buildups is not yet recommended.

So is it possible to achieve as strong a level of adhesion to tooth structure with these new products as you would by using a bonding agent in combination with a more conventional flowable? The simple answer is no, according to tests performed in the RRL, where the bond strengths, especially immediately after photocuring, were substantially lower for the self-adhesive products. It is worth noting, though, that with Vertise Flow in particular, bond strengths to feldspathic porcelain, zirconia (Lava), and three different types of metal were quite high, especially after 24 hours.

However, simple answers may not always be correct. For example, RRL bond strength tests of self-adhesive resin cements also produced significantly lower results compared to a more conventional bonding agent/cement combination. On the other hand, anecdotal reports show that these cements do not appear to be suffering mass debondings. The jury is still out on the bond stability of self-adhesive flowables.

High strength/low wear

Setting aside the comments above about low-stress flowables having questionable wear resistance for restoring contact areas, the latest trend for flowables is the claim that some of them are actually strong enough and wear-resistant enough to be used for the entire restoration, regardless of classification. This means that these specialized flowables presumably could be used to restore even Class II and IV lesions and/or fractures. Indeed, GC America Inc. describes its G-aenial Universal Flo as the first injectable flowable that "performs like a restorative."[1]

GC America Inc. is not alone in claiming that its flowable is as strong and wear-resistant as sculptable, more heavily filled composites. VOCO America promotes Grandio Flow as the "first flowable composite that is strong as universal composites," while Shofu Dental Corporation describes the flexural and compressive strength of Beautifil Flow Plus as being "an injectable hybrid restorative material for all indications."[2,3]

Is this a positive trend? Well, on the surface, this is an attractive option, because squirting a flowable into a cavity preparation is a fairly easy task compared to packing a thicker composite, especially in areas such as a proximal box. However, as noted earlier with the low-stress flowables, depth of cure can rear its ugly head, as evidenced by the manufacturer's recommendation that G-aenial Universal Flo be layered in increments of only 1.0–1.5 mm, depending on the shade. These are wise instructions, verified by tests in the RRL, although the same tests indicate that the manufacturer-recommended 10-second curing time with a high-powered LED curing light is not sufficient. If you use this product, I strongly recommend that you cure each increment for at least 20 seconds, or even 40 seconds for the first increment deep in the proximal box.

If the depth of cure conundrum can be resolved, can you feel confident that one of these "strong" flowables will be adequate for the complete restoration of virtually any lesion? My gut feeling at this point is no. These products probably will perform adequately in primary teeth and minimally invasive preparations, but I would caution against using them as the sole restorative material in moderate to large Class I and II restorations.

The bottom line

Flowable composites used to be merely low viscosity versions of their sculptable brethren, but this legacy

is changing fast. This column is intended to provide an overview of the new flowables before you jump in head-first.

Disclaimer

The author has evaluated all of the products mentioned in this article but has no financial interest in them or their manufacturers.

Author information

Dr. Miller is the president of REALITY Publishing Company and editor-in-chief of its publications. He also maintains a general practice in Houston, Texas.

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Manufacturers

Dentsply Caulk, Milford, DE
800.532.2855, www.surefilsdrflow.com/

GC America Inc., Alsip, IL
800.323.7063, www.gcamerica.com

Heraeus Dental North America, South Bend, IN
800.431.1785, www.heraeus-dental-us.com

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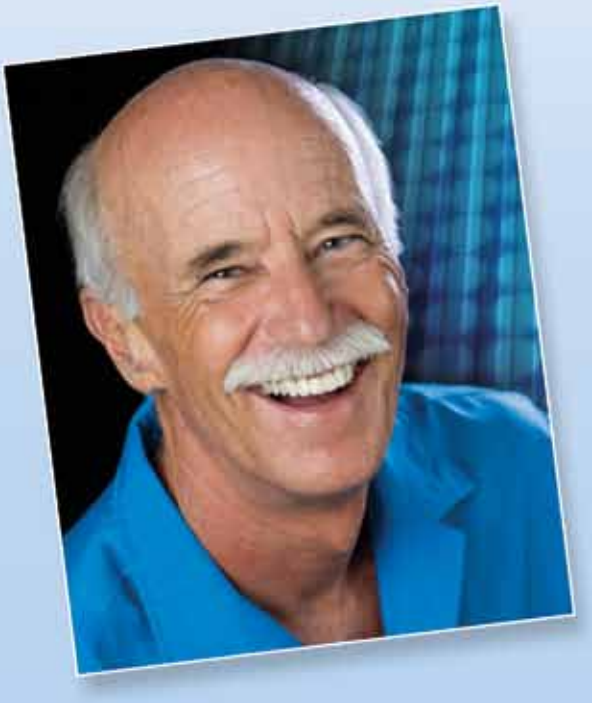

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Evaluation of the microbial flora found in woodwind and brass instruments and their potential to transmit diseases

R. Thomas Glass, DDS, PhD ▪ Robert S. Conrad, PhD ▪ Gerwald A. Kohler, PhD ▪ James W. Bullard, MS

Previous studies of dental devices (toothbrushes, dentures, and protective athletic mouthguards) have demonstrated microbial contamination of these devices and possible transmission of infectious diseases to the users. Since woodwind and brass instruments come into intimate contact with the musician's oral cavity and often are passed from student to student without sanitization, the question arises as to whether these instruments are contaminated and can transmit microbial diseases. The purpose of this study was to determine if woodwind and brass instruments and/or their cases harbor opportunistic, pathogenic, or allergenic microorganisms that can be transmitted to the musician.

The internal components of woodwind and brass instruments harbored opportunistic, pathogenic, and/or allergenic microorganisms. The highest concentrations of microorganisms were found consistently at the mouthpiece end, but there was evidence of contamination throughout the instruments and their cases. The close proximity of contaminated mouthpieces to the oral cavity could facilitate local and systemic dissemination of the resident opportunistic, pathogenic, and/or allergenic microorganisms. General dentists should determine whether patients play a brass or woodwind instrument and be aware of the possible impact of this activity on the oral cavity and the entire body.

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Many children and young people participate in school and extracurricular band ensembles. Woodwind and brass instruments comprise a substantial portion of these ensembles. Often, instruments used by students are on loan from the school and previously have been played by individuals whose health histories are unknown to the recipients. Also, private organizations, such as the Mr. Holland's Opus Foundation, distribute donated used instruments to underprivileged inner-city children.[1] Used woodwind and brass instruments have not been evaluated thoroughly as a suitable habitat for microbial growth. However, the mouthpieces, internal tubing, intricate valves, keys, pads, hinges, and cases could provide potential sites for microbial contamination, facilitating the transmission of microbial diseases.

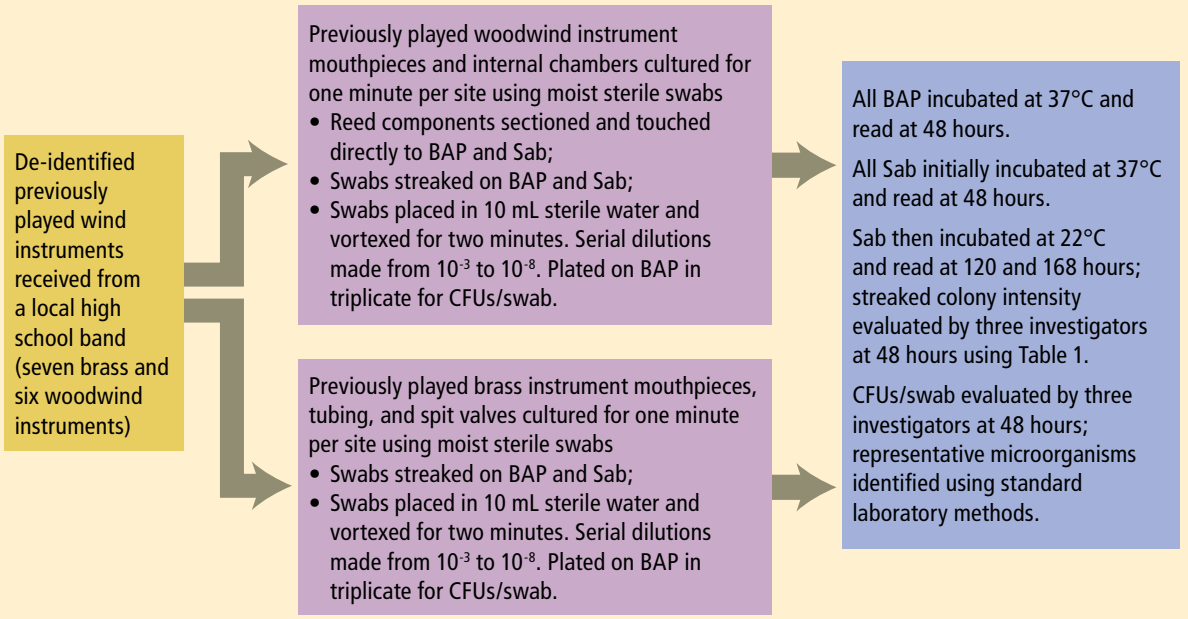
When various parts of woodwind and brass instruments are used, they become repositories for the users' oral and pulmonary secretions.[2] Because these instruments come into intimate contact with the musicians' oral and respiratory mucous membranes, such exposures may facilitate microbial transmission. Furthermore, as these instruments are repeatedly played, they build up visible amounts of organic material, providing an excellent habitat for microbial growth. Even though the instruments may lie dormant during the summer months between school sessions, they could remain contaminated.

Methods for clearing such organic accumulations from woodwind and brass instruments include repeatedly aspirating the secretions from the instrument; evacuating materials from water valves (spit-traps); wiping areas with fingers and cleaning cloths; and flushing the instruments with antimicrobial solutions. These routine procedures could provide further opportunities for disease transmission by contaminating the musicians' hands, which in turn could contaminate other instruments or the musicians' eyes, nose, or mouth. In addition to direct contact, microorganisms could be expelled into the local enclosed environment (the band room) by playing the instruments.

There has been a great deal of research recently into the transmission of microorganisms, including bacteria, fungi, and viruses by oral means. However, little is known regarding the specific health hazards associated with the sharing of contaminated wind instruments. Despite studies confirming a relationship between breathing difficulties and playing wind instruments, no association has been made with the effects of instrument contamination.[3,4]

While minimal research has been conducted specifically on microorganisms harbored in wind

Chart 1. A flow chart outlining the experimental design of this study.



instruments, there is an extensive body of research regarding the presence of opportunistic and pathogenic microorganisms on and within oral devices. Multiple studies conducted by Glass *et al* found that toothbrushes harbor pathogenic microorganisms involved in oral, pulmonary, and systemic diseases.[5-13] These researchers also noted that patients who are immunocompromised were at far greater risk than healthy individuals of developing microbial diseases through contaminated toothbrushes.[9,12]

Additional research on other oral devices such as dentures and protective athletic mouthguards found colonization by similar potential disease-producing microorganisms.[14-23] In the most recent study of 53 protective athletic mouthguards, Glass found that the most common of the 253 Gram-positive isolates were *Staphylococcus spp.* (182) and *Micrococcus spp.* (54).[24] The remaining 17 isolates were various *Streptococcus spp.* In the same study, 14 of the *Staphylococcus* isolates were *S. aureus,* two of which were methicillin-resistant (MRSA). Of the non-aureus *Staphylococcus spp.,* 53% were methicillin-resistant, while 76% of the *Micrococcus spp.* were methicillin-resistant. Even more disconcerting was the finding that 71% of the non-aureus *Staphylococcus* and *Micrococcus spp.* were resistant to triclosan, a common antimicrobial agent used in some instrument rinses. This finding of resistance factors in non-aureus *Staphylococcus spp.* has important clinical implications for the prevention and treatment of infections in humans.

A 2009 study of 1,391 hospitalized patients found that 188 (13.5%) had antimicrobial-resistant infections (ARI), resulting in medical costs ranging from $18,588–$29,069 per patient.[25] The additional societal costs in this cohort were estimated to be $10.7–$15.0 million. Based on this study and several others, it is suggested that such avoidable infections resulted in more than $35 billion in societal cost annually and more than 8 million additional days spent in the hospital nationwide.[26]

The hypothesis of this study was that the internal components and/or the cases of woodwind and brass instruments harbor potentially pathogenic, opportunistic, or allergenic microorganisms that can be isolated and identified by routine laboratory methods.

Materials and methods

In order to answer the hypothesis, the protocol was followed as outlined in Chart 1. A local small-town high school band agreed to participate in the proposed study. For this institutional review board (IRB)-approved study, 13 de-identified

Table 1. Colony intensity scale.

Value	Colonies/cm^2
0	≤5
1	6–25
2	26–100
3	>100, but without confluent growth
4	too numerous to count, with confluent growth

Table 2. The most commonly isolated bacteria (occurring in at least three instruments), with their Gram stain results and illnesses they could produce.

Species	Gram stain/ morphology	No. of instruments (n = 13)	Potential diseases
Aureobacterium spp.	Positive/bacilli	5	Systemic infections in immunocompromised patients
Bacillus cereus	Positive/bacilli	5	Diarrheal/emetic toxins; septicemia; bacteremia; ocular virulence; osteomyelitis
Bacillus megaterium	Positive/bacilli	5	Food poisoning; cerebral abscesses
Brevibacterium spp.	Positive/bacilli	11	Corneal infections; food poisoning; endophthalmitis
Burkholderia cepacia	Negative/ bacilli	6	Pulmonary pathogen for patients with cystic fibrosis, skin and soft tissue infections, surgical wound infections, and genitourinary tract infections
Cellulomonas spp.	Positive/bacilli	7	Acute cholecystitis; sepsis; infective endocarditis; osteomyelitis
Chryseobacterium luteola	Negative/ bacilli	8	*Pseudomonas*-like, opportunistic pathogen; high drug resistance
Kocuria varians	Positive/cocci	9	Brain abscess; opportunistic pathogen in immunocompromised patients
Micrococcus spp.	Positive/cocci	9	Opportunistic pathogens in immuno-compromised patients; drug-resistant
Staphylococcus capitis	Positive/cocci	7	Septicemia; endocarditis; catheter-related infections
Staphylococcus epidermidis	Positive/cocci	6	Nosocomial infections; wound infections; postsurgical infections
Staphylococcus hominis	Positive/cocci	3	Septicemia; blood cultures
Staphylococcus lentus	Positive/cocci	3	Arthritis; urinary/catheter/prosthetic joint infections
Staphylococcus saprophyticus	Positive/cocci	3	Female urinary infections
Other *Staphylococcus spp.*	Positive/cocci	10	Arthritis; catheter and prosthetic joint infections; urinary tract infections.

previously played wind instruments (seven brass and six woodwinds) were utilized. Although the instruments were de-identified, a history was obtained regarding the length of time between when the instrument was last played and the testing. Six of these instruments (three brass and three woodwinds) had been played within a week of testing, while the other seven instruments (four brass and three woodwinds) had not been played for at least one month prior to the study.

Before the microbial flora were sampled, appropriate photographs were made of the interstices and cases of the instruments. A total of 117 different sites, including the mouthpieces, internal chambers, and cases of the study instruments, were cultured by swabbing each area with a moist sterile swab for one minute. All swabs were immediately streaked onto a blood agar plate (BAP) and a Sabouraud dextrose plate (Sab). The reeds were touched directly onto the media, both intact and after cross-sectioning. The swabs or reeds were then placed in 10 mL of sterile water and vortexed for two minutes. Serial dilutions of the test waters were made from 10^{-3} to 10^{-8} and plated on BAP in triplicate for enumeration of colony-forming units (CFUs)/swab. The BAP cultures were incubated at 37°C and were read at 24 and 48 hours. The Sab were incubated initially at 37°C and read at 48 hours for yeasts, then incubated at 22°C and read at 120 and 168 hours for molds. The CFUs/swab were evaluated and tabulated at 48 hours by three investigators. All BAP- and Sab-streaked plates were scored at 48 hours, using the previously described colony intensity scale shown in Table 1.[14,16-19,21]

Bacteria and yeasts were identified using standard laboratory methods, including Gram stains and API strips (bioMerieux, Inc.). Molds were identified and preliminary yeast identities were confirmed

using standard molecular techniques (DNA analyses).

Given the numbers of microorganisms and limited funds/time, antibiotic susceptibilities were performed on only Gram-positive cocci. The susceptibility procedures used standard antibiotic-impregnated disks on pure culture lawns of microorganisms (Kirby-Bauer test).[27,28] The drugs tested were penicillin, oxacillin (methicillin), vancomycin, ciprofloxin, tetracycline, erythromycin, gentamicin, and azithromycin. Zones of microbial inhibition were measured and compared to standards for determination of susceptibility/resistance to individual antibiotics.

The data were analyzed statistically. Correlation coefficients (R^2) were determined using correlation and regression analyses. The *p* values were determined using the unpaired Student's *t*-test.

Results

A total of 117 sites were sampled on 13 de-identified instruments, which consisted of two clarinets, two oboes, two saxophones, two mellophones, two trombones, two trumpets, and one cornet. The most frequently isolated bacteria (occurring in three or more instruments) are listed in Table 2, while the most frequently isolated fungi (occurring in three or more instruments) are listed in Table 3. Examples of partial instrument analyses (random sites) are demonstrated in Figures 1 and 2.

A total of 442 bacterial isolates were initially identified. After eliminating redundancies, 295 different isolates were found in the 117 test sites, for an average of 2.5 isolates/site. Based on colony appearance, morphology, Gram stain reaction, and biochemical means (API strips), the 295 isolates consisted of 95 (32.2%) Gram-positive cocci, 131 (44.4%) Gram-positive bacilli, and 69 (23.4%) Gram-negative bacilli; no Gram-negative cocci were isolated. Of note, only one instrument was positive for *Staphylococcus aureus.* Many of these bacterial isolates are considered to be frank or opportunistic pathogens.

Table 3. The most commonly isolated fungi (occurring in at least three instruments), with their type and the illnesses they could produce. Note that many of the fungi are associated with allergic diseases and that one, *Fusarium oxysporum*, produces a mycotoxin.

Species	No. of instruments (*n* = 13)	Type	Pathogenicity
Aspergillus niger	4	mold	opportunistic
Aureobasidium pullulans	3	yeast	allergenic; opportunistic
Bipolaris spp.	3	mold	allergenic; opportunistic
Candida albicans	3	yeast	opportunistic
Cochliobolus spp.	6	mold	allergenic; opportunistic
Cryptococcus laurentii	4	yeast	opportunistic
Fusarium oxysporum	7	mold	allergenic; mycotoxin; opportunistic
Paecilomyces lilacinus	5	mold	allergenic; opportunistic
Penicillium chrysogenum	11	mold	allergenic; opportunistic
Rhodotorula mucilaginosa	7	yeast	allergenic; opportunistic

All Gram-positive cocci (comprising 14 different species) were tested against a battery of antimicrobials, including methicillin. High levels of methicillin resistance were detected in isolates of *Staphylococcus aureus* as well as in other *Staphylococcus spp.* Furthermore, similar levels of methicillin resistance were found in Gram-positive cocci that are generally considered to be nonpathogenic. Methicillin resistance did not correlate with resistance to any other antimicrobial tested against the Gram-positive cocci.

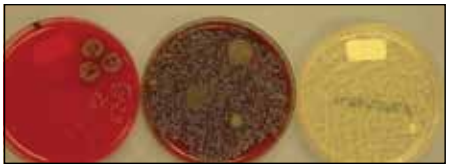
Using standard laboratory and molecular techniques, a total of 19 yeast isolates were detected in eight of the 12 instruments (all six woodwinds and both mellophones). All of the identified yeasts could be considered as opportunistic and/or allergenic pathogens.

The 13 instruments also yielded a total of 58 molds. Again, all of the mold isolates could be considered as opportunistic and/or allergenic pathogens. Interestingly, seven of the mold isolates (*Fusarium oxysporum*) are potential mycotoxin producers. Mycotoxins are secondary metabolites (byproducts) of the growth of the molds and can have substantial toxic side effects for plants, animals, and humans. Certain mycotoxins are also considered carcinogenic.[29]

Even though the number of instruments (13) was low, 117 individual sites were available for statistical analyses. The statistical analyses of the data revealed the following findings:

- There was a high level of correlation between the two methods of quantification (touch culture evaluations compared to serial dilution with colony counts) ($R^2 = 0.9442$).

Metal mouthpiece

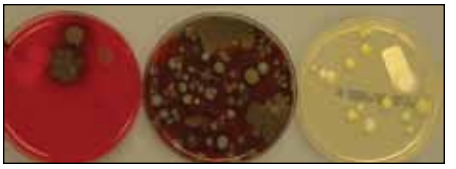


First water valve

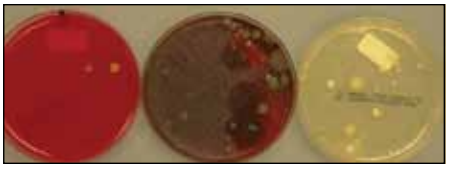
First air valve

Third air valve

Second water valve



Inside bell



Case

Fig. 1. An example of cultures taken from representative sites of a mellophone. The plate on the left shows the CFUs/swab on BAP; the plate in the middle shows the swab streak on BAP; and the plate on the right shows the swab streak on Sab. Note the quantitive and qualitative differences from site to site, including the instrument case.

- There was a low level of correlation between the last time an instrument was played and the bacterial load, confirming that some bacteria remained viable in instruments that had not been played in more than a month ($R^2 = 0.1520$).
- There was an intermediate level of correlation between contamination in the reed/mouthpiece (the most proximal site), the instrument midpoint, and the bell (the most distant site) ($R^2 = 0.856$). The reed/mouthpiece ends were consistently more contaminated than the bell ends. However, it should be noted that

Fig. 2. An example of fungal streak cultures taken from representative sites of an oboe. Again, note the quantitive and qualitative differences from site to site, including the instrument case.

both the instrument midpoints and bells retained microorganisms in sufficient quantities to affect transmission, expose the musicians to toxins, and produce disease.

- Analyses of the differences between the bacterial loads in woodwinds and brass instruments yielded a *p* value of 0.1547, suggesting that woodwind instruments were more heavily contaminated than brass instruments.
- Analyses of the differences between the bacterial loads in reeds as compared to mouthpieces yielded a *p* value of 0.0496, indicating that reeds were significantly more heavily contaminated than mouthpieces.
- Analyses of the differences between the bacterial loads in clarinets and other woodwinds yielded a *p* value of 0.0479, indicating that clarinets were significantly more heavily contaminated than other woodwinds.
- Analyses of the differences between the bacterial loads in clarinets and all other instruments yielded a *p* value of 0.0026, indicating that clarinets were significantly more heavily contaminated than all other instruments, including brass.
- Analyses of the differences between the bacterial loads in metal instruments (including saxophones) and wood/plastic instruments (clarinets and oboes) yielded a *p* value of 0.2376, confirming that the composition of the instrument did not affect contamination.
- Analyses of the differences between the bacterial loads in trombones and all other instruments yielded a *p* value of 0.2229, confirming that contamination of trombones was not statistically different from that of other instruments.
- Analyses of the differences between the bacterial loads in the bells of the instruments and the cases yielded a *p* value of 0.6864, confirming that both sites were equally contaminated.
- Analyses of the differences between the bacterial loads in the mouthpieces and the cases yielded a *p* value of 0.0131, confirming that the mouthpieces were significantly more heavily contaminated than the cases.
- Analyses of the differences between the bacterial loads in the reeds and the cases yielded a *p* value of 0.0043, confirming that the reeds were significantly more heavily contaminated than the cases.
- Analyses of the differences between the bacterial loads in woodwind instrument cases and

brass instrument cases yielded a p value of 0.0008, confirming that not only were the woodwind instruments significantly more heavily contaminated than brass instruments, their cases were, too.

Discussion

The purpose of the present study was to determine whether wind instruments are contaminated by either frank or opportunistic pathogenic microorganisms, which can cause significant disease in the person playing the instrument. Such results could be useful in determining whether these microbes posed a danger of a significant magnitude to warrant periodically sterilizing the instrument to ensure the safety of the musician.

The study followed Chart 1 and measured microbial intensity by both visual examination and CFUs/swab. As confirmed by statistical analyses of the data, there was a statistically significant positive correlation between the two methods of evaluating microbial load.

The results of the current study confirmed that wind instruments are heavily contaminated with a wide variety of bacterial and fungal isolates. Identification of these microbes down to the species level was completed; however, the authors wish to note that using these standard laboratory methods did not isolate fastidious pathogens such as spirochetes, mycoplasma, mycobacteria, and viruses.

The results of the current study also indicate that wind instruments are contaminated with a number of potentially harmful microbes, many of which are associated with minor to serious infectious or allergic diseases. Furthermore, this study also found that many of these microbes are highly resistant to some or most of the antibiotics normally used in general practice, including methicillin.

The medical literature is replete with examples of carriers such as "Typhoid Mary" who harbor and spread potentially deadly diseases without suffering ill effects themselves. The results of this study found that wind instruments could act as reservoirs of such diseases. For this reason, prudence demands that the presence of actual or opportunistic pathogens must be taken seriously in order to protect susceptible musicians from these microorganisms.

It must be stressed that while the results found the heaviest contamination in the reed/mouthpiece sites, there were sufficient microorganisms throughout the instrument interstices and cases to warrant regular sterilization of the entire instrument. Another unexpected finding was that the species of microorganisms were not consistent throughout the instruments. In other words, the microorganisms isolated from the sites closer to the mouthpiece end were different from those isolated from sites closer to the bell end.

The current study confirmed the hypothesis that the internal components of woodwind and brass instruments and their cases harbor potentially pathogenic, opportunistic, and/or allergenic microorganisms. The study also confirmed that microorganisms can be isolated from various components throughout instruments and their cases and can be identified by routine laboratory methods. Because most of the microorganisms detected in this study are considered pathogenic, opportunistic, and/or allergenic, sterilization of the instrument is recommended on a routine basis, and definitely before an instrument is passed to a new user. Currently, ethylene oxide is the only agent known to sterilize instruments effectively.[30]

Because this study used de-identified instruments, no medical histories were obtained. However, anecdotal information from the band teacher/leader confirmed that, at any given time, more than 50% of the band students had some respiratory distress (asthma or bronchitis) that required therapy. Therefore, additional studies must be performed to determine the microbial concentration in the band room before, during, and after band practice. In addition, demographic and medical histories need to be obtained from each band member to confirm the anecdotal information obtained from the band teacher/leader. Finally, because this study analyzed wind instruments obtained from a rural setting, a comparable study should be performed in an urban environment to compare findings.

Conclusion

The results of this study revealed that wind instruments and their cases become contaminated with use and that this contamination can last for extended periods of time. Many of the bacterial and fungal isolates must be considered to be pathogenic, opportunistic, and/or allergenic pathogens. In addition, this study validated the methods used to study contamination of wind instruments and their cases.

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Disclaimer

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COMMENT

Exercise No. 279

Infectious Disease Control

Subject Code 148

The 15 questions for this exercise are based on the article "Evaluation of the microbial flora found in woodwind and brass instruments and their potential to transmit diseases" on pages 100-107. This exercise was developed by Steven E. Holbrook, DMD, MAGD, in association with the *General Dentistry* Self-Instruction committee.

Reading the article and successfully completing the exercise will enable you to:

- recognize the potential for disease transmission from contaminated band instruments;
- recognize the need for periodic sterilization of band instruments;
- identify the pattern of distribution of potential pathogens in and among band instruments; and
- understand the possible consequences to patients from exposure to potential pathogens from contaminated band instruments.

1. What is the only effective method of band instrument sterilization?
   - A. Dry heat
   - B. Moist heat
   - C. Ethylene oxide
   - D. Cold sterilization

2. In a recent study of protective athletic mouthguards, 71% of non-aureus *Staphylococcus* and *Micrococcus* spp. were resistant to
   - A. methicillin.
   - B. glutaraldehyde.
   - C. gentamycin.
   - D. triclosan.

3. High levels of methicillin resistance were found in isolates of
   - A. *Staphylococcus aureus.*
   - B. *Streptococcus mutans.*
   - C. *Treponema denticola.*
   - D. *Fusobacterium nucleatum.*

4. How many of the instruments yielded yeast isolates that could be considered opportunistic and/or allergenic pathogens?
   - A. 2
   - B. 4
   - C. 8
   - D. 12

5. The reed/mouthpiece ends of the instruments were consistently more contaminated than the bell ends. Both the midpoints and the bell ends did not retain microorganisms in sufficient quantities to produce disease.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

6. What percentage of mold isolates found in the instruments were potential mycotoxin producers?
   - A. 12
   - B. 24
   - C. 48
   - D. 96

7. Which band instruments were more heavily contaminated with bacteria?
   - A. Brass
   - B. Percussion
   - C. Woodwinds
   - D. Strings

8. Which of the following woodwind instruments was most contaminated with bacteria?
   - A. Oboes
   - B. Clarinets
   - C. Trombones
   - D. Saxophones

9. Analysis of the bacterial loads revealed that which of the following did not affect bacterial contamination?
   - A. Composition of the instruments
   - B. Length of the reed
   - C. Diameter of the mouthpiece
   - D. Shape of the bell

10. The analysis of bacterial loads confirmed all of the following except:
    A. Reeds were significantly more contaminated than their cases
    B. Mouthpieces were significantly more contaminated than their cases
    C. Woodwind cases were significantly more contaminated than brass cases
    D. The band room was significantly more contaminated than other classrooms

11. Studies have confirmed a relationship between playing band instruments and breathing difficulties. This pathology is the result of playing contaminated band instruments.
    A. Both statements are true.
    B. The first statement is true; the second is false.
    C. The first statement is false; the second is true.
    D. Both statements are false.

12. What do the results of the study indicate?
    A. Band instruments were contaminated with pathogenic microbes
    B. Periodic sterilization of band instruments is not indicated
    C. Asthma in band students is caused by contaminated instruments
    D. Band students are more susceptable to opportunistic pathogens

13. All of the following bacterial isolates were identified from internal components or cases of band instruments or except:
    A. Gram-positive cocci
    B. Gram-positive bacilli
    C. Gram-negative cocci
    D. Gram-negative bacilli

14. Bacterial load analysis confirmed that the bells of instruments were equally as contaminated as their
    A. mouthpieces.
    B. valves.
    C. reeds.
    D. cases.

15. What percentage of hospitalized patients from a 2000 study were found to have antimicrobial-resistant infections?
    A. 3.5
    B. 7.5
    C. 13.5
    D. 16.5

Answer form and Instructions are on pages 159-160.
Answers for this exercise must be received by February 29, 2012.

To enroll in Self-Instruction, click here.

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What every dentist should know about zinc

Amar Patel, DDS ▪ J. Anthony von Fraunhofer, MSc, PhD ▪ Nasir Bashirelahi, PhD

Zinc plays an important role in human physiology, from its involvement in the proper function of the immune system to its role in cellular growth, cell proliferation, and cell apoptosis as well as its essential role in the activity of numerous zinc-binding proteins. However, zinc also plays a key pathophysiological role in major neurological disorders and diabetes. Zinc deficiency is a worldwide problem, whereas excessive intake of zinc is relatively rare. Many patients are exposed to zinc on a regular basis through dentistry as a result of its use in certain restorative materials, mouthwashes, toothpastes and, notably, denture adhesives. Of particular importance to dental professionals are various case reports concerning the neurologic effects of excess zinc intake by patients who routinely use large quantities of zinc-containing denture adhesives. This review presents relevant information concerning the use of zinc in dentistry.

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Zinc is one of the essential trace metals in the human body; other essential trace metals include chromium, selenium, manganese, and copper.[1] Zinc can be found in large quantities throughout the human diet; major sources include oysters, beef, lobster, pork, cereal, yogurt, fish, and eggs.[2] Zinc deficiency, a worldwide problem that affects approximately 4 million people in the U.S. alone, is seen in populations having diets low in red meat and rich in dietary fiber and phytate (inositol hexaphosphoric acid). Zinc deficiency also is observed in alcoholism, chronic renal disease, sickle cell anemia, and malabsorption conditions. The initial manifestations of zinc deficiency are taste and olfactory dysfunctions, but as severity increases, zinc deficiency causes a variety of problems, including impaired brain growth, anorexia, growth retardation, hypogonadism, and delayed sexual maturity.

Research has shown that zinc participates in more than 300 enzymatic reactions; in fact, zinc is present in one form or another in each of the six classes of enzymes.[3] Within these classes, zinc heavily influences carbohydrate and energy metabolism, protein degradation and synthesis, nucleic acid synthesis, and intracellular transportation while providing antioxidant activity.[1]

The pancreatic system also relies on zinc for exocrine and endocrine functions. Another zinc-dependent process is spermatogenesis, as zinc is important for testosterone metabolism.[1] The ubiquitous presence of zinc in the human body has led researchers to study its relation to various forms of cancer, such as prostate and oral cancers.[4,5] The homeostatic properties of zinc allow the body to reduce excretion of zinc during times of insufficiency and increase excretion during periods of excess intake.[6]

Absorption of zinc, copper, and iron via the diet is an active process with similar transport mechanisms.[1] Excess zinc intake, however, has been linked to copper insufficiency, due to the similarity in absorption patterns in the gastrointestinal tract for the two metals.[7] Several studies have connected the link between copper-deficient anemia and neutropenia to an increase in zinc intake.[8,9] Of direct concern to dental professionals, however, has been the recent discovery of neurologic disorders resulting from excessive use of denture adhesives; these products can contain high leachable zinc contents that can cause copper deficiencies.[10]

The recommended daily allowance (RDA) of zinc for adult males (ages 19–70) is 11 mg; for adult females, the RDA is 8 mg.[11] People with diets rich in phytate (for example, vegetable-based diets) could experience mineral deficiencies, typically in developing countries. Since phytate, present in vegetarian diets, is a strong chelator of zinc (as well as calcium, magnesium, and iron), vegetarians and athletes with high-carbohydrate diets could require zinc supplementation.

Zinc supplements are available in a variety of forms; dietary supplements commonly are based on zinc gluconate, zinc sulfate, or zinc acetate, although the percentage of elemental zinc varies each compound. For example, zinc sulfate contains approximately 23% elemental zinc.[12] Other supplemental sources of zinc include OTC cold remedies such as throat lozenges, nasal sprays, and gels. Recent controversy over the side effects of nasal sprays containing zinc has caused the FDA to issue a warning to consumers about anosmia resulting from use of

the sprays. As a result, the producer of these nasal sprays has pulled its products from the market.[12]

Excessive zinc intake causes toxicity, which commonly manifests as nausea, stomachache, and mouth irritation; long-term excessive ingestion can lead to neurological complications. Large doses of zinc supplements are used to treat celiac disease, sickle cell anemia, and Wilson's disease. Although chronic therapeutic use of zinc can cause hypocupremia, microcytic anemia, and neutropenia, such conditions respond to copper supplementation and are reversible.

Zinc use in dentistry

An important enzyme that requires the presence of zinc is Zn-superoxide dismutase (SOD), which is critical for oxidation-reduction reactions within the body. This enzyme converts superoxide into oxygen and peroxide molecules, eliminating free radicals.[13] Endodontic studies performed on healthy and symptomatic dental pulp showed variations in the expression and concentrations of SOD.[14] The benefits of SOD include antioxidant and anti-inflammatory properties and improvements to immune response and brain function. The enzyme is approximately two times more active in teeth with healthy dental pulp than in those with irreversible, symptomatic pulpitis.

In addition to its function within the dental pulp, SOD has played a critical role in other oral health diseases. SOD levels have been studied in patients with oral squamous cell carcinoma (OSCC) and in smokers with periodontal disease. Patients with OSCC showed decreased levels of SOD in tissue and blood samples; the study authors suggested that active progression of OSCC increases oxidative stress on patients who might already have deficient antioxidant mechanisms.[15] Cigarette smokers with chronic periodontitis were found to have decreased levels of SOD compared to healthy nonsmokers.[16] The findings of this study suggest that smoking creates oxidative stress within the oral cavity and results in SOD deficiency, which can predispose patients to periodontitis.

Zinc is also vital in the formation of metallothioneins (MT), which likewise have antioxidant properties.[17] A recent study used immunoassays to determine the expression of MT with p53 in various forms of oral cancer. The results indicated that there was a correlation between MT prevalence and the aggressiveness of oral cancers.[4]

Zinc and caries

Cariogenic diets deficient in zinc have demonstrated increased rates of smooth surface enamel caries in mandibular molars.[18] This finding suggests that zinc plays a critical role in posteruption mineralization. Other studies indicate that zinc is excreted into the saliva in higher concentrations for carious patients; it has been postulated that remineralization with zinc should be considered in patients with active caries.[19]

Zinc and recurrent apthous ulcers

Daily supplementation with 220 mg of zinc for a period of one month has been found to be beneficial for patients subject to recurrent apthous ulcers (RAU).[3] This therapy has been shown to increase zinc levels in serum, albumin, and alkaline phosphatase activity; clinical observation confirmed that lesions disappeared and recurrence rates dropped following zinc supplementation.

Zinc and dentifrices

Zinc can provide additional benefits for the oral mucosa, as it has demonstrated the ability to reduce the inflammatory activity of surfactants.[20] Studies with sodium laurel sulfate, a common ingredient in oral mouthrinses and dentifrices, indicated that the addition of zinc and triclosan contributed to a protective effect on oral mucosa through reduced erythema and inflammation. Another study evaluating the antiplaque properties of various ingredients in mouthrinses discovered that the addition of zinc citrate in conjunction with triclosan decreased plaque formation.[21] The same study found that the addition of zinc citrate decreased inflammatory responses within the oral mucosa. More recent studies have focused on the protective effect of zinc citrate when it is included in dentifrices; patients using a zinc citrate dentifrice exhibited a 27–49% decrease in anaerobic and streptococcal flora.[22]

Zinc and restorative materials

The combination of the adverse effects from zinc deficiencies and excessive zinc intake with the delicate balance the body uses to maintain zinc homeostasis indicate that the presence of zinc in dental products could have negative systemic effects. This is particularly true for dental products that could constitute nontraditional sources of zinc uptake, especially if such products are abused.

Zinc is a widely used element in dental products, notably in inorganic dental cements such as zinc phosphate and polycarboxylate cements (luting agents based in zinc oxide), zinc oxide-eugenol (ZOE) temporary cements, and ZOE endodontic filling materials. At one time, zinc was incorporated

in conventional (low copper) dental amalgams, but these materials have largely been displaced by high copper amalgams. Another major use of zinc in dental materials is in denture adhesives or fixatives, predominantly in the form of the triple salt formulation comprising zinc, magnesium, and calcium salts of gantrez acid (polymethyl vinyl ether maleic acid).

Zinc oxide, used in permanent and provisional cements and temporary filling materials, has been shown to possess inherent antimicrobial effects.[23] Further, the antibacterial properties of zinc oxide are being tested outside the field of dentistry for their effectiveness against a variety of bacteria, including *Escherichia coli*.[24,25] It should be noted that polymer-based sealer materials are being increasingly used in endodontics, with a trend away from traditional zinc oxide-based materials, despite certain clinical advantages. Interestingly, one criticism leveled against ZOE root canal sealers—cytotoxicity—has been shown to be caused by the eugenol component, not zinc oxide.[26]

The neurotoxic effects of zinc have been demonstrated by *in vitro* studies of dental amalgam placed in cortical cell cultures of glial and neuronal cells.[27] Although amalgam contains a variety of potentially neurotoxic metals (mercury, copper, tin, silver, and zinc), zinc leakage caused the toxicity effects when amalgam was placed in direct contact with neural cells. However, due to zinc's complex interaction with the body, a clear dose-dependent toxicity was not established. This study did not establish that the clinical use of amalgam was linked to neurotoxicity *in vivo*; instead, it alerted practitioners to the fact that mercury is not the most neurotoxic metal in dental amalgam. Additionally, it was suggested that incorporation of a zinc chelator within the amalgam restorative material would reduce concerns over neurotoxic effects arising from zinc leaching due to leakage effects.[27]

In an effort to provide further understanding of potential adverse effects from zinc release, a study was performed using dentin as a substrate to examine the *in vitro* release of zinc from restorative materials.[28] The authors concluded that without the presence of dentin, high concentrations of zinc were released into solution. In some instances, these levels exceeded the cytotoxic levels for cells. However, with the presence of dentin, the release of zinc was greatly diminished.[28]

A case report from Japan in 2005 reported the development of palmoplantar pustulosis (PPP) in a patient, the cause of which was ascribed to dental restorations. The clinical symptoms of PPP are the presentation of pustules, vesicles, and scaly erythema over the palmar and sole regions. A forearm allergen test administered to the patient determined that the zinc contained in the dental restorations caused the condition, which was alleviated following removal of the restorations.[29]

Zinc and denture adhesives

In recent years, the neurology literature has published case reports on the examination of patients experiencing hypocupremia and its neurologic side effects.[30-32] These studies are of particular interest to dentistry because the source of zinc uptake was determined to be excessive use of denture adhesives. In at least one case, excessive use was defined as patient administration of two or three tubes of denture adhesive per week over a period of years. The actual prevalence of denture adhesive-induced hypocupremia is unknown, but it may be higher than anticipated if patient use of such products greatly exceeds recommended dosages.

The instructions for use of denture adhesives (packaged with the product) suggest that optimal use involves placing a thin film or a series of dots across the intaglio surface and/or within the sulcus of the denture. When this recommendation is followed, approximately 0.5–1.5 g of denture adhesive would be placed on the denture. Since the average tube of denture adhesive contains 68 g of paste, a single tube should last a patient 3–10 weeks with daily use, although actual consumption would depend on the number of adhesive applications per day.[30] It is only recently that packaging of denture adhesives included warnings regarding overuse of these products and potential adverse systemic effects.

The corollary of the complex exchange mechanism of absorption in gut cells is that an excess uptake of zinc will lead to an acquired copper deficiency. This competitive binding between zinc and copper is used therapeutically for individuals with Wilson's disease; affected individuals are prescribed zinc supplements to decrease serum copper levels. In comparison, patients reported to have abused denture adhesive had zinc intakes that were 5–23 times the supplemental dosing provided to patients with Wilson's disease.[31]

Systemic effects arising from copper deficiency have been previously described and were attributed to hematologic and neurologic disorders.[31] Although the clinical symptoms—notably neurological effects associated with copper deficiency—have not always been described in detail, these symptoms have included myelopolyneuropathy, optic neuritis, motor neuron

disease, and peripheral neuropathy. Commonly, these symptoms initially manifest as paresis of the lower extremities that progresses to include the upper extremities. These patients also have reported a loss of balance and varying symptoms of myelopathy involving the corticospinal tract and dorsal columns.[31]

Hyperzincemia is now considered to be the second most common cause of copper deficiency myelopathy, with the leading cause being a history of upper gastrointestinal surgeries.[31] When patients suffering from hyperzincemia were taken off the denture adhesive and given copper supplements, serum levels for both metals returned to normal.[30] The timing of diagnosis and immediate treatment are critical in preventing irrevocable neurologic changes associated with zinc.[31]
In the three studies summarized here, there were varying degrees of neurologic improvement after cessation of denture adhesive use. As noted, the estimated daily exposure of zinc from denture adhesive use for these patients ranged from 350–1,700 mg. While this intake is very high, it does not directly reflect the uptake dosage, as the mechanism of zinc uptake from denture adhesive through the oral mucosa has not been quantified.[31]

Summary

Zinc has great nutritional importance and is usually absorbed into the body through dietary intake. However, the presence of zinc in a number of dental materials, especially denture adhesives, appears to provide an additional source of zinc intake. Pathological consequences of excessive zinc intake, particularly its possible interference with the absorption of copper arising from excessive use of denture adhesive creams, should be a matter of concern for all dentists who treat patients with dentures. Zinc excess might be an example of an induced essential trace metal imbalance that could affect the entire body.

When encountering neurological syndromes in patients, dentists should consider the possibility of hyperzincemia due to excessive zinc intake. It must be noted, however, that this issue has been controversial and litigious. Currently, the FDA has issued no warnings regarding the use of denture adhesives, but dentists should admonish their patients to limit the use of denture adhesives in accordance with manufacturers' instructions. Finally, the studies cited here indicate that the use of essential trace metals and vitamins should be considered holistically, not as individual elements.

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COMMENT

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Dentin hypersensitivity and its management

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Dentin hypersensitivity is a common patient complaint that is more prevalent than the profession realizes. It is important for dentists to diagnose dentin hypersensitivity by exclusion and provide appropriate treatment recommendations for patients. Various treatment methods have been proposed but no universally accepted desensitizing agent or treatment has been identified. When a patient has symptoms that can be attributed to dentin hypersensitivity, a thorough clinical examination should be carried out to rule out other likely causes prior to diagnosis and treatment. Depending on the identified cause, a combination of individualized instructions on proper oral health behaviors, use of at-home products, and professional treatment may be required to manage the problem.

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Addy and Urquhart defined *dentin hypersensitivity* as short, sharp pain arising from exposed dentin, typically in response to chemical, thermal, or osmotic stimuli that cannot be explained as arising from any other forms of dental defect or pathology.[1] Dentin hypersensitivity is a prevalent oral problem, affecting more than 40% of adults worldwide and more than 40 million people in the United States.[2-4] It has been reported to afflict 15–20% of the adult population, typically those between the ages of 20 and 50, with a peak incidence between the ages of 30 and 39.[5] Some studies have reported prevalence levels as high as 68%.[6] Patients with periodontal diseases are at particularly high risk for dentin hypersensitivity, and studies report that over 70% of periodontal patients experience it.[7,8] The condition can last for days to weeks or indefinitely, unless treatments are provided.

Although patients who experience dentin hypersensitivity may mention it during a routine dental visit, most of them do not specifically seek treatment for this problem, most likely because they do not view it as a significant dental health problem.[9] However, dentin hypersensitivity can significantly affect an individual's quality of life—it limits dietary choices, can impede effective oral hygiene, and can have a negative effect on esthetics.

The incidence of dentin hypersensitivity is expected to rise as diets change; however, prevention of both caries and periodontal disease may result in improved oral health status and retention and functionality of the dentition.

In a recent random telephone survey, 62% of the respondents reported a slight twinge upon consumption of hot, cold, sour, or sweet food, all of which can cause dentin hypersensitivity.[10] Further, it was found that the most common initiating factor for dentin hypersensitivity among the respondents was consumption of cold drinks.

Studies have reported that premolars are most commonly affected by dentin hypersensitivity.[11] However, another study found that mandibular incisors were most commonly affected and determined that most hypersensitive areas were found on the facial surface of teeth.[10]

Dentin hypersensitivity usually occurs in patients between the ages of 30 and 40; the incidence then declines with age.[11] The most likely reason for this decrease may be related to changes in the pulp, in particular, dentinal sclerosis and the development of secondary or tertiary dentin.

In 2009, the Academy of General Dentistry (AGD) conducted a member survey on dentin hypersensitivity.[12] Among the 710 members who responded, nearly 60% noted that the frequency of tooth erosion had increased over the last five years. However, more than half of the respondents (56%) reported that less than 25% of their patients seek information from them regarding dentin hypersensitivity. Thirty percent of the respondents reported that the youngest age group to demonstrate tooth surface loss was the one covering ages 5–7.

Etiology

In a normal tooth, dentin is covered in the crown by enamel and, in most areas of the root, by a thin layer of cementum. Each tooth contains many thousands of dentinal tubules, which are microscopic tubular structures that radiate outward from the pulp (Fig. 1). These dentinal tubules are typically 0.5–2.0 μ in diameter and are connected to the pulp by a plasma-like biological fluid. Each tubule contains a cytoplasmic cell process called a *Tomes' fiber* and

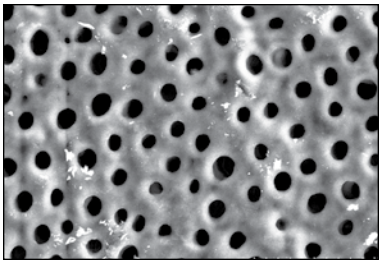


Fig. 1. A scanning electron microscopy image of exposed dentin surface (2000x).

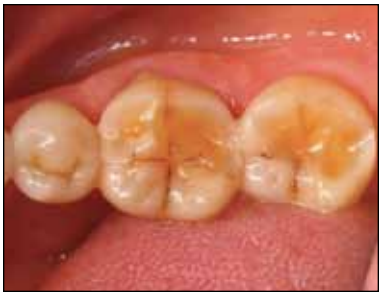


Fig. 2. Enamel loss exposing dentin in molars.

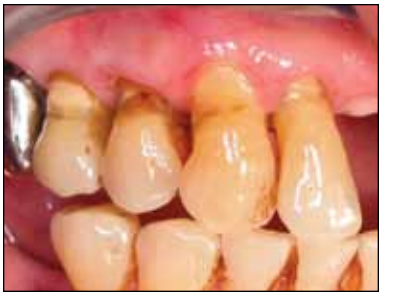


Fig. 3. Gingival recession exposing tooth roots.

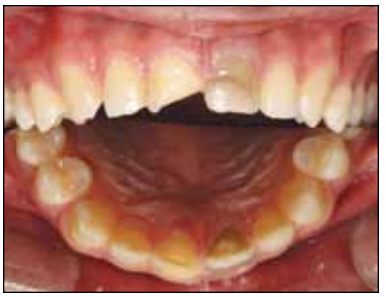


Fig. 4. Dental erosion due to frequent intake of acidic beverages.

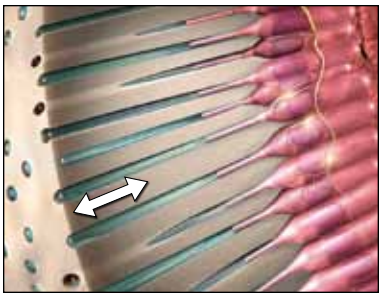


Fig. 5. Pain elicited by movement of fluid in dentinal tubules.

an odontoblast that communicates with the pulp.

There are two types of nerve fibers within the dentinal tubules, myelinated (A-fibers) and unmyelinated (C-fibers). The A-fibers are responsible for the sensation of dentin hypersensitivity, perceived as pain in response to all stimuli. Depending on the depth, approximately 30,000 tubules can be found in 1 mm^2 in a cross-section of dentin. One study found the number of open dentinal tubules per surface area in the exposed dentin surface of teeth with dentin hypersensitivity to be eight times that of teeth that did not respond to stimuli.[13]

The primary causes of dentin hypersensitivity are enamel loss on the tooth crown (Fig. 2) and gingival recession exposing the tooth root (Fig. 3). Enamel loss can be a result of aggressive and/or incorrect toothbrushing, overconsumption of acidic foods, and/or tooth grinding caused by stress and parafunctional behaviors. A recent study found that many people frequently ingest fruits, lemon tea, fruit juice, and soft drinks.[10] The frequent intake of these foods and beverages can cause tooth erosion and dentin hypersensitivity (Fig. 4). In addition, some dental restorative and surgical procedures can cause the gingiva to recede from the normal position at the crown-root junction. When the root is exposed to the oral environment, the cementum covering the root can be removed easily, resulting in exposure of the underlying dentin and dentin hypersensitivity.

Dentin hypersensitivity also has been reported during and following external tooth bleaching. The mechanisms of tooth sensitivity after external tooth bleaching have not yet been fully determined. Studies have attempted to evaluate pulpal histology after bleaching but have produced contradictory results.[14] However, many researchers have suggested that inflammatory mediators can play an important role in causing pain related to hypersensitivity.[15]

Mechanism of dentin hypersensitivity

The exact mechanism of dentin hypersensitivity is still unclear and continues to be the subject of research. One commonly accepted theory is Brannstrom's hydrodynamic theory, which suggests that changes in the fluid flow in dentinal tubules can trigger pain receptors present on nerve endings (located at the pulpal aspect) to fire nerve impulses, thereby eliciting pain (Fig. 5).[16] This hydrodynamic flow can be increased by changes in temperature, humidity, air pressure, and osmotic pressure or by forces acting on the tooth. Physical pressure and hot or cold foods and drinks are typical triggers in people with dentin hypersensitivity.[15]

Managing dentin hypersensitivity

According to the 2009 AGD member survey, only 20% of dentists reported areas that patients indicated were sensitive during a

Table 1. Recommendations to prevent dentin hypersensitivity. (Adapted from: Drisko CH. Dentine hypersensitivity—Dental hygiene and periodontal considerations. Int Dent J 2002;52(5):385-393.)

Suggestions for patients	Suggestions for dental professionals
Avoid using large amounts of toothpaste or reapplying it during brushing	Avoid overinstrumenting the root surfaces during scaling and root planing, particularly in the cervical area of the tooth
Avoid medium- or hard-bristle toothbrushes	Avoid overpolishing exposed dentin during stain removal
Avoid brushing teeth immediately after ingesting acidic foods	Avoid violating the biological width during restoration placement, as this can cause recession
Avoid brushing teeth with excessive pressure	Avoid burning the gingival tissues during in-office bleaching
Avoid excessive flossing or improper use of other interproximal cleaning devices	Advise patients to be careful when using at-home bleaching products
Avoid picking or scratching at the gingiva or using toothpicks inappropriately	

dental examination.[12] Most cases (56%) of dentin hypersensitivity were detected by the patient indicating that an area was sensitive. The two most frequent initial physical symptoms of dentin hypersensitivity were teeth cupping (52%) and glassy or translucent tooth appearance (34%). The two most common causes of dentin hypersensitivity were aggressive toothbrushing (34%) and/or drinking too many acidic beverages (19%). According to the respondents, many patients (56%) managed their sensitivity by avoiding consumption of cold foods or beverages. The most common strategy for professional dental management of dentin hypersensitivity was the application of topical fluoride (39%). Although abrasion from incorrect toothbrushing was common, only 20% of the respondents provided counseling specifically on brushing.

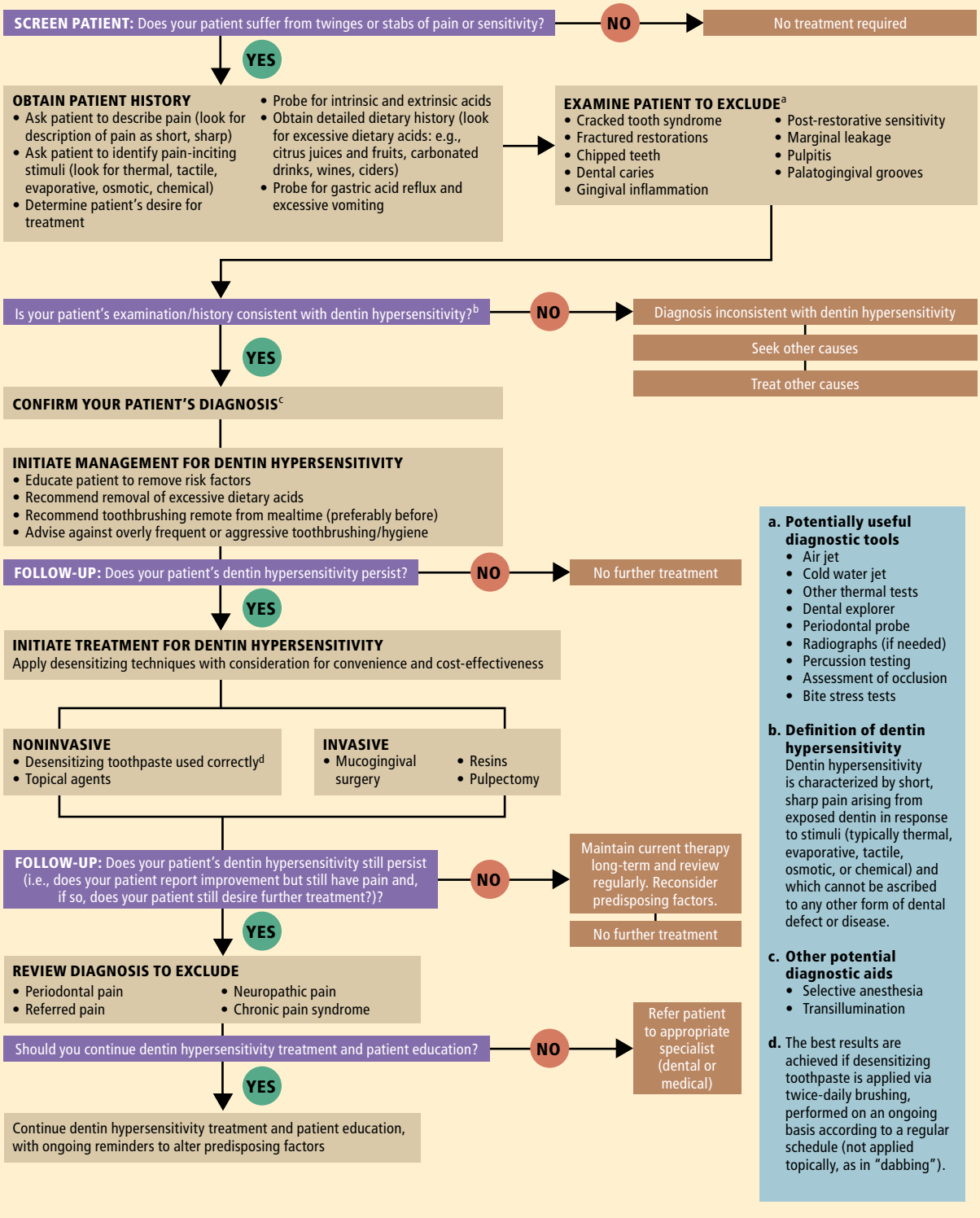
In 2003, the Canadian Advisory Board on Dentin Hypersensitivity (CABDH) conducted a survey of dentists and dental hygienists in Canada using a 66-item questionnaire. The survey found that fewer than half of the 542 respondents (331 dentists and 211 dental hygienists) considered a differential diagnosis for dentin hypersensitivity, even though it is by definition a diagnosis of exclusion.[17] The survey also revealed that many respondents (64% of dentists and 77% of hygienists) incorrectly cited bruxism and malocclusion as triggers for dentin hypersensitivity, while only a small percentage of the respondents (7% of dentists and 5% of dental hygienists) could correctly identify erosion as a primary cause. Furthermore, 17% of dentists and 48% of hygienists were unable to identify the accepted theory of hypersensitivity. Approximately half of the respondents reported that they lacked the confidence to manage a patient's pain caused by dentin hypersensitivity. Also, only half of the respondents reported that they would try to modify the patient's predisposing factors to control the pain.

This survey also revealed a lack of understanding of desensitizing toothpastes among the respondents.[17] Most dentists (56%) and dental hygienists (68%) thought that these toothpastes could prevent dentin hypersensitivity, while 31% of dentists and 16% of hygienists believed that desensitizing toothpastes could not provide relief from dentin hypersensitivity. These results indicate a need for continued dental education on the diagnosis and management of dentin hypersensitivity.

Dentin hypersensitivity meets all of the criteria necessary to be considered a genuine pain syndrome.[18] It is important for people who suffer from pain with symptoms similar to those of dentin hypersensitivity to consult a dentist, because dentin hypersensitivity may share similar symptoms with dental caries and advanced periodontal diseases. In addition, the cause of the pain should be identified and a diagnosis by exclusion must be made for dentin hypersensitivity, ruling out other conditions requiring different treatment. Once the diagnosis of dentin hypersensitivity is confirmed, the dentist often needs to discuss the patient's oral hygiene habits and diets. Precautions and actions may need to be taken by both patient and dentist. A list of preventive recommendations is shown in Table 1.[19]

Tooth sensitivity is to be expected following dental whitening treatments, independent of technique and products used.[20] A clinical trial compared various methods of external teeth bleaching and found that tooth sensitivity is more common

Chart 1. Algorithm for diagnosis and management of dentin hypersensitivity. (Canadian Advisory Board on Dentin Hypersensitivity. Consensus-based recommendations for the diagnosis and management of dentin hypersensitivity. J Can Dent Assoc 2003;69(4):221-226. Reprinted with permission.)



and in greater sensitivity with in-office, chemical-activated or light-activated 35% hydrogen peroxide solution.[20] Therefore, dentists could consider recommending at-home bleaching with a low concentration of peroxide, such as custom-formed trays with 10% carbamide peroxide or 3.5% hydrogen peroxide; another option is a 6% carbamide peroxide varnish. It is essential to inform patients that all whitening procedures can cause hypersensitivity, although it does not always occur. Since the mechanism of tooth sensitivity after external tooth bleaching is unknown, management is mainly supportive. The use of analgesics may help to reduce tooth sensitivity. A clinical trial found that a single 600 mg dose of ibuprofen administered orally reduced tooth sensitivity during, but not after, the treatment period.[14]

Dietary changes and behavior modifications, such as decreasing the intake of acid-containing foods or carbonated drinks, often are necessary to manage dentin hypersensitivity. The patient also should be shown correct brushing techniques, because improper toothbrushing has often been closely correlated to dentin hypersensitivity. It has been shown that manual and power toothbrushes used with a desensitizing toothpaste are almost equally effective in reducing dentin hypersensitivity symptoms.[21] A systematic, structured approach to the problem of dentin hypersensitivity has been developed and incorporated into an easy-reference algorithm for diagnosis and management by the CABDH (Chart 1).[17]

Home management with desensitizing toothpastes

Using a desensitizing toothpaste is considered by many as the "first option" in relieving dentin hypersensitivity. This treatment is effective, but it often takes four to eight weeks for pain relief. Desensitizing toothpastes provide relief from dentin hypersensitivity symptoms in two ways: First, they interrupt the neural response to pain stimuli by the penetration of potassium ions through the tubules to the A-fibers of the nerves, thereby decreasing the excitability of these nerves (Fig. 6). Second, they occlude open tubules to block the hydrodynamic mechanism (Fig. 7).

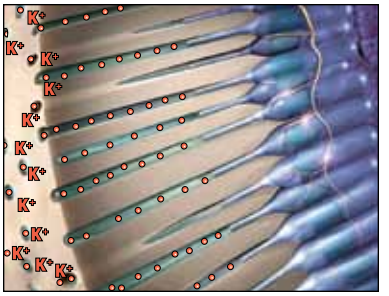


Fig. 6. Interruption of the neural response to pain stimuli with potassium ions.

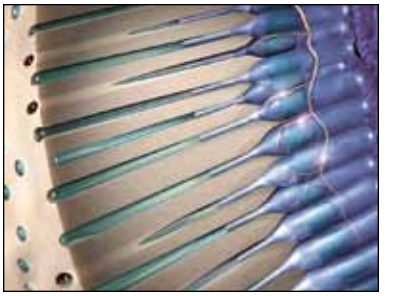


Fig. 7. Occlusion of the open tubules to prevent pain stimuli.

Desensitizing toothpastes such as Sensodyne (GlaxoSmithKline), Colgate Sensitive (Colgate-Palmolive), and Elmex Sensitive (GABA International AG) contain potassium salts, strontium salts, and/or fluoride compounds. These compounds use different approaches to produce the desensitizing effect. Potassium salts, such as potassium nitrate and potassium chloride, provide potassium ions to decrease the excitability of nerves that transmit pain sensation. Strontium salts, such as strontium chloride and strontium acetate, form mineralized deposits within porous dentinal tubules and create a barrier on the surface of the exposed dentin. Fluoride compounds, such as sodium fluoride and amine fluoride, form precipitation of insoluble metal compounds, mainly calcium fluoride globules, that promote remineralization and occlude dentinal tubule openings on the exposed dentin surface.

Desensitizing toothpastes with new chemicals, such as amorphous calcium phosphate and casein phosphopeptide-amorphous calcium phosphate (ACP-CPP) and arginine-calcium carbonate (arginine-$CaCO_3$) and calcium sodium phosphosilicate (CSPS) bioactive glass, are now available commercially. The arginine-$CaCO_3$ and ACP-CPP products have a similar mechanism of action to occlude and block open dentinal tubules from external stimuli associated with dentin hypersensitivity.

When combined with water, ACP crystallizes on the teeth in the form of new enamel. CPP stabilizes ACP until it is applied to teeth. CPP also helps bind ACP to plaque, bacteria, soft tissue, and dentin, where ACP is slowly released to form enamel. MI Paste (GC America Inc.) contains ACP-CPP, while MI Paste Plus incorporates 0.2% sodium fluoride (900 ppm fluoride). In 2008, Reynolds *et al* reported that a dentifrice containing 2% CPP-ACP plus 1,100 ppm fluoride was superior to an ACP-CPP dentifrice in arresting caries progression and remineralizing enamel subsurface lesions.[22]

A new toothpaste containing arginine-$CaCO_3$ (Pro-Relief, Colgate-Palmolive) was introduced in 2009. Arginine is a naturally occurring amino acid that is combined with $CaCO_3$ to form a deposit that seals open dentinal tubules. A recent clinical trial demonstrated that brushing with a toothpaste containing 8% arginine-$CaCO_3$ is effective in reducing dentin hypersensitivity.[23]

CSPS bioactive glasses (NovaMin, GlaxoSmithKline) are known to induce osteogenesis in physiological systems and have been shown to be able to seal and clog open dentinal tubules.[24] When NovaMin particles come in contact with saliva and water, they react by releasing calcium and phosphate ions to seal open dentinal tubules. SootheRx (3M ESPE), a toothpaste containing NovaMin, has been shown to reduce dentin hypersensitivity.[25]

In-office professional care

In addition to asking patients to use desensitizing toothpastes at home, dentists can apply a variety of professional products to exposed dentin surfaces to reduce dentin hypersensitivity. These products include resin-based materials, glutaraldehyde, hydroxyethylmethacrylate (HEMA), potassium oxalates, sodium fluoride varnish, and silver diamine fluoride (SDF) solution. These products generally occlude and seal exposed dentinal tubules. Some dentin bonding agents, such as Clearfil New Bond (Kuraray Dental) and Xeno III (Dentsply International), have demonstrated success in sealing dentinal tubules to treat and prevent sensitivity without an etching agent. A dentin bonding agent that requires an acidic agent opens the pathway for the diffusion of monomers into the collagen network, but it also facilitates the outward seepage of tubular fluid from the pulp to the dentin surface. This process deteriorates bonding for some of the current adhesives.[26]

An aqueous solution of glutaraldehyde and HEMA, such as Gluma Desensitizer (Heraeus Kulzer Inc.) or Calm-It (Dentsply Caulk), has been used as a desensitizing agent, with glutaraldehyde serving as the mechanism for tubule occlusion.[27] Some dentists use potassium oxalate to precipitate and occlude dentinal tubules to treat dentin hypersensitivity. Super Seal (Phoenix Dental) is a potassium oxalate-based, acid-resistant desensitizer that can be applied with a cotton pellet for root sensitivity after periodontal treatment.

Fluoride can be incorporated incrementally into fluorapatite crystals on the tooth surface, making the surface more resistant to acid dissolution. Fluoride also enhances enamel remineralization, increasing the speed of remineralization and also increasing the mineral content of exposed dentin.[28] Fluoride varnish is a popular agent used by dentists because it can be applied quickly and easily. Furthermore, it sets rapidly on tooth surfaces so that gagging and swallowing are minimized. Due to their simplicity in clinical use, fluoride varnishes containing 5% sodium fluoride, such as Duraphat (Colgate-Palmolive), Duraflor (Medicom), and Fluorilaq (Pascal International, Inc.), are becoming more popular for treating dentin hypersensitivity.

An extended-contact varnish (Vanish XT, 3M ESPE) is a photocured fluoride varnish that forms an immediate layer of protection to relieve dentin hypersensitivity. This varnish is a resin-modified glass ionomer that contains glycerophosphate for calcium and phosphate release in addition to fluoride. The formation of resin tags provides an immediate and extended period of occlusion of the dentinal tubules.

SDF is another emerging fluoride agent. Recent reviews conclude that SDF not only desensitizes dentin, it also arrests caries progression.[29,30] Saforide (Toyo Seiyaku Kasei Co., Ltd.) contains 38% SDF, or approximately 44,800 ppm of fluoride ion. It is a colorless solution widely used in countries such as Australia, China, and Japan. A transient mucosal irritation may develop after topical application, but no serious complications were reported. However, SDF is currently unavailable in the United States.

Iontophoresis, a technique that utilizes a low galvanic current to accelerate ionic exchanges and precipitation of insoluble calcium with fluoride gels, has also been used to occlude open dentinal tubules.[31] Dention (Pikosystem Co., Ltd.) is a portable iontophoresis device that uses four alkaline batteries to deliver sodium fluoride gel using a spoon tray with a low electric current to minimize dentin hypersensitivity. Two or three four-minute treatments generally are required to eliminate or reduce the dentin hypersensitivity for a period of two to six months.

Arginine-$CaCO_3$ also is used as an active ingredient in a professionally used prophy paste to manage dentin hypersensitivity. A clinical study of 390 patients indicated that professional prophylaxis by dentists and dental hygienists using an arginine-$CaCO_3$ paste could reduce dentin hypersensitivity significantly.[32] Furthermore, dentists can apply a dental sealant and cavity varnish to cover the exposed dentin surface. In conditions where enamel and/or dentin have been lost due to abrasion, erosion, and/or abfraction, leaving a notching of the root,

filling materials such as glass ionomer and composite resin can cover the exposed root and restore tooth morphology.

In addition to topical application of various products, other clinical treatment methods have been used. One option is to use lasers, either alone or in combination with surface treatments such as topical fluoride application, to manage dentin hypersensitivity.[33] Gingival grafts are another option, particularly when gingival recession is progressive, when there are esthetic concerns, or if dentin hypersensitivity is unresponsive to more conservative treatments. A clinical study of 11 cases reported success with a two-stage surgical technique.[34]

Conclusion

Although dentin hypersensitivity is a common oral health problem for many adult population groups, high-quality scientific studies on the epidemiology, biologic mechanism, and treatment of this condition are lacking. Many treatment methods have been proposed, yet no universally accepted or highly reliable desensitizing agent or treatment has been identified. Well-conducted clinical trials are needed to provide high-quality, evidence-based outcomes to guide clinicians and patients in choosing the most appropriate treatment for dentin hypersensitivity.

When a patient has symptoms that can be attributed to dentin hypersensitivity, the dentist should perform a thorough clinical examination to rule out the other likely causes prior to diagnosis and treatment. Depending on the identified cause, a combination of individualized instructions on proper oral health behaviors, use of at-home products, and professional treatment may be required to manage the problem.

Disclaimer

The authors have no financial, economic, commercial, and/or professional interests in any of the products or manufacturers listed in this article.

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Manufacturers

Colgate-Palmolive, New York, NY
800.763.0246, www.colgate.com

Dentsply Caulk, Milford, DE
800.523.2855, www.caulk.com

Dentsply International, York, PA
800.877.0020, www.dentsply.com

GABA International AG, Therwil, Switzerland
41.61.415.6060, www.gaba.com

GC America Inc., Alsip, IL
800.323.7063, www.gcamerica.com

GlaxoSmithKline, Research Triangle Park, NC
888.825.5249, www.gsk.com

Heraeus Kulzer Inc., South Bend, IN
800.431.1785, www.heraeus-dental-us.com

Kuraray Dental, New York, NY
800.879.1676, www.kuraraydental.com

Medicom, Tonawanda, NY
800.361.2862, www.medicom.com

Pascal International, Inc., Bellevue, WA
800.426.8051, www.pascaldental.com

Phoenix Dental, Fenton, MI
877.463.9905, www.phoenixdental.com

Pikosystem Co., Ltd., Godollo, Hungary
36.30.630.3571, www.pikosystem.hu

Toyo Seiyaku Kasei Co., Ltd., Osaka, Japan
www.toyo-hachi.co.jp

3M ESPE, St. Paul, MN
888.364.3577, www.3m.com

COMMENT

Exercise No. 280

Dentinal Hypersensitivity & Treatment

Subject Code 161

The 15 questions for this exercise are based on the article "Dentin hypersensitivity and its management" on pages 115-122. This exercise was developed by Gus E. Gates, DDS, MAGD, in association with the *General Dentistry* Self-Instruction committee.

Reading the article and successfully completing the exercise will enable you to:

- define dentin hypersensitivity and give its etiology;
- describe the prevalence of dentin hypersensitivity; and
- discuss methods and materials for the treatment of dentin hypersensitivity.

1. Dentin hypersensitivity can be defined as a _____ duration, _____ pain arising from exposed dentin.
   - A. long, sharp
   - B. short, sharp
   - C. short, dull
   - D. long, dull

2. Less than 20% of periodontal patients have problems with dentin hypersensitivity. This is because patients with periodontal disease are at a lower risk for dentin hypersensitivity.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

3. Dentin hypersensitivity is a problem that does not significantly affect a patient's quality of life. For this reason, most patients do not seek treatment for it.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

4. According to patients, what is the most common initiating factor for dentinal hypersensitivity?
   - A. Sour food
   - B. Hot drinks
   - C. Cold drinks
   - D. Sweet food

5. Which teeth are most commonly affected by dentin hypersensitivity?
   - A. Incisors and canines
   - B. Molars and premolars
   - C. Premolars and incisors
   - D. Canines and molars

6. Dentin hypersensitivity usually occurs in patients in which age bracket?
   - A. 20–29
   - B. 30–39
   - C. 40–49
   - D. 50–59

7. Within the dentinal tubules, the unmyelinated nerve fibers (C-fibers) are responsible for the sensation of dentin hypersensitivity. The number of open dentinal tubules per surface area in teeth with dentin hypersensitivity is eight times that of non-hypersensitive teeth.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

8. Tooth erosion and dentin hypersensitivity can be caused by frequent consumption of all the beverages listed below except:
   - A. Lemon tea
   - B. Orange juice
   - C. Diet cola
   - D. Coffee

9. According to a 2009 Academy of General Dentistry survey, what is the most common strategy for dentists to manage dentin hypersensitivity?
   - A. Using topical fluoride
   - B. Improving tooth brushing
   - C. Applying sealant material
   - D. Changing patient drinking habits

10. Suggestions to patients for preventing dentin hypersensitivity include all of the following except:
    A. Avoid medium or hard toothbrushes
    B. Avoid brushing teeth immediately after ingesting hot foods
    C. Avoid using large amounts of dentifrice during brushing
    D. Avoid excessive flossing

11. Suggestions for dental professionals to prevent dentin hypersensitivity include all of the following except:
    A. Avoid the use of all home bleaching products
    B. Avoid overpolishing exposed dentin
    C. Avoid violating the biological width during restoration placement
    D. Avoid overinstrumenting the root surface during scaling

12. A clinical trial compared various methods of external tooth bleaching and found that tooth sensitivity is more common with in-office systems that contain _____% of hydrogen peroxide.
    A. 20
    B. 25
    C. 30
    D. 35

13. Which of the following is not found in a desensititizing toothpaste?
    A. Potassium salts
    B. Strontium salts
    C. Fluoride compounds
    D. Magnesium

14. Fluoride compounds decrease the excitability of the nerves to stimuli by forming mineralized deposits with the porous dentinal tubules. This creates a barrier on the surface of the exposed dentin.
    A. Both statements are true.
    B. The first statement is true; the second is false.
    C. The first statement is false; the second is true.
    D. Both statements are false.

15. Which chemical has been shown to form new enamel on teeth?
    A. Amorphous calcium phosphate
    B. Casein phosphopeptide
    C. Calcium carbonate
    D. Calcium sodium phosphosilicate

Answer form and Instructions are on pages 159-160.
Answers for this exercise must be received by February 29, 2012.

To enroll in Self-Instruction, click here.

self CDE 2 HOURS CREDIT instruction

Diametral tensile strength of composite core material with cured and uncured fiber posts

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The aim of this study was to determine the influence of different types of posts and post head designs on the fracture resistance of a composite resin core material using the diametral tensile strength (DTS). Seventy-five disc specimens were prepared using a composite core and prefabricated glass fiber posts and were divided into four test groups and one control group ($n = 15$). The use of fiber posts reduced the DTS of the composite core material; the DTS value of the control material was significantly higher ($p = 0.05$) than all of the test groups.

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Fiber posts are used extensively to restore endodontically treated teeth because they present some potential advantages over metal posts, such as a modulus of elasticity similar to that of dentin, high tensile strengths compatible with Bis-GMA bonding procedures, esthetics, and easy handling characteristics.[1-3] Prefabricated fiber-reinforced composite (FRC) posts are used to provide retention to a composite resin core buildup when the coronal tooth exhibits an extensive loss. Prefabricated FRC posts have been used as a possible substitute for cast post and core restorations of endondontically treated teeth.[4,5] According to the predominant view, the post and core should be used to increase the retention of fixed prosthetic reconstruction, not for reinforcement.[6]

Several post designs and surface characteristics are used to increase retention and to optimize stress distribution on the root; for this reason, the post head design is an important factor in creating a reliable substructure for a core restoration.[7] Post heads can be flat, spherical, or serrated; the most commonly used core materials are amalgam, composite, and glass-ionomer cement.[8] In some situations, the clinician faces the challenge of shortening the post when it is too long compared to the preparation inside the root. Cutting the fiber post at its apical portion may lead to a post that is shorter than expected and requires replacement. On the other hand, cutting the post head after cementation avoids the risk of the post being too short; however, if the post has a specially designed head, this feature is removed and the extra retention could be lost.

Retention values provide a rapid and convenient way of comparing post stability. Core buildup materials with greater retention are more resistant to dislodgement, which occurs due to lateral occlusal stresses.[9] The failure rate of crowns placed over fiber post and cores has been measured to be 8%; the major cause of failure was interfacial failure between post and core materials.[7-11] The interaction between composite resins and fiber-reinforced posts is critical for the success of restorations placed over these materials. The experimental and manufacturer's surface treatments as well as the adhesive application have enhanced the bond strength between fiber posts and resin cement.[12]

In FRC post technology, glass or quartz fibers are coated with a silane coupling agent to improve the adhesion at the fiber-resin matrix interface, protect fibers from damage during handling, modify the catalytic and wettability properties of fiber surfaces, and increase the chemical durability of the fiber-matrix interface, especially to water.[12] However, the silane coupling agent is able to chemically bridge only resins and hydroxide-covered inorganic substrates.[13] Moreover, a chemical bond is possible only between the composite resin core material and the exposed fibers of the post at the fiber post/composite core interface.

The highly cross-linked polymers of the matrix in FRC posts do not have any functional groups available for reaction.[13,14] In FRC materials such as EverStick (StickTech), an effort to solve the problem of adhering to highly cross-linked polymers has been made by utilizing semi-interpenetrating polymer network (IPN) structures.[14] With this technology, the fibers are pre-impregnated with a

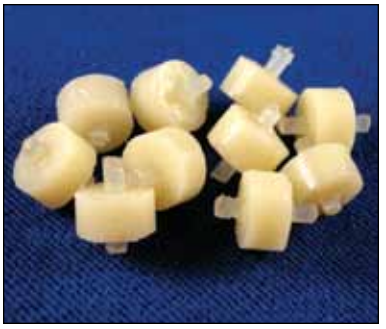
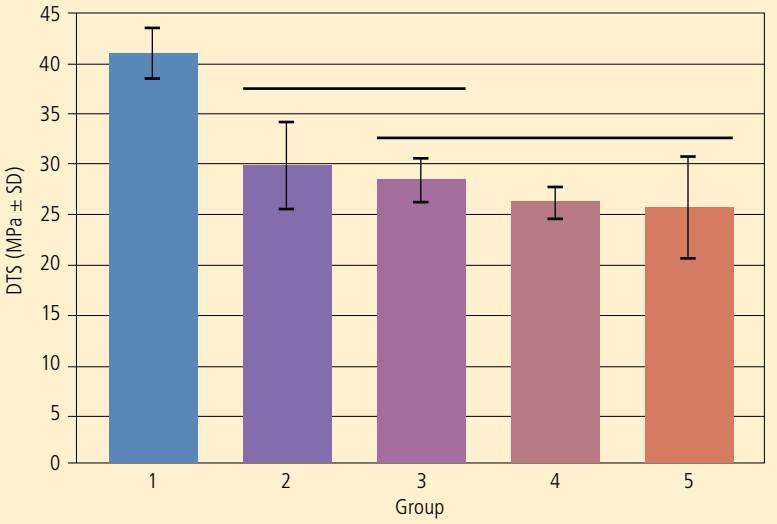


Fig. 1. Posts centered in core buildup material.

Table 1. Core materials used in this study.

Group	Core material	Manufacturer	Lot No.
1 (control)	ParaCore	Coltene/Whaledent	0095236
2	EverStick (conventional)	Stick Tech Ltd.	2050426-ES-125
3	ParaPost (without head)	Coltene/Whaledent	MT-52625
4	ParaPost (conventional)	Coltene/Whaledent	MT-52625
5	EverStick (separated head)	Stick Tech Ltd.	2050426-ES-125

Chart 1. Average (±SD) DTS values (MPa) and Tukey's B rank order test results. A solid line indicates values that present no significant difference ($p = 0.05$).



polymethylmethacrylate (PMMA), which may be partially dissolved by the application of a photocuring resin for five minutes. As a result of the partial dissolution at the surface of the fiber frame, grooves and undercuts are created where micromechanical bonding can be established in addition to the chemical adhesion. According to the manufacturer, the post surface is thereby "reactivated" to offer considerably more favorable conditions for adhesion to the core or the luting material.[15]

Little information is available in the literature about the alteration of the design of ParaPost or EverStick posts within composite core material. Therefore, the objective of this study was to evaluate the diametral tensile strength (DTS) when cured glass fiber posts (ParaPost) and uncured glass fiber posts (EverStick) with different designs are bonded to ParaCore core buildup material. This study had two null hypotheses: There is no difference in DTS of the composite resin core material with or without a post; and there is no difference in DTS of the composite resin core material with or without conventional or modified posts with or without a head.

Materials and methods

Seventy-five disc-shaped specimens 6.0 mm in diameter and 3.0 mm thick ($n = 15$) were produced using a stainless steel jig.[11] The posts were incorporated at the centers of the composite resin core material (Fig. 1); the composite core materials are shown in Table 1.

Composite resin discs with no posts were prepared as a control group (Group 1). For Group 2, a conventional EverStick post was used. Group 3 used ParaPost Fiber Lux (Coltene/Whaledent) after removing the head portion; the ParaPost surfaces were coated with a non-rinse conditioner (ParaBond, Coltene/Whaledent), as suggested by the manufacturer. One drop from each of two adhesives (ParaBond Adhesive A and ParaBond Adhesive B, Coltene/Whaledent) was mixed, applied to the post surface, and air-dried for five seconds. In Group 4, ParaPost Fiber Lux was used with the head intact; specimens were prepared as described for Group 3. In Group 5, an EverStick post with a modified end was used. The fibers at the post end were spread apart to allow the composite material to flow in

between prior to polymerization. Each specimen was photopolymerized (QHL75, model 506, Dentsply International, output: 600 mW/cm^2) for 120 seconds. Specimens were stored in distilled water at 37°C for seven days prior to the mechanical test.

For DTS testing, compressive loading was subjected perpendicular to the circumferential area of the disc specimen using a universal testing machine (Instron Model 8501; Instron Corp.) at 0.5 mm/min crosshead speed. Load was applied until failure occurred. DTS values were calculated using the formula described below:

$$\sigma_x = \frac{2p}{\pi DT}$$

where σ_x is the DTS (MPa), p is the force (N), D is the specimen diameter (mm), and T is the specimen thickness (mm).[16] Means and standard deviations (SD) were calculated and data were statistically analyzed using one-way ANOVA and Tukey's B-rank order tests at $p = 0.05$.

Results

A comparison of DTS values for all groups tested is shown in Chart 1. The DTS values were separated into three groups at $p < 0.05$. These values ranged from 25.72 MPa for Group 5 to 41.07 MPa for Group 1. Tukey's test revealed that the control group exhibited significantly higher DTS values than all of the other materials tested ($p < 0.05$). Groups 2 and 3 exhibited DTS values that were 27–31% lower than that of the control group, while the DTS values of Groups 4 and 5 were 37% lower than that of the control group. In addition, the mean DTS values for Group 2 were significantly higher than those for Groups 4 and 5 ($p < 0.05$). No significant difference was found between the DTS of ParaPost with a head (Group 4) and ParaPost without a head (Group 3) ($p > 0.05$).

Discussion

DTS is an alternative to direct tensile testing suitable for brittle materials; the main advantages of this test are its relative simplicity and the reproducibility of the results. For the DTS test, a disc of the brittle material is compressed along the radial direction until fracture occurs, at which point the compressive stress applied to the specimen introduces a tensile stress in the material in the plane of the force being applied by the test machine.[16]

In the present study, the first hypothesis was not validated, as the composite resin core material without a post showed higher DTS than the composite resin core material with a post. The second hypothesis was partially accepted, in that no difference in DTS was observed between ParaPost with a head and ParaPost without a head, while the conventional EverStick post presented higher DTS than the modified EverStick post.

The design of the post and core specimens in the present study represented a clinical scenario in which there is limited interocclusal height. Clinically, when a core material is added to the post, it should extend approximately 2.0 mm above the post head; however, some clinical situations do not allow such extension and the post head is finished flush with the core's top surface.[11,16] If the specimens in this study had allowed the post to extend to only half the thickness of the core, simulating an ideal clinical situation of 2.0 mm of core above the post head, higher DTS values may have been recorded.[11]

In the present study, modification of the ParaPost (Groups 3 and 4) did not present a significant difference in DTS values, indicating that the ParaPost head is ineffective in increasing retention of the core buildup material to the post when compressive forces are applied. The clinical implication of this finding is that the ParaPost head can be cut off prior to or after cementation when a shorter post is required at both ends (head or apical), without compromising the retention of the core buildup material. These results are consistent with those from a previous study.[11] In addition, modification of the EverStick post design resulted in significantly lower DTS values compared to the conventional EverStick post, indicating that separation of EverStick fibers weakens the entire specimen in tension.

The control group, consisting of ParaCore buildup material only with no posts, exhibited the highest DTS values (41.07 MPa) of all of the groups. A range of DTS values from 32–52 MPa for six photopolymerized composite resins has been reported previously.[17] Incorporation of posts in the core specimens resulted in a significant reduction in the DTS values of the specimens, regardless of the type of post used. These findings demonstrate that the composite resin core material provides higher fracture resistance when used as a solid block. The clinical significance of this finding needs to be further explored; additionally, posts with other head designs should be tested.

Conclusion

Within the limitations of this study, it can be concluded that the inclusion of posts weakens composite resin cores in tension; there was no difference in DTS between the cured ParaPost and the uncured EverStick post. Also, the ParaPost head appears to be ineffective in

increasing retention of the post to the core material; therefore, the post head can be cut off in order to achieve the desired post length.

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Disclaimer

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COMMENT

Exercise No. 281

Dental Materials

Subject Code 017

The 15 questions for this exercise are based on the article "Diametral tensile strength of composite core material with cured and uncured fiber posts" on pages 125-128. This exercise was developed by William U. Wax, DDS, FAGD, in association with the *General Dentistry* Self-Instruction committee.

Reading the article and successfully completing the exercise will make you aware of:

- the types of available posts;
- the importance of post head design; and
- the effects of a post on composite core materials.

1. The modulus of elasticity of fiber posts as compared to metal posts is similar to that of
   - A. enamel.
   - B. dentin.
   - C. composite resin.
   - D. Bis-GMA resins.

2. The main purpose of a post and core is to
   - A. retain the restoration.
   - B. fill in undercuts prior to prepping the tooth.
   - C. re-establish the vertical height of the tooth.
   - D. reinforce the remaining tooth structure.

3. Which of the following is not a post head design mentioned in the article?
   - A. Flat
   - B. Spherical
   - C. Serrated
   - D. Ovoid

4. Failure of a restoration placed over a fiber post and core can be traced to failure between
   - A. the crown and the core.
   - B. the core and the dentin.
   - C. the post and the dentin.
   - D. the post and the core.

5. What is used to improve adhesion between fibers and the resin matrix of the post?
   - A. Methylmethacrylate
   - B. Resin cement
   - C. Polycarboxylate cement
   - D. Silane

6. Which method is used to improve adhesion between FRC posts and the core material?
   - A. Self-curing resin cement
   - B. Polycarboxylate cement
   - C. PMMA impregnation
   - D. Exposing OH groups in the post

7. The study showed that the use of a post increases the strength of the core. Removing the head of a ParaPost increases the strength of the core as opposed to leaving the head on.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

8. A core material should extend approximately ____ mm above the head of the post.
   - A. 2
   - B. 3
   - C. 4
   - D. 5

9. Leaving the EverStick fibers intact provided greater fracture resistance than separating them. In the study, omission of a post produced the highest DTS values.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

10. The ability to maintain core retention to a ParaPost without a head allows one to
    - A. shorten the post to suit intraoral conditions.
    - B. bond directly to a posted root.
    - C. use amalgam as a core material.
    - D. use glass ionomer as a core-cementing medium.

11. What percentage of crowns placed over fiber post and core buildups fail?
    - A. 6
    - B. 8
    - C. 10
    - D. 12

12. The FRC post matrix does not have available _____ with which to react.
    A. wetting agents
    B. fibers
    C. functional groups
    D. organic substrates

13. What is used to partially dissolve the PMMA of pre-impregnated fibers?
    A. Silane
    B. Polycarboxylate cement
    C. DTS liquid
    D. Photocuring resin

14. Experiments with post head configuration are designed to _____ retention and _____ stress distribution on the root.
    A. increase; optimize
    B. decrease; optimize
    C. increase; facilitate
    d. decrease; facilitate

15. Modification of an EverStick post end was accomplished by
    A. spreading the fibers.
    B. photocuring the fibers.
    C. coating the post with resin.
    D. shortening the post.

Answer form and Instructions are on pages 159-160.
Answers for this exercise must be received by February 29, 2012.

To enroll in Self-Instruction, click here.

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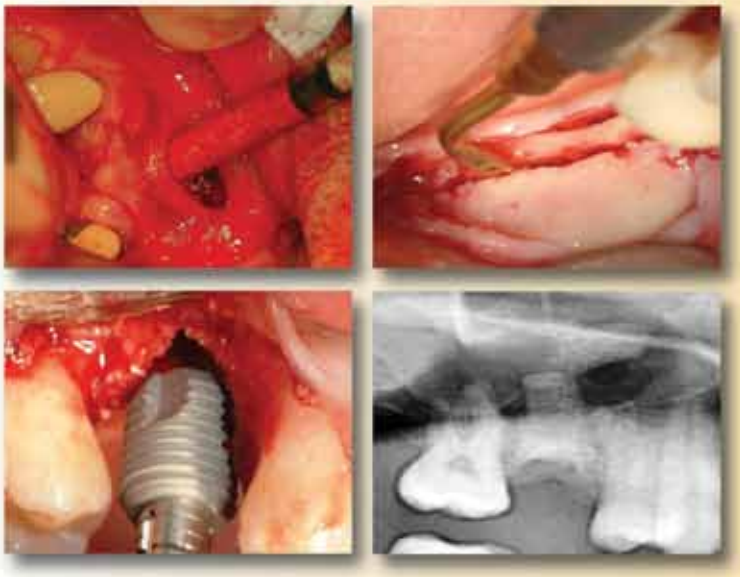

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- *Visor technique - gain mandibular bone height*
- *Flap design and suture techniques*
- *Preparation of fibrin membrane*
- *Sterile technique-barrier drapes & gowns*
- *Treating complications*
- *Billing insurance codes*

Incomplete cusp fractures: Early diagnosis and communication with patients using fiber-optic transillumination and intraoral photography

Samer S. Alassaad, DDS

The diagnosis of incomplete cusp fractures has primarily relied on patient symptoms, which sometimes results in late treatment approaches. The transillumination of tooth structure by a fiber-optic light source can be considered an important adjunct tool in the diagnosis of incomplete cusp fractures before they reach their end stages. Furthermore, transilluminated teeth can be documented by intraoral photography, using a two-handed technique by holding a transillumination device and an intraoral camera simultaneously, with the resulting images shared with the patient. This simple, painless, and noninvasive technique can be incorporated easily into daily practice to evaluate high-risk sites, regardless of patient symptoms. This article reviews incomplete cusp fractures, explains how to detect them using transillumination and intraoral photography, and addresses how to discuss the results with patients.

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Incomplete cusp fractures are oblique dentinal fractures that usually originate at the internal line angles of intracoronal preparations; they can result in complete cuspal fracture, with or without root involvement, if they are permitted to progress to a natural conclusion.[1] Although one study demonstrated that complete cusp fractures of posterior teeth are a common occurrence, with an incidence of 69.9 per 1,000 person-years, incomplete cusp fractures are very subtle and can be a challenge to diagnose.[2,3]

Cusp fractures are seen most commonly in teeth weakened by large intracoronal restorations, where restoration effects are thought to be associated with a reduced amount of dentin supporting the cusps of restored teeth.[2-5] In addition, the risk of cusp fractures increases with the presence of excursive interferences and parafunctional occlusal habits, carious lesions, and aging.[1,3,5-9] In a tooth with healthy pulp tissue, incomplete cusp fractures can be symptomatic and are reported most commonly as persistent sensitivity to cold and chewing; however, they also can be asymptomatic.[3] Early diagnosis is most important in the management of incomplete fractures to limit the propagation of the crack and subsequent microleakage, involvement of the pulpal or periodontal tissues, or catastrophic failure of the cusp.[7,8,10]

As incomplete cusp fractures propagate along the internal line angles of intracoronal preparations and toward enamel, diagonal or horizontal crack lines will become more visible near the enamel surface; they also may be complicated by a vertical component when the crack crosses a buccal or a lingual groove or a proximal marginal ridge.[11] Although visual observation can

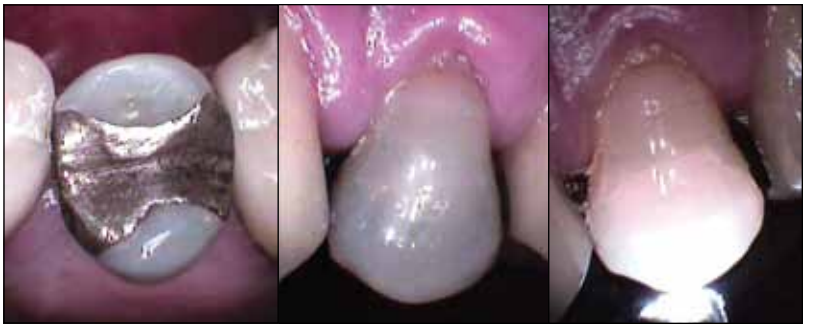

Fig. 1. Maxillary second premolar. *Left:* Occlusal view of cusps weakened by an intracoronal metallic restoration. *Center:* Buccal view. *Right:* Buccal view of a transilluminated buccal cusp showing an incomplete fracture.

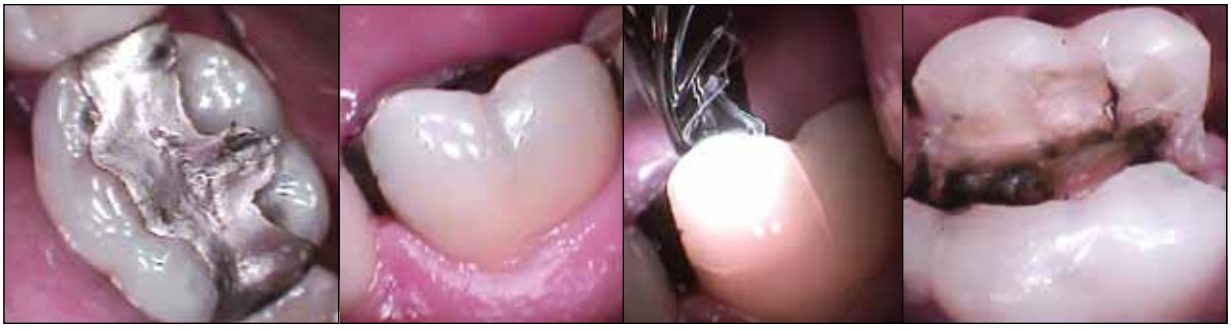

Fig. 2. Mandibular first molar. *Far left:* Occlusal view. *Center left:* Lingual view. *Center right:* Lingual view of a transilluminated mesiolingual cusp. An oblique fracture warrants further investigation. *Far right:* Oblique fracture involving both mesiolingual and distolingual cusps viewed under the light source of the intraoral camera.

detect what appears to be a crack or a fracture of the tooth structure, it may be difficult or impossible for the clinician to differentiate it from an insignificant craze line.[12,13] When teeth with significant fractures are transilluminated using a fiber-optic light source, they will show a well-defined demarcation of blocked illumination at the fracture lines (Fig. 1); meanwhile, structurally sound teeth, including those with craze lines, will transmit the light throughout the tooth structure.[9,10,12]

Magnification is a key element in the codiagnosis of incomplete cusp fractures. While dentists can rely on various magnification devices to assist in their diagnosis, patients have a clear view of incomplete cusp fractures only with intraoral photography, especially when intraoral cameras with 40–50x magnification are used. As a result, these images can be used to clearly communicate the conditions that many patients have a difficult time understanding through verbal explanations and can satisfy their concerns regarding the treatment plan.[14] These images also create valuable records of the patient's condition prior to the start of dental restorative procedures.[14]

Devices and techniques

Capturing high-quality intraoral images of transilluminated teeth that demonstrate incomplete cusp fractures requires a two-handed technique. This technique is not difficult to master, but it requires practice and patience. The dentist uses one hand to hold the transillumination device and the other hand to hold the intraoral camera and keeps his or her eyes on the screen. The only assistance that may be needed from a staff member is retraction and saliva control.

A pen-sized cordless transillumination device that emits an intense beam of cool, white light powered by an LED and transmitted through a focused glass fiber-optic element (Microlux Transilluminator, AdDent, Inc.) is used along with a wand-like intraoral camera that has the ability to automatically compensate for the intensity of incoming light (Advance Cam intraoral camera, TPC Advanced Technology).

The dental operating light is turned off to reduce the other sources of light to a minimum. The intraoral camera is positioned in the lingual or buccal vestibule and stabilized so that it covers the lingual or buccal surfaces of the tooth. The transillumination device is positioned on the suspected cusp tip and moved around the cusp until the incomplete fracture is well-defined on the screen, at which point the image is captured.

Placement of the light source at a right angle to the fracture plane will result in the light beam being interrupted by the fracture, thereby illuminating only the fractured portion while the rest of the tooth remains dark. On the other hand, if no crack is present, the light beam will not be interrupted and will dissipate gradually.

Once an incomplete cusp fracture is identified, removing the existing restoration together with its liner and any present caries is recommended to directly visualize the extension of the fracture.[1,8] Oblique fractures usually will be visible at internal line angles of the preparation. Some of these fractures can appear lighter than the rest of the tooth structure due to refraction of the illuminating light of the operatory or the intraoral camera along the fracture line (Fig. 2). Old fractures under metallic restorations may be accentuated due to the presence of stains

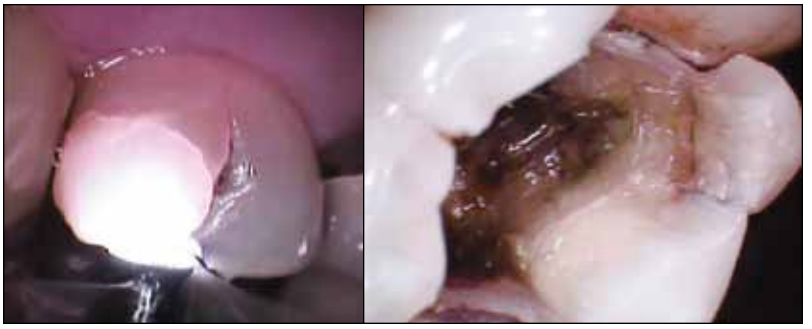

Fig. 3. Maxillary second molar. *Left:* Lingual view of a transilluminated distolingual cusp. *Right:* Intracoronal surface of a distolingual cusp. An old fracture is accentuated by the presence of a stain.

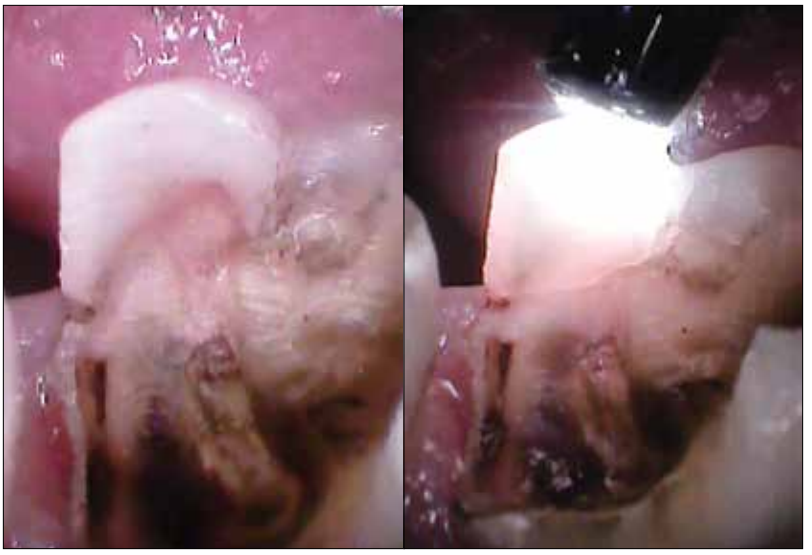

Fig. 4. Intracoronal surface of a mesiolingual cusp on a mandibular first molar. *Left:* The oblique fracture is not completely visible under the light source of the intraoral camera. *Right:* The extension of the oblique fracture is more visible with fiber-optic transillumination.

(Fig. 3). However, the extension of some other fractures may be determined only by fiber-optic light transillumination (Fig. 4).

Discussion

A variety of transillumination devices have been used to reveal incomplete fractures; however, pen-sized cordless units specifically manufactured for this purpose are best-suited for such a diagnostic technique. Their light portal is easily and closely adapted to different sections of the tooth in different directions. They emit adequate light intensity to highlight fractures by being completely interrupted at the fracture line. They also can be viewed directly by the eye without a protective device.

The transillumination device can be considered an important adjunct tool in the diagnosis of incomplete cusp fractures before they reach end stages. However, a slight variation in the position of the transillumination device will yield a less-demarcated fracture line. The presence of deep restorations and caries also can block fiber-optic light transmission, making the use of fiber-optic transillumination problematic.[1] As a consequence, other diagnostic tests such as magnification and tactile examination should be considered.[9]

At the same time, evaluating the restoration's structural and marginal integrity, carious lesions, occlusal interferences, and heavy occlusal forces is advised. If removal of the restoration is indicated for reasons other than incomplete cusp fractures, the transillumination device can still be used (after complete removal of the restoration and caries) to detect any incomplete fracture that might not have been visible during the initial examination process.[3]

Although extraoral cameras offer higher resolution, most wand-like intraoral cameras are capable of capturing images with adequate resolution that can be magnified and viewed on computer monitors and printed for further documentation purposes. Intraoral cameras also have small heads that are easily positioned and stabilized at the lingual or buccal side of the transilluminated tooth to capture images without requiring the use of a mirror as an additional device. Because of their ability to automatically compensate for the intensity of incoming light, intraoral cameras can easily capture details of the brightly transilluminated fracture line and the surrounding tooth structure when used with the intense light emitted by the pen-sized cordless units.

Once an incomplete cusp fracture is diagnosed, it should be considered structurally unsound,

and protection from occlusal forces to minimize fracture propagation is indicated.[1,11] Many techniques have been described to protect teeth with fractured cusps. Definitive treatment has included occlusal adjustment, pin-retained amalgams, bonded amalgams, bonded composites, cusp overlay restorations, and full-coverage crowns, with excellent prognosis.[6,8,10] However, future research may indicate that intracoronal restorations and occlusal adjustments are insufficient to stop structural breakdown and that more protective extracoronal coverage is indicated.[11]

Summary

Fiber-optic transillumination and intraoral photography are some of the most accessible technologies that dentists can incorporate into their practices. When used simultaneously, these technologies are worth even more in terms of diagnosis, treatment planning, documentation, education, and presentation of treatment to today's more visually focused patients. These devices can be implemented regularly as a part of the examination process to detect incomplete cusp fractures and to evaluate high-risk areas such as cusps weakened by large restorations, occlusal trauma, and carious lesions, regardless of patient symptoms.

Disclaimer

The author has no financial, economic, commercial, and/or professional interests in any of the companies whose products or devices are included in this article.

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COMMENT

Utility and effectiveness of computer-aided diagnosis of dental caries

Kyle D. Tracy, DMD ▪ Bradley A. Dykstra, DDS ▪ David C. Gakenheimer, PhD ▪ James P. Scheetz, PhD
Stephanie Lacina ▪ William C. Scarfe, BDS, MS ▪ Allan G. Farman, BDS, PhD, DSc

Digital radiography has created a growing opportunity for computer-aided diagnostic (CAD) tools. The Logicon Caries Detector (LCD), with upgraded CAD software based on user feedback, was re-evaluated for its effectiveness via a retrospective clinical study.

Using the upgraded LCD software, 12 dentists (evaluators) blindly assessed 17 radiographs taken by another (attending) dentist, who restored 28 proximal surfaces. The attending dentist confirmed the presence of early dentinal caries, as well as identifying 48 surfaces as *caries-free* or *with enamel caries only subject to noninvasive treatment.* The radiographs, imported into the software using a digital imaging and communications in medicine (DICOM) reader, were visually assessed under typical operatory lighting conditions, then with the aid of the software's density analysis tool. The effectiveness of the evaluators was gauged by calculating two measures of performance, sensitivity and specificity, for the detection and classification of dentinal caries.

Sensitivity among all evaluator dentists was 30% with the initial image; 34% with the brightness and contrast adjusted image; 39% when the image was sharpened; and 69% when the density analysis tool was utilized. Specificity was found to be 97% with the initial image; 95% with the brightness and contrast adjusted image; 93% with the sharpened image; and 94% when the density analysis tool was used.

Compared to the unaided eye, the LCD can significantly improve dentists' ability to detect and classify caries. Dentists may be able to find twice as much early dentinal caries requiring restoration (or at least aggressive noninvasive treatment) than previously, while not unnecessarily restoring additional healthy teeth. The LCD enables dentists to obtain more information from dental digital radiography than is possible with the unaided eye, leading to improved patient care.

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Early proximal surface dental caries can be difficult to detect, classify in terms of depth, and diagnose visually with radiographs. The advent of digital radiology alone has not changed this situation significantly. Studies have shown that none of the digital radiography systems (charge coupled device/complementary metal oxide semiconductor [CCD/CMOS] sensors and phosphorous plates) afford better (or, in some cases, even comparable) diagnostic capability for proximal caries detection and classification than analog intraoral D-, E-, and F-speed film kit.[1-12] Timely treatment is imperative to halt the progress of caries; consequently, methods of improving caries detection are valuable. While digital radiography on its own does not yet provide an improved diagnostic capability, it makes possible technological advancements that aim to extract more information from radiographs than the trained eye can readily see. Software programs such as computer-aided diagnostic (CAD) tools might have the potential to increase early detection and classification of dental caries and quantitatively monitor its state over time, demonstrating the advantages of using digital radiography versus film.

The Logicon Caries Detector (LCD) (Carestream Dental LLC), a patented, FDA-approved computer diagnostic tool, is an example of available CAD software.[13,14] This software program has been available since 1998 for use with the Kodak RVG Digital Radiography System (formerly the Trophy RVG system) (Carestream Dental LLC). The clinical study conducted to support the FDA application demonstrated that this software could help dentists detect 20% more cases of proximal surface caries penetrating into the dentin and needing restoration than they could find with the unaided eye.[14,15] At the same time, the software did not result in additional surfaces being restored unnecessarily.

Based on subsequent findings from several university laboratory studies using extracted teeth and feedback from dental practices using the software in a clinical environment, the LCD has been upgraded to include methods for reducing calculation failures due to complicated tooth geometry (surface contacts and overlaps); a region

of interest (ROI) adjustment tool that automatically computes multiple calculations to help locate the greatest extent of the caries; a manual override of the ROI tool to allow the user to easily survey the proximal surface for variations in the caries pattern; full-screen filters for the display image to provide the maximum amount of visual information without affecting the calculations; and a DICOM file reader to allow the program to be used with any DICOM-compatible intraoral radiograph.[16-18] (The DICOM version of this product is not commercially available at this time.) The purpose of the current article is to present a retrospective clinical evaluation of the updated LCD software, using patient treatment records.

In March 2001, the National Institutes of Health (NIH) published a consensus statement on diagnosis and management of dental caries, expressing a need for advances in radiographic methods of diagnosing noncavitated lesions and a need for clinical studies to evaluate the efficacy of new methods. The work reported in this article contributes to both of these needs as identified by the NIH panel of nonadvocate, nonfederal experts following a number of presentations from prominent investigators in the field.[19,20]

In January 2002, an International Consensus Workshop on Caries Clinical Trials (ICW-CCT) was held in Scotland; it included a presentation on modern concepts of caries management.[21] Seven linked steps were proposed to facilitate caries management clinically:

1. Caries detection
2. Lesion measurement
3. Lesion monitoring by repeated measures
4. Caries activity measures
5. Diagnosis, prognosis, and clinical decision-making
6. Interventions/treatments
7. Outcome of caries control/management

The CAD program described in this article contributes directly to steps 1–3, and the results from those steps provide important input to steps 4–7.

CAD has become a major research field in medical imaging and diagnostic radiology.[22] Systems are available for applications such as detection of breast cancers in mammograms and malignant nodules in chest radiographs. A key to success in the medical field has been the realization that computers by themselves are not effective enough for automatically diagnosing diseases; rather, CAD, which brings the doctor into the decision loop, is more effective than the computer alone or the doctor alone. Radiologists use the computer output for a "second opinion" but still make the final diagnosis and treatment decision themselves. The LCD has been developed for the dental field using exactly this approach. This article outlines how the LCD has improved dentists' diagnostic performance in proximal caries detection and classification.

Materials and methods

Study protocol

Radiographs were collected by one of the authors (BAD, referred to in this article as the *attending dentist*) during routine visits of patients to his private practice and diagnosed by him for interproximal caries visually *and* using the LCD. The attending dentist has had the LCD for a number of years and is familiar with its operation and utility in helping to determine whether caries is present on a surface, how deep the caries extends, and whether the surface needs to be restored, treated noninvasively, or merely monitored.

After examination, the attending dentist developed a treatment plan to restore those surfaces where he diagnosed the decay had entered the dentin and restoration was necessary. During the restoration process, photographs were taken to document the depth of decay, based on appearance of decalcification of the enamel (evidenced as white material instead of the normal, translucent enamel material) and staining of the dentin (brown spots). A tactile inspection also was performed to identify soft spots.

At the same time, the attending dentist recorded surfaces which were caries-free or had caries in the enamel that required monitoring and noninvasive treatment. This determination was based on direct inspection of surfaces when there was no adjacent tooth and/or based on his long history of periodically seeing the same patient and taking a series of radiographs, analyzing the suspect surfaces with the LCD, and tracking the results over time.

In cases where caries was present in the enamel but the attending dentist did not believe that restoration was required, the patient was advised to follow one or more of the following instructions: improve oral hygiene using brushing and especially flossing; change diet and minimize consumption of sweets, soft drinks, and so forth; use a daily fluoride rinse or daily fluoride tray treatment; and possibly use a recalcification product such as MI Paste (GC America Inc.). The LCD was used during follow-up visits to monitor the state of the caries and to assess the effectiveness of these noninvasive measures, with the goal being to avoid restoring the suspect surfaces.

Seventeen of the attending dentist's radiographs were selected for this study for two reasons: They had one or more surfaces with confirmed dentinal decay that had

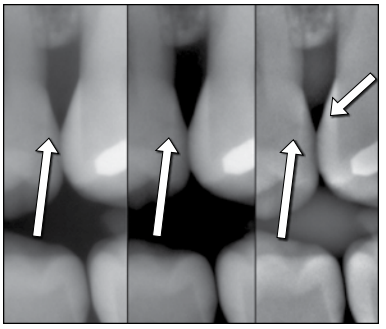

Fig. 1. Visual appearance of caries (indicated by arrows) in initial *(left)*, brightness and contrast-adjusted *(center)*, and sharpened *(right)* images for surfaces 13D (left tooth) and 14M (right tooth).

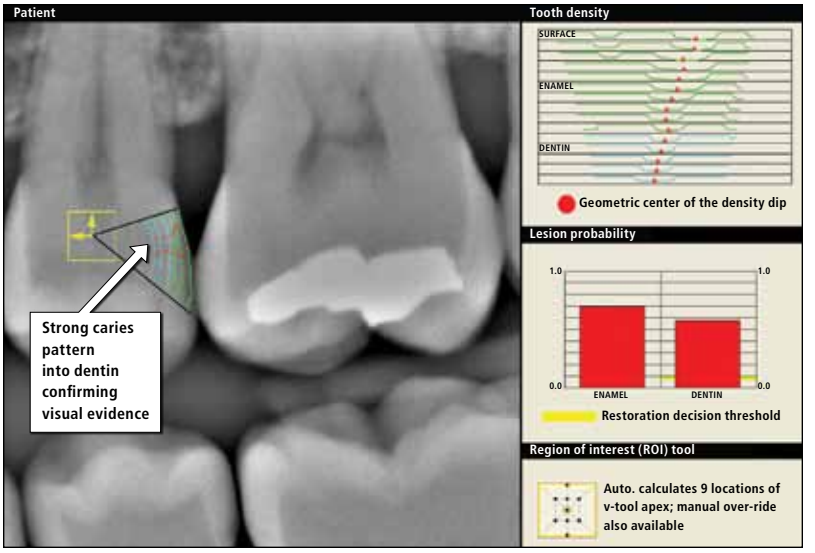

Fig. 2. The LCD density analysis, pattern recognition, and correlation with known caries database for premolar surface 13D.

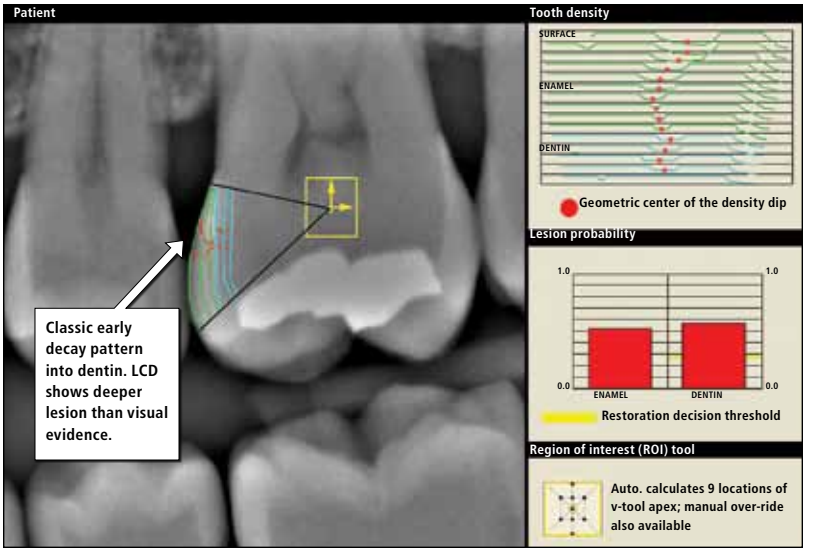

Fig. 3. The LCD density analysis, pattern recognition, and correlation with known caries database for molar surface 14M.

been detected visually and/or with the LCD by the attending dentist but was not readily obvious on the radiograph and the surfaces had been a challenge to detect and classify; and they included caries-free surfaces and surfaces where decay appeared to be in the enamel only. These latter surfaces were tracked by the attending dentist for several years (2006–2009) during periodic examinations to confirm their condition. The type of treatment (restoration or noninvasive) was decided prior to any consideration of the radiographs' use in this study.

It should be noted that the attending dentist did not experience any false positives when performing restorations after using the results from the LCD; this may be due to the fact that the LCD was only part of his decision to restore a surface. The patient's age, dietary habits, oral hygiene, and caries history were also considered when determining treatment plans.

Hardware and software

Images were collected by the attending dentist using the Kodak RVG 6000 digital radiography system (Carestream Dental LLC). The surfaces were analyzed by the attending dentist as described above (and later by an independent team of evaluators as described below) for proximal caries using the LCD (Version 4.0 Build 55) in four different modalities: visual assessment of each surface using the initial image; visual assessment of each surface using the image with the brightness and contrast adjusted; visual assessment of each surface using the sharpened image; and

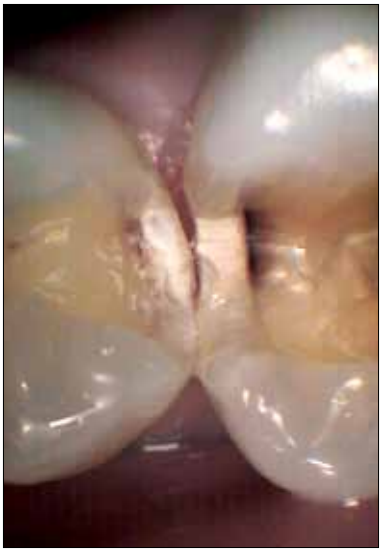

Fig. 4. Clinical confirmation of dentinal caries for surfaces 13D (left) and 14M (right), based on decalcified enamel (white tooth material) and dentin staining (brown spots).

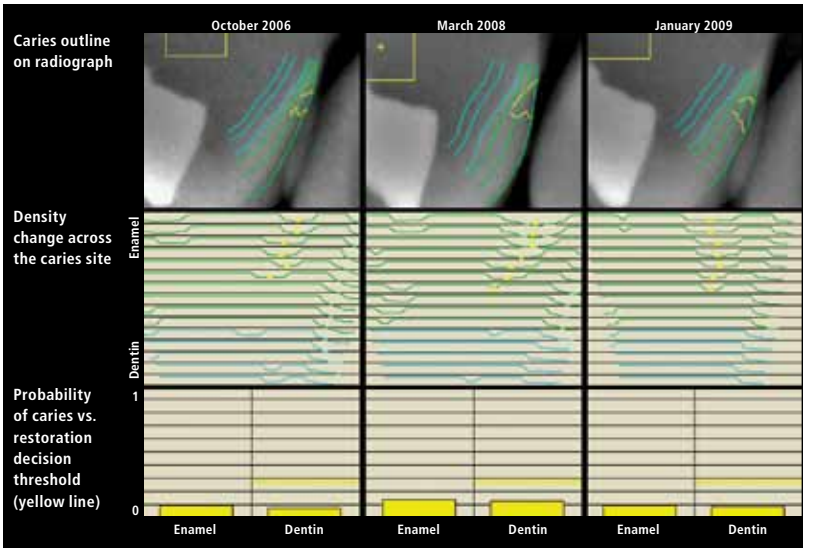

Fig. 5. LCD analysis of one enamel caries site during three patient visits.

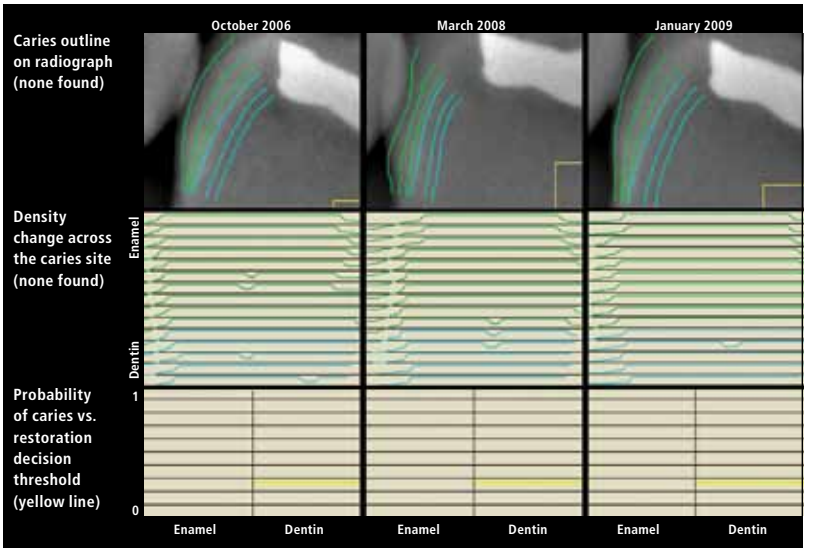

Fig. 6. LCD analysis of one caries-free surface during three patient visits.

assessment of each surface with the aid of local tooth density analysis and caries pattern recognition. This last modality also correlates the results with a histological database of known caries, producing a probability that carious lesions are present on the subject surface and comparing that probability to a decision threshold for recommending that the dentist consider restoration of the surface (based on a 15% false positive rate).

Examples of the first three modalities are shown in Figure 1, while Figures 2 and 3 demonstrate examples of the fourth modality for the two contact surfaces shown in Figure 1, both of which had dentinal caries. Figure 4 highlights the findings of the attending dentist when he restored these same surfaces (photo taken with a Kodak 1000 intraoral video camera). Figure 5 shows the LCD results over a period of 27 months for an example surface; the attending dentist monitored it during patient follow-up visits due to caries in the enamel but deemed it *to not require restoration.* Figure 6 shows the LCD results over the same 27-month period for a surface that the attending dentist designated as *caries-free.*

Retrospective blinded clinical trial

The 17 radiographs selected for this study were saved in DICOM format so that the LCD could be evaluated independently of the Kodak Dental Imaging Software (KDIS) that had been used with the RVG 6000 sensor to collect the images.

Table 1. Results of retrospective clinical diagnoses: Sensitivity and specificity.

Sensitivity (true positive rate)

Evaluator's viewing modality	Mean	Standard deviation	Coefficient of variation	Standard error	95% confidence interval	
					Lower	Upper
Initial image	30.4	15.1	0.50	4.4	21.6	39.1
Brightness and contrast-adjusted image	34.2	13.6	0.41	3.9	26.4	42.1
Sharpened image	39.3	15.8	0.41	4.6	30.2	48.4
LCD density analysis	68.8	12.1	0.17	3.5	61.8	75.7

Sensitivity (true negative rate)

Evaluator's viewing modality	Mean	Standard deviation	Coefficient of variation	Standard error	95% confidence interval	
					Lower	Upper
Initial image	96.7	5.5	0.06	1.6	93.6	99.8
Brightness and contrast-adjusted image	95.3	7.9	0.08	2.3	90.9	99.8
Sharpened image	93.1	8.6	0.09	2.5	88.2	97.9
LCD density analysis	94.1	3.8	0.04	1.1	92.0	96.2

All figures are percentages except coefficient of variation, which is the ratio of standard deviation to mean value.

Twenty-eight proximal surfaces in these radiographs were restored, and the attending dentist provided photographic evidence of the caries penetration into the dentin (generally showing decalcification through the enamel and brown spots in the dentin, as shown in Fig. 4). In addition, 48 proximal surfaces in these radiographs had been determined by the attending dentist to be either *caries-free* or *having caries in the enamel only,* which needed to be watched and treated noninvasively.

Twelve practicing licensed dentists from the University of Louisville School of Dentistry served as evaluators. The evaluators viewed the set of 17 images independently, with no knowledge of which surfaces had been restored by the attending dentist or which ones were designated as *caries-free* or *with enamel caries only.*

One person (author KDT) served the role of university study coordinator. He first trained the evaluators in the use of the LCD (typically within one hour) on an independent set of radiographs not used in the study itself, then recorded their assessment of the subject set of 17 radiographs during a series of sessions tailored to each evaluator's schedule. The coordinator also had no knowledge of which surfaces had been restored and which ones were designated as *caries-free* or *with enamel caries only.* The images were presented to each evaluator in a different order, based on a randomization process. Initially, none of the evaluators were familiar with the LCD; also, they had limited experience with digital radiography because the school clinic had not yet integrated digital intraoral radiography.

For each radiograph, the evaluators were asked to assess all of the proximal surfaces except for those partially off the radiograph, those with serious overlaps blocking the view of the enamel region of the tooth, those with severe cervical burnout, those with crowns or large restorations already in place, and those in which the exposure was very poor and proper visual assessment was not possible. A total of 159 surfaces on the 17 radiographs were assessed by each evaluator as part of the study. There were 28 confirmed cases of dentinal caries on the 159 surfaces, for a prevalence of 18%.

For each surface, evaluators were asked to classify caries depth using the following four-point scale: 0 = no caries present; 1 = caries less than halfway through the enamel; 2 = caries halfway or more through the enamel but not into the dentin; and 3 = caries through the enamel and touching or entering the dentin. For each radiograph, evaluators were asked to systematically assess all of the surfaces with one modality before moving on to the next modality. The study objective was to measure the incremental value of

one modality with increased image analysis features over the previous simpler one, so the evaluators were prevented from using an earlier modality on the same image later in the study.

The study coordinator recorded each assessment by the evaluators. The evaluators all used the same computer workstation in the same room under the same artificial lighting conditions (representative of a dental office without windows). The evaluators were allowed to work at their own pace, with no time restrictions. The study objectives, scope, and diagnostic protocol were reviewed and approved by the institutional review board (IRB) of the University of Louisville and overseen by two faculty members (authors AGF and WCS).

Results

Table 1 shows the mean values, standard deviations, coefficients of variation, standard errors, and 95% confidence intervals for sensitivity and specificity for the 12 evaluators. Table 2 shows the significance of the differences in the performance of the evaluators using the different viewing modalities, based on the nonparametric *p* value produced by the Wilcoxon signed-rank test. It is generally accepted that the difference between two modalities is considered significant if the *p* value is less than 0.05, and the lower the *p* value, the more significant the result.[23]

For this study, sensitivity equaled the total number of Class 3 lesions assessed independently by the evaluators and recorded by the study coordinator for surfaces in the image set confirmed by the attending dentist to have caries in the dentin, divided by the total number of such confirmed surfaces (28).

When viewing the initial image, sensitivity was low (30%). Use of the brightness and contrast and sharpening filters improved evaluator performance only modestly (34–39%). On the other hand, use of the LCD density analysis tool produced a sensitivity (69%) which more than doubled that of the initial image. In terms of significance, when the evaluators used the LCD density analysis tool, their results were much more significant ($p = 0.0005$) compared to when they merely visually assessed the radiographs or used the filters.

The LCD density analysis was performed by each evaluator on each surface by selecting the desired proximal region to be analyzed using a custom v-tool (shown in Fig. 2 and 3) that executed the calculation automatically. When a calculation is run, the density analysis automatically conducts nine separate calculations by moving the apex of the v-tool inside the yellow box (ROI tool) shown in the image, with the greatest extent of the decay being displayed. The evaluators also were given the option to manually override the ROI tool by moving the apex of the v-tool inside the yellow box that updates the calculation. Evaluators had the further option of running the software in a fully

Table 2. Statistical significance of different viewing modalities.

Sensitivity (true positive rate)

Comparison of evaluator's viewing modalities		Mean difference	Non-parametric *p* value*
Initial image	Brightness and contrast-adjusted image	3.8	0.0156
Initial image	Sharpened image	8.9	0.0029
Initial image	LCD density analysis	38.4	0.0005
Brightness and contrast-adjusted image	Sharpened image	5.1	0.0156
Brightness and contrast-adjusted image	LCD density analysis	34.6	0.0005
Sharpened image	LCD density analysis	29.5	0.0005

Specificity (true negative rate)

Comparison of evaluator's viewing modalities		Mean difference	Non-parametric *p* value*
Initial image	Brightness and contrast-adjusted image	-1.4	0.3453
Initial image	Sharpened image	-3.6	0.0170
Initial image	LCD density analysis	-2.6	0.0818
Brightness and contrast-adjusted image	Sharpened image	-2.2	0.1293
Brightness and contrast-adjusted image	LCD density analysis	-1.2	0.4082
Sharpened image	LCD density analysis	+1.0	0.4778

*Based on Wilcoxon signed-rank test.

manual mode when they traced the tooth edge and the dentinoenamel junction.

The LCD density analysis provided useful information that improved the evaluators' ability to assess surfaces with subtle dentinal caries, since it more than doubled their performance compared to their visual assessment of the initial image.

The specificity results are outlined in the lower half of Tables 1 and 2. *Specificity* is defined as the total number of surfaces diagnosed as Class 0, 1, or 2 (caries-free or caries only in the enamel) by the evaluators and recorded by the study coordinator for surfaces in the image set that were originally diagnosed as such by the attending dentist, divided by the total number (48) of such surfaces diagnosed by the attending dentist. The mean value of specificity for the 12 evaluators on these surfaces was greater than 90% for all viewing modalities, ranging from 93–97% depending on the modality, indicating that the evaluators easily identified surfaces that did not need to be restored (based on the attending dentist's diagnosis), regardless of which modality was used. In addition, in most cases there was no significant difference between the modalities ($p > 0.05$ in all cases but one). Therefore, the LCD did not have a statistically significant negative impact in terms of prompting the need for unnecessary restorations.

The variation in performance between the 12 evaluators is evident in Table 1 by the values for standard deviation, coefficient of variation, standard error, and 95% confidence interval. For sensitivity, the range is large between evaluators viewing the initial image, the brightness and contrast-adjusted image, and the sharpened image, but it is noticeably smaller when they used the LCD, best shown by comparing the coefficients of variation. For specificity, the variation in performance among evaluators is relatively small and is not significantly dependent on viewing modality.

Discussion

The attending dentist who provided the radiographs for this study used the LCD in his practice. He found all 28 of the surfaces with dentinal caries that were retrospectively assessed by the evaluators. At the same time, he experienced no false positives. However, unlike the evaluators, he had several years of experience in using the LCD in a clinical environment. In addition, he had the advantages of being able to conduct an oral examination and to use his knowledge of the patient's age, dietary habits, caries history, and oral hygiene in his diagnosis.

Truth (the goal standard) for specificity was determined differently than it was for sensitivity in this study. Since the attending dentist clearly was not going to open patients' teeth to prove that they did not have caries in the dentin, his diagnoses of surfaces were based on following the surfaces for several years during patients' recall visits. He also took additional radiographs during follow-up visits to reassess the state of the sites of concern and used the LCD to aid in those reassessments. This method also is used in medical radiology, because no one would be willing to conduct (or undergo) invasive surgery to prove true negatives.[24-26]

It also is important to note that no false negatives were involved in the calculation of sensitivity, nor were any false positives involved in the calculation of specificity, because the evaluators did not see or treat the patients in this retrospective study. For the purposes of this study, sensitivity equals the evaluators' true positive rate, while specificity reflects their true negative rate.

The wide variation in the evaluators' ability to find surfaces needing restoration using the unaided eye could be due to the radiographs with obvious dentinal caries being excluded from this study; the remaining cases were subtle and required careful inspection of the radiographs. The amount of time spent by each evaluator on any radiograph was not controlled; therefore, some evaluators may have performed better (or worse) compared to others because they spent more (or less) time inspecting the radiographs.

In addition, it should be noted that none of the evaluators were using digital radiography or the LCD in their jobs in the school clinic. Still, with limited training and no extended period of experience, the LCD clearly helped the evaluators find significantly more cases of dentinal caries that needed to be restored; it also reduced the statistical spread among evaluators in the sensitivity results. At the same time, this tool appeared to have essentially no negative impact on the evaluators' specificity (that is, it did not cause them to significantly misdiagnose more surfaces as having dentinal caries that otherwise did not need restoration).

Conclusion

CAD software can be very useful in extracting additional information from digital radiographs to help dentists diagnose and monitor proximal caries. The LCD program used in this study more than doubled the evaluators' performance in detecting early caries that needed restoration, while not causing a significant number of unnecessary restorations. The evaluators in this study received a minimal amount of training

(approximately one hour) and had no prior experience with the LCD. The same program can be used to monitor enamel caries sites over time to determine if noninvasive treatments are arresting (or possibly recalcifying) the sites.

It was possible to conduct this study with the caries detection software alone because the images were provided in DICOM format. Similar studies could be conducted with images from other sensors if they were saved in DICOM format.

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Disclaimer

The LCD and associated intellectual property are owned by Carestream Health, Inc. (formerly a division of Eastman Kodak), Rochester, New York. The device is manufactured in the U.S. for Carestream Health by GA Industries, Rancho Palos Verdes, California, and is distributed in the U.S. by Carestream Dental LLC (formerly PracticeWorks, LLC), Atlanta, Georgia, a subsidiary of Carestream Health, Inc. *Logicon* is a trademark of the Northrop Grumman Corporation, Los Angeles. Dr. Gakenheimer and Ms. Lacina are employees of Carestream Dental LLC, and Dr. Gakenheimer is president and CEO of GA Industries.

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Manufacturers

Carestream Dental LLC, Atlanta, GA
800.944.6365, www.carestreamdental.com

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COMMENT

Management of multiple trauma avulsion of anterior primary teeth: A three-year follow-up

Claudia Marina Viegas, MDS ▪ Ana Carolina Scarpelli, MDS ▪ Joao B. Novaes-Junior, PhD
Henrique Pretti, MDS ▪ Alexandre Fortes Drummond, PhD ▪ Saul Martins Paiva, PhD

Dental trauma can cause physical, esthetic, and psychological problems. This paper presents the case of a 2-year-old boy who suffered multiple avulsions of the maxillary anterior teeth. Treatment consisted of fixed orthodontic appliances with artificial anterior teeth. The clinical follow-up lasted for three years. The procedure for the re-establishment of esthetic and dental function was based on a simple, low-cost therapeutic solution. The child and parents were satisfied with the treatment results.

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Dental trauma in children can create physical, esthetic, and psychological problems for both the child and the parents.[1] *Avulsion* is a dental trauma injury characterized by the complete dislocation of the tooth or teeth from the alveolus.[2] The premature loss of incisors is a concern for the parents of children affected by this type of trauma, and the quest for treatment often includes anxiety regarding esthetic and functional harm.[3] Although infrequent, avulsion can result in consequences to the permanent teeth, including enamel defects, which are clinically diagnosed as discoloration.[4] Malformations, impacted teeth, and disturbances to the eruption and development of permanent teeth also may occur.[2]

This article describes the diagnosis and treatment of a case of multiple avulsions of the maxillary primary incisors and canines suffered by a child who was the victim of a car accident.

Case report

A boy, aged 2 years and 4 months, was brought by his mother to the Pediatric Dentistry and Orthodontics Clinic of the Federal University of Minas Gerais, Brazil, for dental treatment. The mother presented three primary teeth and a CT scan. She said that her son had been run over by a car three days earlier and received primary care in the emergency ward of a public hospital. On the day of the accident, a CT scan of the boy's head (Fig. 1) was performed. No fracture or alteration was diagnosed, but the child had suffered avulsion of the maxillary primary incisors and canines and was referred for dental treatment (Fig. 2).

During the clinical examination, the dentist noted the exposure of the upper alveolar edge and the presence of visible bone spicules. The region was cleaned with 0.9% sodium chloride solution (Farmax) and a sterile gauze compress (Cremer). The mother was instructed on hygiene of the teeth and traumatized region. Recall appointments were held at two-month intervals to follow the healing process.

Four months after the initial visit, the wound had scarred and a new clinical examination was performed, noting the presence of the primary first molars and the absence of the primary maxillary second molars. A diagnosis was

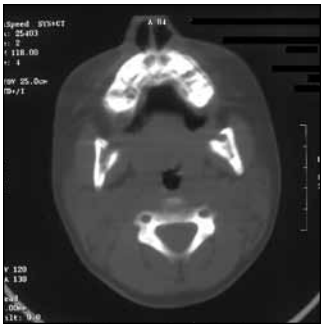

Fig. 1. A CT scan of the patient's head, illustrating the absence of primary maxillary incisors and canines.

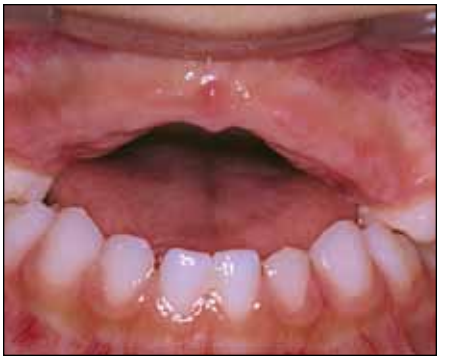

Fig. 2. A frontal view of the patient after avulsion of the primary maxillary incisors and canines.

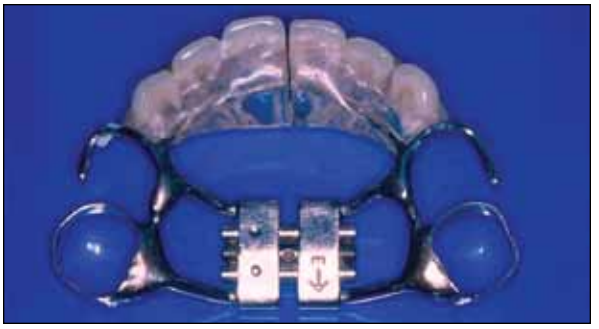

Fig. 3. The Hyrax appliance, constructed with six artificial maxillary anterior teeth.

Fig. 4. An intraoral view of the patient nine months after the initial visit, showing the Hyrax appliance in place.

Fig. 5. The fixed-space maintainer with six artificial maxillary anterior teeth.

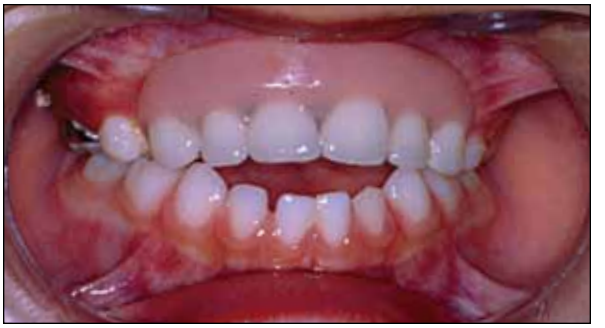

Fig. 6. An intraoral view of the patient 15 months after the initial visit, showing the fixed-space maintenance appliance in place.

made of atresia of the jaw, associated with mouth breathing and pacifier sucking. It was decided to delay treatment until after the complete eruption of the primary second molars, which occurred nine months after the accident.

An esthetic, functional restorative solution was defined for the atresia of the maxilla. A Hyrax appliance (orthodontic palatal split screw 11.0 mm, Morelli Orthodontics) was created with six artificial maxillary anterior teeth (canines, lateral incisors, and central incisors), with bands on the maxillary second molars and retention on the maxillary first molars.[5] The appliance was activated following the Hyrax activation protocol of ¼ turn in the morning and ¼ turn at night for 14 days (Fig. 3 and 4). After six months, the appliance was replaced with a fixed-space maintainer without an activation screw and a segmented palatine arch to not hinder maxillary growth (Fig. 5 and 6). Photos of the child were taken three years after the initial visit (Fig. 7–9).

It is worth noting that the patient maintained consistent dental monitoring and that he was advised to maintain it until the permanent teeth were fully descended. Both the child and his mother were very satisfied with the treatment.

Discussion

Whenever possible following avulsion, it is important to locate the avulsed tooth and perform radiographic examinations to ensure that the missing tooth has not undergone intrusion.[2,4] In the case reported here, the child had experienced avulsion of the six maxillary anterior teeth, which was confirmed by the CT scan and the avulsed teeth that the mother brought to the clinic.

Reimplantation of avulsed teeth is not recommended, as the risks for a 2-year-old child are numerous and include aspiration, inflammatory bone resorption, abscess formation, and interference with the development of the permanent tooth germ.[2,4] In this case, no reimplantation was performed. In order to minimize the psychological, physical, and functional repercussions stemming from the dental trauma, fixed appliances with artificial teeth were created.

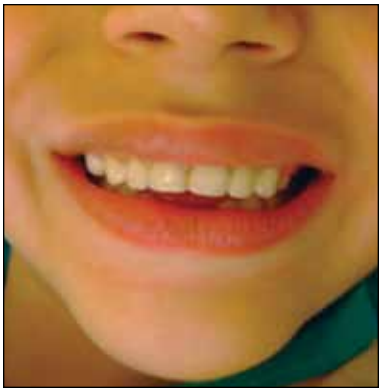

Fig. 7 and 8. Intraoral views of the patient three years after the initial visit, showing the fixed-space maintenance appliance in place.

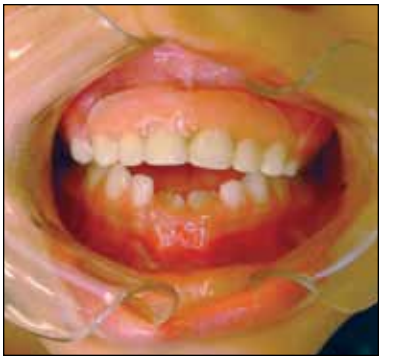

Fig. 9. An extraoral view of the patient three years after the initial visit, showing the fixed-space maintenance appliance in place.

Because the patient's maxillary arch constriction was related to mouth breathing, a maxillary expansion appliance was produced first. Rapid expansion of the maxilla is indicated for children when constriction of the maxillary arch is related to mouth breathing and a high palatal vault.[6] The Hyrax appliance was selected because of its maxillary expansion properties.[7,8] The primary first and second molars were used to anchor the appliance, since these teeth are capable of supporting the strong forces produced during rapid expansion of the maxilla.[8]

Following maxillary expansion, a fixed-space maintenance appliance was fabricated with artificial anterior teeth to maintain the space in the arch due to early loss of the canines and incisors, which could negatively affect the normal development of the dentition. Canines are known to be important for space maintenance during the development of the dentition.[9]

Summary

Considering the case presented and the result achieved, the use of fixed orthodontic appliances with artificial anterior teeth proved to be an efficient alternative in the re-establishment of function and esthetics. The self-esteem of the child involved was restored, demonstrating the importance of oral esthetics. Furthermore, the treatment plan involved a simple and low-cost procedure, which makes it useful for a potentially large number of patients.

Acknowledgements

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Enalapril-induced angioedema: A dental concern

Kim K. McFarland, DDS, MSHA ▪ Eric Y.K. Fung, PhD

Drug-induced angioedema is a rare but potentially life-threatening side effect of increased levels of bradykinin. It may be overlooked and diagnosed as a dental-related problem due to its appearance as facial swelling. A clear understanding of the pathophysiology of angioedema can better serve both physicians and dentists in providing the most appropriate care for patients.

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Angioedema is an abrupt, diffuse edematous swelling of the soft tissues of a localized body area involving the skin, mucosa, and subcutaneous tissues. The extremities are most commonly affected, although the face, genitals, trunk, and neck also can be involved.[1] This disorder also is referred to as *Quincke's disease* after the clinician who reported changes in tissue permeability.[2] The most common cause of this disorder is mast cell degranulation leading to the release of histamine or the activation of bradykinin formation.[2] However, in 0.1–1% of patients, angioedema has been reported as an adverse side effect of a class of drugs known as *angiotensin-converting enzyme (ACE) inhibitors*.[3-5]

ACE inhibitors are widely used in the treatment of essential hypertension and congestive heart failure, renal failure, and diabetic nephropathy.[6-8] This class of drugs blocks the enzyme that converts angiotensin I to the potent angiotensin II, which has vasoconstrictor and sodium-retaining activity.[6] As a result, ACE inhibitors reduce blood pressure by decreasing peripheral vascular resistance without reflexively increasing cardiac output, rate, or contractility. Drugs in this class are listed in the table. ACE inhibitors are contraindicated during pregnancy due to increased risk of fetal renal failure, intrauterine growth retardation, and other congenital defects.[6]

Side effects of this class of ACE inhibitors include dry cough, allergic skin rashes, drug fever, altered sense of taste, postural hypotension, and hyperkalemia.[6] Dry cough is a common side effect that occurs in approximately 15% of patients and is caused by increased levels of bradykinin. Angioedema is a rare but potentially life-threatening adverse side effect that often is misdiagnosed or overlooked by some physicians, who may consider it to be a dental-related problem.[2,4,5] This adverse drug effect can occur at any time during drug treatment and manifests as swelling of the face, extremities, lips, mucous membranes, tongue, glottis, or larynx.[3-5] The following case report documents a case of drug-induced angioedema during treatment with enalapril.

Table. ACE inhibitors.

Drug	Brand name(s)
Benazepril	Lotensin
Captopril	Capoten
Enalapril	Vasotec
Fosinopril	Monopril
Lisinopril	Prinivil, Tensopril, Zestril
Moexipril	Univasc
Perindopril	Aceon
Quinapril	Accupril
Ramipril	Altace, Tritace
Trandolapril	Mavik

Case report

A 55-year-old man came to a community health center dental clinic with left facial swelling (Fig. 1). The patient explained that he was referred to the dental clinic after visiting the local hospital's emergency room, where he was informed that

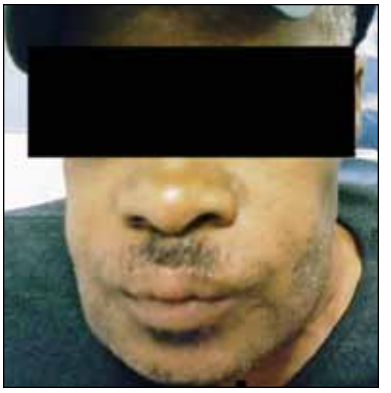

Fig. 1. Front view of the patient depicting facial swelling.

he had a dental abscess that was causing his face to swell. The patient had a medical history of idiopathic hypertension, chronic obstructive pulmonary disease, gastrointestinal problems, and endogenous depression. The patient was taking the following medications on a daily basis: metoprolol 50 mg; omeprazole 40 mg; amlodipine 10 mg; enalapril 10 mg; and escitalopram 20 mg; he also was taking clonazepam 0.5 mg twice daily. The patient did not report any known drug allergies.

A clinical and radiographic examination of the patient's teeth revealed no apparent dental decay or abscess. The patient was partially edentulous, was missing most of his posterior teeth, and recently had tooth No. 20 extracted (Fig. 2). The remaining teeth were not sensitive to temperature or percussion. No purulent exudate or swelling was associated with the teeth, but chronic generalized periodontal disease was present. Tooth No. 21 exhibited vertical bone defects and deep periodontal pockets measuring more than 9.0 mm. However, the periodontal disease did not appear to be the cause of the facial swelling, which was confined to the interstitial spaces surrounding the facial musculature.

A medical consultation by a community health center physician was provided to rule out the possibility of allergic reaction. The physician determined that, since the facial swelling was unilateral and the patient had no history of drug allergies, the cause of the swelling was a dental infection. The dentist informed the patient about his periodontal disease but noted that the periodontal disease might not be the cause of the swelling. The dentist prescribed amoxicillin 500 mg, 1 gm stat and 500 mg every six hours until gone, and acetaminophen with hydrocodone 5/500 mg, one tablet every six hours as needed for pain.

After leaving the dental clinic, the patient crossed the street to the neighborhood pharmacy to fill the prescriptions. While at the pharmacy, the patient called the dentist and asked if he could have tooth No. 21 removed. The dentist agreed, because removal could empirically rule out a dental infection as a potential cause of the facial swelling. The patient returned immediately to the dental clinic.

Two cartridges of local anesthetic, 2% lidocaine 1:100,000 epinephrine, were administered via an inferior alveolar nerve block and local infiltration. A simple forceps extraction of tooth No. 21 was performed. The patient was given postsurgery instructions, both orally and in writing, and was dismissed.

Approximately two hours later, a nurse at the emergency room of the local hospital called the dentist to say that the patient had returned to the emergency room with left facial swelling. The emergency room doctor needed to know what drugs had been administered to the patient while he was at the dental clinic and what procedure had been performed. The patient was extremely concerned that his facial swelling had not decreased despite removal of the tooth. After being examined by the emergency room staff, the patient was instructed to return home and follow the postoperative instructions provided by the dental clinic.

Later that evening, the patient returned to the hospital emergency room with difficulty breathing. The patient's facial swelling had diminished on the left side but was now present on the right side. At the emergency room, the following drugs were administered to the patient: diphenhydramine 50 mg (IV), famotidine 40 mg (IV), methylprednisolone 125 mg (IV), and epinephrine (1:1,000) 0.3 mg subcutaneously. The emergency room physician instructed the patient to stop taking enalapril. The patient was instructed to take prednisone 20 mg twice daily for five days and hydroxyzine 50 mg every six hours as needed. The patient responded well to drug treatment and made a full recovery.

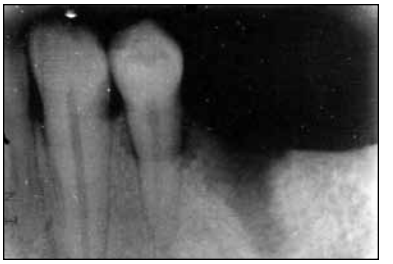

Fig. 2. Dental radiograph demonstrating periodontal disease and recent tooth extraction.

Discussion

Angioedema can be induced by allergic reactions or NSAIDs, which are frequently accompanied by urticaria.[6] However, ACE inhibitor-induced angioedema is seldom accompanied by hives.[2] Although enalapril-induced angioedema can occur at any time during drug therapy, it usually occurs during the first week.[9] In addition, it is more likely to occur in blacks, patients over the age of 65, and patients with a history of drug rash or seasonal allergies.[3,4,10] ACE inhibitor-induced angioedema is caused by increased levels of bradykinin and impairment of aminopeptidase P and dipeptidyl peptidase IV, which are involved in the metabolism of substance P and bradykinin.[11,12] Most cases of ACE inhibitor-induced angioedema

resolve upon cessation of the medication.[4,5] Common drug treatments may include oral treatment with antihistamines, corticosteroids, and systemic administration of epinephrine.[4,6]

In this instance, the patient had been taking enalapril for more than two years; therefore, etiopathic angioedema must be considered in the differential diagnosis of patients with facial swellings of an unknown origin. An awareness of this issue and a clear understanding of the pathophysiology of angioedema can benefit both physicians and dentists in providing the most appropriate treatment.

Summary

Swelling of the lips, face, or oral cavity could indicate an idiopathic allergic reaction to an ACE inhibitor. Although patients may have a long history of taking ACE inhibitors with no resulting side effects, the presence of swelling could indicate an allergic reaction. It is very important to rule out idiopathic allergic reactions, especially when patients present with facial swelling of an unknown origin.

Disclaimer

The authors have no financial, economic, or commercial interests related to the topic or drugs presented in this article.

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Interdental papilla overgrowth

John K. Brooks, DDS
Nikolaos G. Nikitakis, DDS, PhD

A 21-year-old woman was referred to a specialized oral medicine clinic by her general dentist for evaluation of a nodule on her maxillary anterior gingiva. The patient first noticed the lesion when she was 15 years old. The mass gradually increased in size, but relatively rapid growth was noticed during the last few months. The lesion bled mildly during toothbrushing but otherwise was asymptomatic. The patient was a nonsmoker and her oral hygiene was satisfactory. Her medical history was significant for hypothyroidism, which had been managed with levothyroxine for the last few years, and mitral valve prolapse with regurgitation. Clinical examination revealed a nontender nodule of normal coloration and fibrous consistency arising from the interdental papilla between the right maxillary central and lateral incisors (Fig. 1). A periapical radiograph did not reveal any bone defect in the area. The lesion was surgically removed and submitted for histopathological examination (Fig. 2).

Which of the following pathologic disorders is the most compatible diagnosis?

A. Oral focal mucinosis
B. Peripheral giant cell granuloma
C. Peripheral ossifying fibroma
D. Peripheral odontogenic fibroma
E. Pyogenic granuloma

Diagnosis is on page 154.

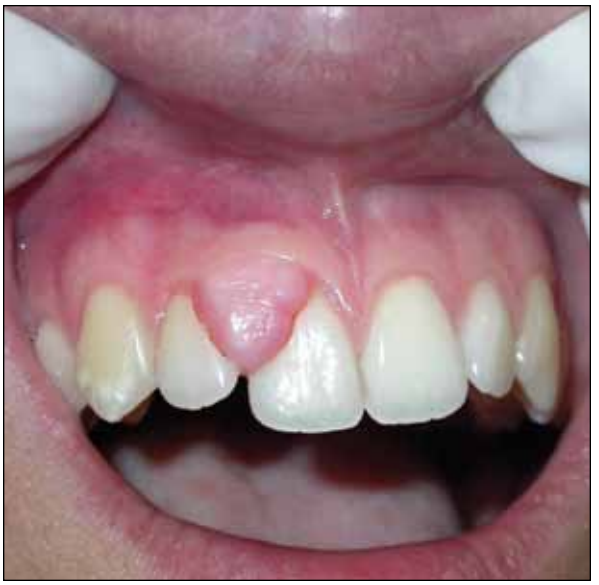

Fig. 1. Sessile mass on the maxillary anterior gingiva.

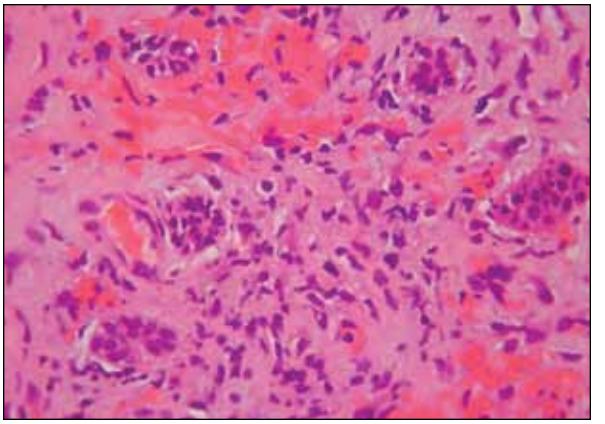

Fig. 2. Islands of odontogenic epithelium are visible in a background of fibrous connective tissue (H&E stain, magnification 200x).

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Rubbery palatal mass

John K. Brooks, DDS
Nikolaos G. Nikitakis, DDS, PhD

A 42-year-old woman sought evaluation at the University of Maryland Dental School urgent care clinic for an oral "swelling" that had gradually increased in size during the last seven or eight years. The patient reported constant, intense, sharp pain associated with the lesion, often radiating to her right ear and down her neck. The pain was exacerbated by opening or closing her mouth, swallowing, and speaking. The severity of the pain led to sleep disruption; also, the patient recently began experiencing right-sided headaches. The medical history was significant for hypertension, which was controlled by amlodipine, clonidine, and metroprolol. In addition, the patient was taking escitalopram oxalate for depression. The patient denied alcohol or tobacco usage.

Which of the following is the most appropriate diagnosis?

A. Pleomorphic adenoma
B. Inflammatory myofibroblastic tumor
C. Fibrosarcoma
D. Leiomyosarcoma
E. Spindle cell carcinoma

Diagnosis is on page 154.

Clinical examination revealed a 2.5 cm x 2.0 cm irregular, rubbery mass arising from the palatal aspect of the maxillary right tuberosity. The tumor was bilobed with a deep central fissure; the buccal aspect of the mass was mobile, while the palatal component was firm and exhibited multiple, linear erythematous streaks (Fig. 1). The inferior surface was ulcerated, attributed to chronic trauma from the opposing third molar. The lesion appeared to have caused rotation and buccal displacement of the maxillary second molar. There was no lymphadenopathy. An MRI indicated a right palatal mass with a hyperintense signal (Fig. 2). An incisional biopsy was performed for histopathologic review (Fig. 3). Immunohistochemical staining was focally positive for actin.

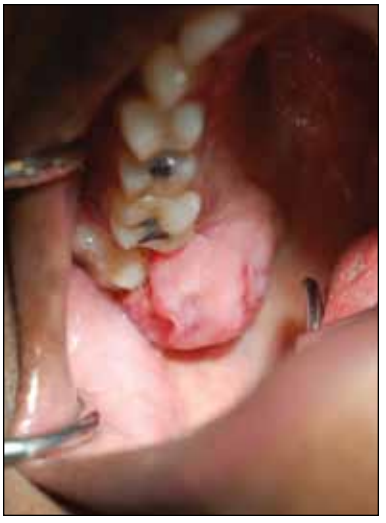

Fig. 1. Expansile soft tissue mass along the posterior hard palate.

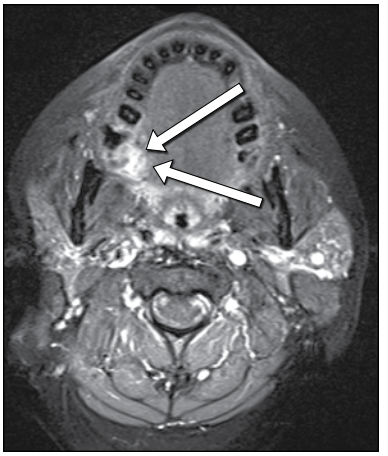

Fig. 2. A heterogeneous signal with diffuse borders is seen on the MRI (arrows). The tumor appears to have caused rotation and buccal displacement of the maxillary second molar.

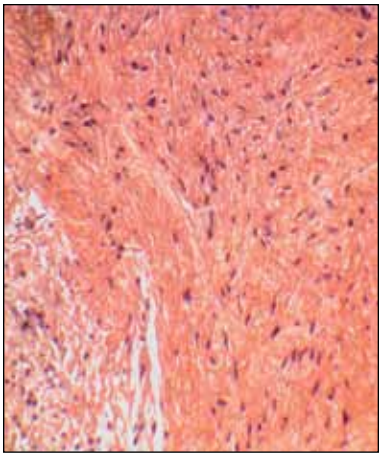

Fig. 3. Numerous spindle cells are set against a collagenous background. Scattered inflammatory cells are present as well (H&E stain, magnification 200x).

Oral Diagnosis

Interdental papilla overgrowth

Diagnosis:

D. Peripheral odontogenic fibroma

Peripheral odontogenic fibroma (POF) is a relatively rare benign odontogenic tumor of ectomesenchymal origin and is regarded as the extraosseous counterpart of the central odontogenic fibroma. Typically, POFs are clinically described as indolent, singular, firm sessile masses of normal mucosal surface and color. These tumors arise in the tooth-bearing regions of the jaws, with a greater affinity for the mandibular anterior and premolar gingiva. Less frequently, lesions occur on the maxillary gingiva and the edentulous alveolar mucosa. Lesional displacement of teeth is an uncommon feature. The size of reported tumors has ranged from 0.3–3.4 cm. The mean age of affected patients is 37, and the tumors have a slight female predilection. Although POFs are not locally destructive, resorption of the subjacent bone can be seen infrequently on radiographs or during surgical exploration.

Microscopically, lesions exhibit a nonencapsulated epithelium with narrow, deeply plunging rete ridges. The submucosa displays interwoven fascicles of fibrous connective tissue, occasionally interspersed with a more myxoid stroma. Islands of inactive odontogenic epithelial rests are scattered within the stroma. In addition, multinucleated giant cells and spherical dystrophic calcifications, resembling dentin, cementum, and/or bone, can appear in the underlying connective tissue. Cut surfaces of surgical specimens often exhibit a gritty texture.

The treatment of choice for POFs is complete surgical resection; however, it should be emphasized that recurrence has been reported as high as 50%, usually within two years postoperatively. Moreover, at least 20% of this subset will demonstrate a propensity to recur two or more times.

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Rubbery palatal mass

Diagnosis:

B. Inflammatory myofibroblastic tumor

The term *inflammatory myofibroblastic tumor* (IMT) refers to a rare, diverse group of lesions with varying etiologies that present as spindle cell proliferations with an intense inflammatory component. There is a wide spectrum of phenotypes of IMTs, with subsets ranging from a reactive lesion to a benign neoplasm or to a more aggressive or possbile malignant process. The most frequent site of occurrence of IMTs involves the lungs, with fewer cases found in the visceral organs and the head and neck. Only a small number of oral IMTs have been documented, mostly occurring on the buccal mucosa.

The mean age of patients with oral IMTs is 35; in contrast, the majority of affected patients with extraoral lesions are diagnosed during the first two decades of life (mean age = 10). Generally, there is a slight female predilection. An alarming feature of oral IMTs is their reported rapid growth rate, often attaining sizes of 2.0 cm in less than two months. The majority of oral IMTs are characterized as solitary, painless, erythematous nodules with a firm consistency.

Histopathologically, three basic cellular patterns of IMT have been recognized, all of which display specialized spindle cell populations of myofibroblasts. One variant is composed of scattered myofibroblasts in an edematous myxoid background, admixed with plasma cells, lymphocytes, eosinophils, and dispersed blood vessels. The second pattern is predominated with dense aggregations of spindle cells in a myxoid and collagenized setting, with clusters of plasma cells and lymphoid nodules. Each of these two subtypes exhibits ganglion-like cells. The third subset is distinguished by the presence of collagen sheets with sparse populations of plasma cells and eosinophils. Immunohistochemical staining may offer diagnostic and prognostic applications.

The modality of treatment for oral IMTs usually entails complete surgical excision, although select cases

with a more aggressive behavior respond to chemotherapeutic agents. Of note, at least one-fourth of oral IMTs extend into contiguous structures. Although the limited number of oral cases of IMT have not demonstrated recurrence or malignant transformation, patients should undergo reassessment for at least 10 years. Overall, the recurrence rate for IMTs is 19–25%, and 8–18% of lesions may become malignant.

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Self-Instruction

Exercise No. 255

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1. A	2. A	3. C	4. D
5. B	6. A	7. D	8. C
9. A	10. B	11. D	12. C
13. B	14. D	15. C	

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1. A	2. C	3. B	4. C
5. B	6. B	7. D	8. B
9. A	10. A	11. C	12. A
13. C	14. D	15. A	

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1. C	2. B	3. C	4. A
5. D	6. C	7. B	8. B
9. D	10. A	11. C	12. B
13. A	14. D	15. C	

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	Exercise No. 279	Exercise No. 280	Exercise No. 281
1.	A B C D	A B C D	A B C D
2.	A B C D	A B C D	A B C D
3.	A B C D	A B C D	A B C D
4.	A B C D	A B C D	A B C D
5.	A B C D	A B C D	A B C D
6.	A B C D	A B C D	A B C D
7.	A B C D	A B C D	A B C D
8.	A B C D	A B C D	A B C D
9.	A B C D	A B C D	A B C D
10.	A B C D	A B C D	A B C D
11.	A B C D	A B C D	A B C D
12.	A B C D	A B C D	A B C D
13.	A B C D	A B C D	A B C D
14.	A B C D	A B C D	A B C D
15.	A B C D	A B C D	A B C D

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Quality of illustrations	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Clarity of objectives	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
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Management of the severely worn dentition with different prosthetic rehabilitation methods: A case series

Emre Mumcu, DDS, PhD ▪ Onur Geckili, DDS, PhD ▪ Hakan Bilhan, DDS, PhD ▪ Tolga Kayserili, DDS, PhD

Clinicians are often faced with the challenge of restoring a severely worn dentition. Esthetic and functional rehabilitation of patients in this condition represents a noteworthy clinical challenge. Although treatment options for the severely worn dentition with reduced occlusal vertical dimension can be limited, providing a functional and esthetic restoration in these situations is crucial for restoring the patient's quality of life. Different treatment approaches for the rehabilitation of worn dentition are presented in this case series.

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Tooth wear has been described as the loss of tooth substance resulting from abrasion, attrition, erosion, or abfraction.[1] *Abrasion* is the loss of tooth surface caused by friction from foreign substances other than tooth-to-tooth contact.[2] *Attrition* is tooth wear caused by the rubbing together of opposing occlusal surfaces of teeth during mastication or parafunction.[2,3] *Erosion* (corrosion) indicates the progressive loss of tooth structure through nonbacteriogenic chemical processes.[1] *Abfraction* is the pathologic loss of tooth structure attributed to mechanical loading, resulting in noncarious cervical lesions.[1,2]

Etiologic factors also include diet, gastroesophageal disease, eating disorders, bruxism, harmful oral habits, and congenital anomalies such as amelogenesis imperfecta and dentinogenesis imperfecta.[1,2,4]

Although some degree of tooth wear is acknowledged as a normal part of the aging process, known as *physiologic wear,* problems arise when the normal rate of tooth wear is accelerated by unusual endogenous or exogenous factors.[1,2]

Prior to treating tooth wear, it is crucial to determine the causes and to try to eliminate them following treatment.[1,2] It is often believed that tooth wear is the result of bruxism, although other etiologic factors may be involved.[2] Clinicians must fully understand other possible causes of wear and how the appearance of the dentition may differ according to the cause of wear.[2] For example, wear caused by attrition is located only in occlusal contact areas. Facial or lingual surfaces of teeth are affected only if opposing teeth are in contact in these areas during excursive movements. Also, a similar amount of tooth wear is visible in both arches.[1,2]

Erosion or corrosion can occur as the result of endogenous sources, such as bulimia or gastroesophageal reflux disease, or exogenous sources, such as acidic beverages, citrus-sucking habits, and the use of amphetamine drugs, chewable vitamin C tablets, or aspirin.[1,2,4] Corroded tooth surfaces have imprecise extensions, unlike attrition lesions.[2] Bulimia affects the palatal surfaces of maxillary anterior teeth and also can affect the buccal surfaces of posterior teeth.[1] Citrus sucking affects the labial and palatal surfaces of the maxillary incisors, increasing the translucency and sharpness of these teeth.[1,2] Old amalgam restorations could begin to protrude from posterior teeth.[1]

Abrasion can occur as a result of gritty foods, abrasive tooth polishes, improper usage of toothbrushes and toothpicks, damaging oral habits such as tobacco chewing and pencil or nail biting, or clasps of removable dentures; it also can be an occupational hazard for tailors and shoemakers.[1,4] Abrasion from food results in worn occlusal areas without outlined borders. A general rounding effect, microscopic pits, or scratches are visible on tooth surfaces.[4] Also, cervical wedge-shaped lesions are noticeable from toothbrush strokes.

Abfraction can be seen primarily in the cervical region of teeth. To differentiate abfraction from abrasion, the reasons for occurrence should be considered. Abfraction lesions occur from the loading forces placed on teeth during static events, such as swallowing or clenching, or cyclic events, such as chewing or bruxing.[1]

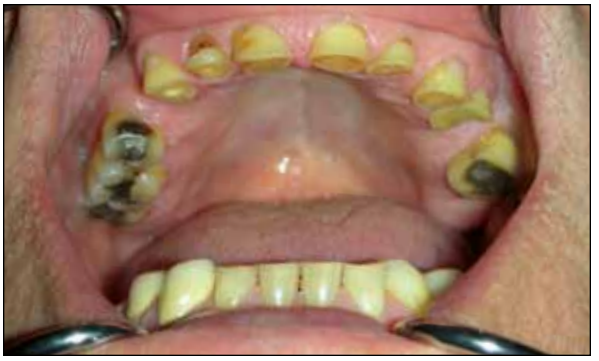

Fig. 1. Intraoral view of worn maxillary teeth.

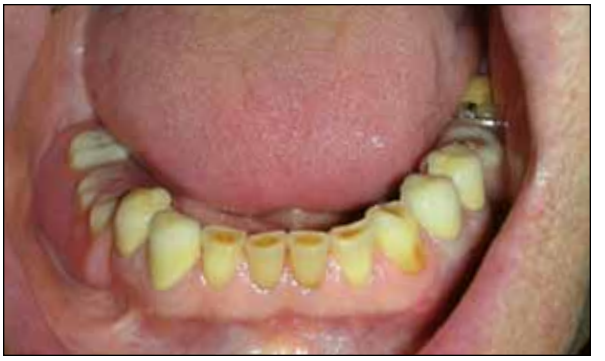

Fig. 2. Mandibular removable partial denture with worn artificial teeth.

Fig. 3. Intraoral view of the cast metal post-and-core restorations after cementation.

Fig. 4. Final view of the metal-ceramic crowns.

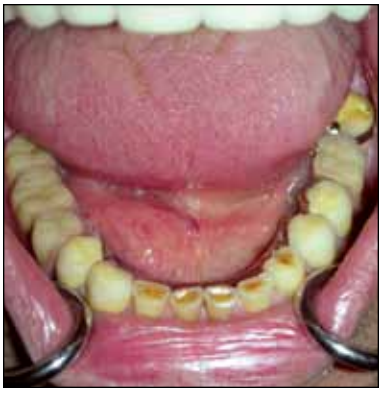

Fig. 5. Post-treatment view of the removable partial denture.

A differential diagnosis is not always possible because more than two mechanisms may be involved in the etiology of tooth wear.[1,2,4] Once the clinician has developed a complete understanding of the etiology, a treatment plan can be formulated. The number of teeth to be treated, condylar position, space availability, vertical dimension of occlusion (VDO), and the choice of restorative material must be considered.[4,5]

Before starting any restorative treatment, an initial interview—including a detailed review of the patient's medical and dental history, a discussion of the patient's usual diet, and an evaluation of potential work-related factors and detrimental oral habits—should be conducted.[1,2] The clinical examination should include observation of specific wear patterns and VDO using previously described techniques.[5-7] Loss of tooth structure does not necessarily mean loss of VDO; in fact, it may be difficult to determine if the VDO has been lost. Several aspects such as loss of posterior support, history of wear, phonetic evaluation, interocclusal distance, and facial appearance should be examined carefully.[1,4] The clinical examination can be enhanced with the use of stone study casts, intraoral photographs, radiographs, and salivary tests.[1]

In situations where loss of tooth structure has occurred and the VDO is still acceptable, treatment may include crown lengthening, orthodontic movement with limited intrusion, and surgical repositioning of a segment of teeth and supporting alveolar bone. Whenever the clinical evaluation demonstrates the necessity to restore the VDO, a trial period with removable occlusal splints can be followed by crown placement and

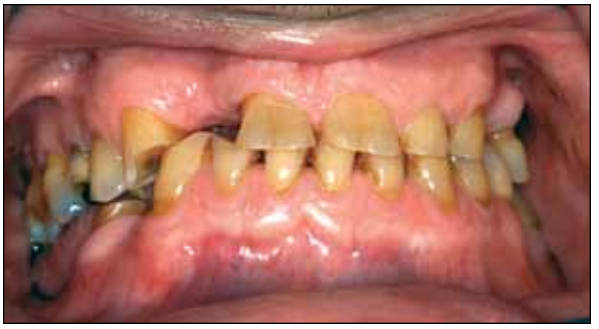

Fig. 6. View of the generalized worn dentititon.

Fig. 7. Final view of the patient after the cementation of metal-ceramic crowns.

fixed partial dentures or cast overlay removable partial dentures.[1] In definitive rehabilitation, the final choice of treatment depends on the condition of the patient's remaining teeth.[1]

The following case series presents different prosthetic management options for the treatment of a worn dentition.

Case reports

Case report No. 1

A 63-year-old man came to the clinic with severely worn teeth and generalized hypersensitivity (Fig. 1). There were no significant findings in the patient's medical history. Possible causes of tooth wear had been evaluated and conversation with the patient revealed a grinding habit and a high consumption of acidic drinks. His dental history included no treatment of the maxillary teeth and restoration of the mandibular edentulous region with four porcelain crowns and a mandibular removable denture with precision attachments. Clinical examination revealed generalized worn dentition in the maxillary and mandibular anterior regions as well as worn artificial teeth on the mandibular removable denture (Fig. 2). It was determined that the 3.0–4.0 mm loss of VDO was caused by a combination of attrition and erosion. Clinical examination was improved with the use of stone study casts, intraoral photographs, and periapical radiographs. Since the optimal VDO was lost, the task of rehabilitation was easier to accomplish, because the dimension could be regained without surgical or orthodontic interventions.

Maxillary anterior teeth were treated endodontically and restored with cast metal post-and-core restorations for extending the VDO (Fig. 3). The provisional restorations were fabricated according to the increased VDO and were temporarily cemented. Since the masticatory muscles and the temporomandibular joint showed no clinical signs or symptoms of discomfort during this period, the definitive metal-ceramic crowns were fabricated and cemented using a polycarboxylate cement (Poly-F Plus, Dentsply DeTrey GmbH) (Fig. 4). Simultaneously, the worn artificial teeth of the mandibular partial denture were replaced with new ones (Fig. 5). To protect the restorations, an occlusal splint was created and used. Follow-up one year later revealed no complications with the prosthesis and excellent patient satisfaction.

Case report No. 2

A 56-year-old man was referred to the clinic with a severely worn dentition. Conversation with the patient revealed gastroesophageal reflux disease and a nail-biting habit. Clinical examination revealed generalized severely worn maxillary and mandibular teeth (Fig. 6).

Preliminary impressions were made with an irreversible hydrocolloid impression material (Xantalgin, Heraeus Dental North America), and the maxillomandibular relationship was transferred into a semi-adjustable articulator (ARTI S4, IML Instrument Mechanic Lab, Inc.) using a facebow transfer for estimating a suitable treatment option. An acrylic maxillary occlusal splint was constructed at a 4.0 mm increase of VDO to assess the patient's adaptation to a reorganized occlusal scheme. After three months of adaptation to the new VDO, all teeth were prepared and restored with metal-on-porcelain crowns (Fig. 7).

Case report No. 3

A 58-year-old woman with a severely worn dentition came to the clinic expressing the desire to have her teeth restored for reasons of function, dental hypersensitivity, and esthetics. The patient's medical and dental histories were recorded and radiographs were taken. A history of nocturnal and diurnal bruxism

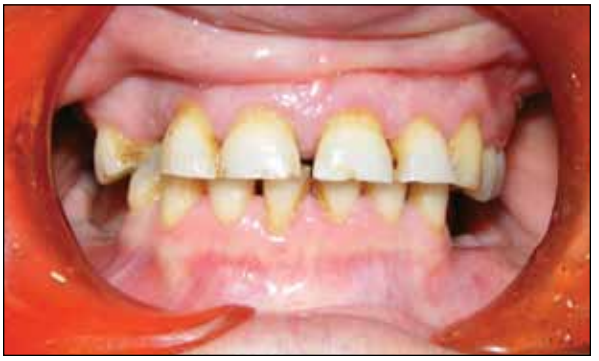

Fig. 8. View of the reduced VDO due to worn teeth.

Fig. 9. Final view of the patient after increasing the VDO.

was reported. Intraoral examination revealed a loss of dental structure, especially from the maxillary first and second incisors, and several missing teeth, both in the maxilla and mandible (Fig. 8). The patient had lost her teeth approximately 12 years earlier and had not worn any prosthesis since that time. Clinical determination of VDO was achieved using the same method from case report No. 1, and a 3.0 mm loss of VDO was determined, depending on the loss of posterior support.

Impressions were made for diagnostic examination with an irreversible hydrocolloid (Xantalgin), and stone models were mounted to a semi-adjustable articulator with occlusal records and a facebow transfer (ARTI S4) of the patient. The occlusal scheme was reorganized using bimaxillary acrylic occlusal splints. Bilateral and simultaneous contact of all posterior teeth was achieved using these acrylic occlusal splints. Because there were no signs or symptoms of discomfort after a three-month trial period, the existing teeth were restored with metal-ceramic crowns, while the plan was to replace the missing posterior teeth in both arches with removable partial dentures with precision attachments. All maxillary and mandibular teeth were prepared by guidance of the occlusal splints.

Metal-ceramic restorations were fabricated in accordance with the increased VDO. After the removable partial denture was fabricated, the fixed segment was cemented. Centric occlusion, protrusive contacts, and canine guidance were established in the definitive restorations (Fig. 9). The patient was satisfied and the recall evaluation six months later showed no complications.

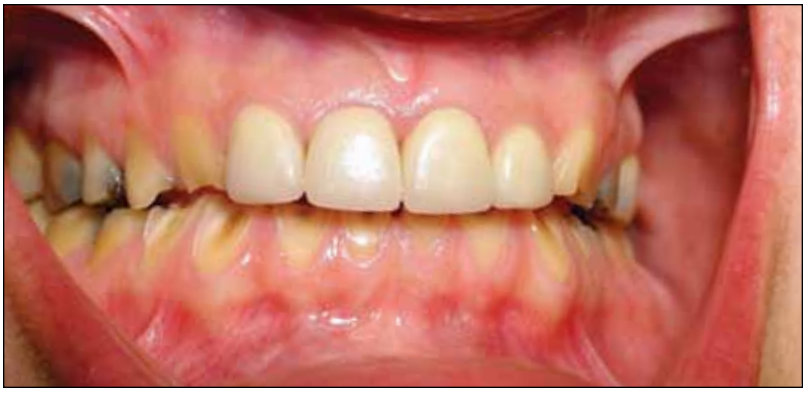

Fig. 10. Initial view of a patient with worn teeth.

Case report No. 4

A 36-year-old woman came to the clinic with generalized worn dentition (Fig. 10). Similar to case reports No. 2 and 3, the VDO had to be increased and tested for several months; a removable overlay denture was fabricated for this purpose (Fig. 11 and 12). The use of such a denture provides several advantages, such as better function and better esthetic estimation of the final rehabilitation outcome. Because the loss of tooth substance occurred primarily in the mandible, the plan was to increase the VDO using a mandibular provisional overlay denture. Another advantage of this treatment modality is a longer adaptation period for the

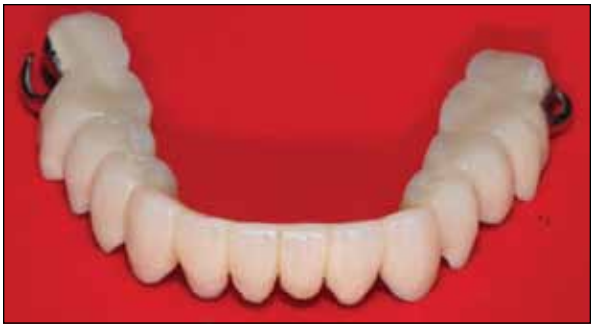

Fig. 11. View of the removable overlay denture.

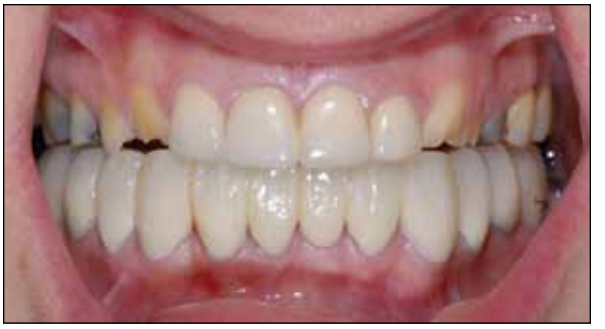

Fig. 12. Intraoral view of the overlay denture.

patient established via restored esthetics and function.

Discussion

Reconstruction of the severely worn dentition can create a challenge for clinicians. The best treatment for any wear depends on early recognition of the wear, but it can be difficult and even impossible to do this.[1,2] All four cases presented here had severe worn dentition situations requiring full-mouth rehabilitation with a need to increase the VDO. If an increase in VDO is indicated and performed, the patient should return for a follow-up visit in several months.[4] In all cases, diagnostic evaluations were made on semi-adjustable articulators, and provisional restorations or occlusal splints were used for the adaptation of the musculoskeletal system before the definitive restorations were delivered. Despite warning against increasing the VDO, evidence from long-term observations supports the view that, in general, the patient will adapt to such an increase and that the new VDO is stable.[4,6,7] Determining and eliminating factors causing tooth wear is critical in long-term preservation of the new VDO and restorations. Inserting an occlusal splint in a patient with a history of bruxism appears to be essential to protect the restorations.

Summary

In this case series, satisfactory and stable clinical results were obtained by restoring the VDO, with drastic improvement in esthetics and function justifying the procedures used.

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Manufacturers

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COMMENT

Opiate overdose in an adolescent after a dental procedure: A case report

James Hawthorne, MD ▪ Pamela Stein, DMD, MPH ▪ Madeline Aulisio ▪ Laurie Humphries, MD
Catherine Martin, MD

Oxycodone/acetaminophen is a combination of acetaminophen and the opiate oxycodone. It is an effective analgesic that is commonly prescribed postoperatively. The potential for misuse, diversion, abuse, and overdose with opiates in general is an area of increasing concern to all prescribing clinicians. This case report illustrates the possibility of a severe or potentially fatal outcome to a common prescribing practice. Caution is emphasized when prescribing opiates, and screening for substance misuse and suicide risk factors is recommended.

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A 16-year-old boy came to an outpatient university-based psychiatric office, accompanied by his parents. The reason for his referral was a recent suicide attempt by overdose: Approximately three months earlier he had attempted suicide by taking approximately 30 Percocet tablets of unknown strength and was hospitalized in an inpatient child and adolescent psychiatric ward for four days.

The patient said that four months prior to this visit, his wisdom teeth were removed and he subsequently was prescribed oxycodone/acetaminophen (Percocet). He began taking the Percocet as prescribed, but, over time, he developed the habit of taking two or three tablets per week, as these helped him to cope with stresses he encountered in school. These stresses included falling behind on assignments, being caught cheating on his homework, his perception of parental pressure to succeed, and peer pressure to use drugs. He soon needed more Percocet, so he accessed his mother's and grandfather's prescriptions, taking them for his own usage.

This pattern continued for approximately one month until the stresses from school became too great and the patient attempted suicide as described above. His reasons for the suicide attempt included exacerbation of pressure from school and perceived parental pressure to succeed. He did not overtly tell anyone of his intentions, although he sent a text message to a friend that was indicative of suicide intent. The friend informed her father, who contacted the patient's parents, who rushed him to the local emergency room.

The patient was medically cleared, and psychiatric admission to the adolescent unit followed. During this admission he was diagnosed with obsessive-compulsive disorder, depression, and opiate abuse; was prescribed fluoxetine (Prozac) 10 mg; and was subsequently discharged home, with follow-up to be made at the outpatient clinic. Upon arrival at the clinic, the patient was judged to be suffering from clinical depression and his obsessive-compulsive symptoms were improved. He also was no longer misusing opiates. The fluoxetine was continued, and the possibility of increasing the dosage was discussed. The patient was referred to a psychologist for psychological testing, and continuance of therapy was encouraged.

The patient had no previous history of psychiatric diagnoses. His early development and growth were unremarkable. His medical history included acne treated with isotretinoin (Accutane) and premature male pattern baldness, which caused him significant emotional distress. The patient lived at home with his biological parents, ages 44 and 43, and two younger sisters, ages 6 and 14. He attended a local high school, where his grades were mostly Bs, struggling particularly in reading and writing. He had multiple friends at school, none of whom used drugs. He described himself as a perfectionist and felt that this contributed to his stress at school. Significant family psychiatric history included a great-grandfather and great-uncle who committed suicide; a grandfather with treatment-resistant depression; a first cousin with depression and ADHD; and multiple family members with alcohol dependence.

Referral for psychological testing showed the patient to be a student of average intelligence (107 on

the WAIS-III) who likely would perform poorly on repetitious tasks under a time pressure. Overall, his scholastic abilities were on a level comparable to those of his classmates. However, he scored significantly lower in the areas of reading comprehension, writing, and the application of instructions. These deficiencies were in the face of above-average school performance that suggested significant over-achieving on his part, which may have contributed to the stresses that he experienced.

Discussion

This case illustrates many issues of concern to any clinician who prescribes opiates to adolescent patients, including adolescent suicide risk, the misuse and diversion of opiates, and undiagnosed psychiatric illness.

Suicide is the third leading cause of death among adolescents in the United States, with rates beginning to rise after the onset of puberty and stabilizing in early adulthood.[1,2] Annually, the two suicide methods that adolescents use most commonly are suffocation (including hanging) and firearms.[3] Intentional self-poisoning, such as in this case report, is the third most-commonly used method by adolescents, accounting for 5% of all adolescent suicides in the U.S. in 2006.[3]

Predicting which patients are at risk for suicide can be approached through the evaluation of risk factors, which include substance misuse; previous suicide attempts; psychiatric illness; family history of depression and suicide; current stressors; recent loss; hopelessness; history of abuse; and exposure to adolescent suicides.[2,4] The patient demonstrated several of these known risk factors for suicide prior to being prescribed Percocet, including stress at school, depression, anxiety, and an extensive family history of depression and suicide. He also took the acne medication Accutane, which has been linked anecdotally to depression and suicidal behavior in teens, although no clear causative link has been established.[5]

In addition to these pre-existing risk factors for suicide, the patient began to misuse prescription opiates as a form of self-medication for his depression and anxiety. This substance misuse was another risk factor in his eventual suicide attempt.[6] This case demonstrates the importance of screening adolescents for undiagnosed depression as well as suicide risk factors prior to the prescription of opiates.

Misuse and diversion of prescription opiates is another area of concern demonstrated in this case, as the patient's misuse of prescription opiates contributed to his eventual suicide attempt. Over the last decade, the steadily rising number of annual prescriptions for opiates has contributed to increased access to these medications.[7] Currently, the U.S. is the world leader in opiate consumption, using 80% of all opiates and 99% of the world's supply of hydrocodone.[8] The increasing access to opiate medications has been a factor in the rising rates of misuse and diversion of these substances by adolescents.[9] Prescription medications now constitute the fastest-growing group of substances being misused by adolescents.[10]

Predicting which patients will misuse prescription medications can be difficult; however, the evaluation of psychosocial risk factors can help to stratify patients based on risk of misuse. Poor school performance, depression during the past year, high levels of risk taking, and the use of other substances are highly correlated with the misuse of prescription medications.[11] The patient in this case reported two of these risk factors: unsatisfactory school performance and depression.

The importance of identifying patients at risk for substance misuse and suicide is well-illustrated in the case described here. The patient had been suffering from undiagnosed depression and anxiety, which he attempted to self-medicate by misusing prescription opiates. These undiagnosed psychiatric conditions, his substance misuse, the growing stress at school, and easy access to opiates both through his recent prescription and the presence of unused opiates in the household ultimately contributed to his suicide attempt.

What role do prescribing clinicians have in identifying mental illness and hopefully decreasing the chance of the sequence of events seen in the case presented here? Dentists and oral surgeons are increasingly involved in preventive screening; for example, they often are the first clinicians to identify tobacco use. The evaluation of substance misuse and suicide risk factors is another area of preventive screening that should be completed prior to prescribing a substance with both abuse liability and potential lethality. This evaluation could consist of a short questionnaire, completed by the patient, which would stratify patients based on risk factors for substance misuse and suicide.

The authors have compiled a short questionnaire that is specifically targeted to evaluate known suicide and substance misuse risk factors in adolescents. This screening tool (Fig. 1) can be customized to meet the needs of the prescribing clinician. Adolescent patients should be told that the results of the questionnaire are confidential except when it is determined that the patient is reporting suicide intent. In these

This questionnaire should be completed by you, the patient. Please select the answer which most applies to you.

1. ❑ Male ❑ Female		
2. How old are you? _____		
3. What grade are you in? _____		
4. Are your grades: ❑ improving ❑ staying the same ❑ getting worse		
5. Do you have a lot of stress at school or home?	❑ yes	❑ no
6. Do you smoke cigarettes?	❑ yes	❑ no
7. Do you use smokeless tobacco (dip or chew)?	❑ yes	❑ no
8. Have you had any trouble with the law?	❑ yes	❑ no
9. Have you ever had thoughts of killing yourself?	❑ yes	❑ no
10. Have you tried to kill yourself?	❑ yes	❑ no
11. Do you know anyone your age who has killed themselves?	❑ yes	❑ no
12. Has anyone in your family killed themselves?	❑ yes	❑ no
13. Do you feel hopeless?	❑ yes	❑ no
14. Have you recently lost someone you love?	❑ yes	❑ no
15. Have you ever been abused by anyone?	❑ yes	❑ no
a. ❑ physically		
b. ❑ sexually		
c. ❑ emotionally		
16. Do you feel sad most of the time?	❑ yes	❑ no
17. Do you see a mental health professional?	❑ yes	❑ no
18. Do you drink alcohol?	❑ yes	❑ no
19. Have you ever used drugs?		
a. Marijuana	❑ yes	❑ no
b. Cocaine	❑ yes	❑ no
c. Meth	❑ yes	❑ no
d. LSD, PCP	❑ yes	❑ no
e. Huffed/sniffed	❑ yes	❑ no
20. Have you ever used someone else's prescription medicine?	❑ yes	❑ no
If so, what medication was it? _____		

Fig. 1. Treating with opiates: Adolescent screening test (TOAST).

cases, the dentist or oral surgeon will review the concerns with the patient and share them with his or her guardian to ensure the patient's safety. If an adolescent patient reports being abused, this must also be reported to the appropriate authorities. In all cases, the patient's safety must be a priority.

Prescribing practices could be altered based on the results of the questionnaire. Options could include changing the analgesic class to an NSAID or acetaminophen if serious safety concerns become apparent through the screening and follow-up questioning.[12,13] If needed, opiates could still be used judiciously, ensuring parental monitoring of medication and prescribing only the necessary amount. When a patient is deemed to be at risk for suicide, appropriate steps should be taken to ensure patient safety, including parental monitoring and referral to a trusted colleague for psychiatric evaluation and treatment.

Summary

Prescription opiates are increasingly being misused by adolescents, and caution should be exercised when prescribing these medicines. Special consideration should be given to undiagnosed psychiatric illness and suicide potential. Clinicians should consider using a screening tool that would identify adolescents at risk for suicide as well as the development of substance misuse. This questionnaire (or some variation) could be integrated into routine screening questions administered prior to most adolescent dental appointments, especially those at which opiates might be prescribed.

Author information

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COMMENT

Gradual surface degradation of restorative materials by acidic agents

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The aim of this study was to investigate the effect of acidic agents on surface roughness and characteristics of four restorative materials. Fifty-two discs were created from each restorative material: metal-reinforced glass ionomer cement (Ketac-S), resin-modified glass ionomer cement (Fuji II LC), resin composite (Filtek Z250), and amalgam (Valiant-PhD); each disc was 12 mm in diameter and 2.5 mm thick. The specimens were divided into four subgroups ($n = 13$) and immersed for 168 hours in four storage media: deionized water (control); citrate buffer solution; green mango juice; and pineapple juice. Surface roughness measurements were performed with a profilometer, both before and after storage media immersion. Surface characteristics were examined using scanning electron microscopy (SEM). Statistical significance among each group was analyzed using two-way repeated ANOVA and Tukey's tests.

Ketac-S demonstrated the highest roughness changes after immersion in acidic agents ($p < 0.05$), followed by Fuji II LC. Valiant-PhD and Filtek Z250 illustrated some minor changes over 168 hours. The mango juice produced the greatest degradation effect of all materials tested ($p < 0.05$). SEM photographs demonstrated gradual surface changes of all materials tested after immersions. Of the materials evaluated, amalgam and resin composite may be the most suitable for restorations for patients with tooth surface loss.

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Restorative treatment is necessary when a patient suffers tooth surface loss, which is a functional loss of dental hard tissue and commonly includes an unacceptable change in esthetics, dentin hypersensitivity, and, in severe cases, pulpal exposure.[1,2] A suitable restoration may be required to restore the affected tooth. These materials should achieve an intimate adaptation with cavity interfaces to best resist microleakage and the influx of oral irritants. In other words, the materials used would not lead to postoperative sensitivity, interfacial staining, or recurrent caries.

Currently, several different restorative materials are recommended for tooth surface loss lesions, including glass ionomer cement, reinforced glass ionomer cement, resin-modified glass ionomer cement, composite resin, and amalgam.[3] The advantages and disadvantages of each material's properties should be considered prior to choosing it for the restoration.

Composite resin is a mixture of polymers or resins and glass particles or fillers.[4] This material bonds to the tooth structure and can provide an acceptable esthetic result. However, it is not as effective for the restoration of large, defective posterior teeth.

Glass ionomer cement is composed mainly of calcium fluoroaluminosilicate glass in the powder, which reacts with the aqueous polyacrylic acid or related polymeric acid.[5] It is especially effective for treating erosion lesions because of its potential to release fluoride ions into the underlying dentin to protect the tooth structure; however, glass ionomer cement is susceptible to fracture and exhibits low wear resistance.[6]

Development of the glass ionomer cement brought about cermet (ceramic-metal) cement, where glass and silver are fused together.[7] The silver particles improve some mechanical properties of the cement and increase their resistance.[8,9]

In the recently introduced resin-modified glass-ionomer cements, polyacids in a conventional glass ionomer cement are modified with a pendant methacrylate group.[10] As a result, it has been claimed that the mechanical properties of glass ionomer cement were improved.[11,12] However, some clinicians believe that resin-modified glass ionomer cement should be used with caution on the occlusal surface, as it has a high rate of degradation compared with resin composite and amalgam.[4,13]

Finally, amalgam has been used for restorations for a long time (nearly 200 years). It is an alloy that results from the reaction of the ions of silver, tin, and copper acting with mercury.[13] Amalgam has positive physical properties for posterior teeth restoration; however, it requires retention and resistance cavity formation for the restoration.

The long-term clinical service of restorative materials depends on their physical characteristics. One

Table 1. Restorative materials investigated in this study.

Product	Type of material	Main constituents	Mixing	Batch No.	Manufacturer
Ketac-S	Metal-reinforced glass ionomer cement	Silver (40% w/w)	Capsulated	139517	3M ESPE
Fuji II LC	Resin-modified glass ionomer cement	Resin-modified polyacrylic acid, ion leachable glass	Hand-mixed (3:1 P/L)	0202271	GC America Inc.
Filtek Z250	Composite resin	Bis-GMA, zirconia/silica fillers	One-paste	20021127	3M ESPE
Valiant-PhD	Amalgam	Silver, tin, copper, palladium, mercury	Capsulated	020913	Dentsply Caulk

Bis-GMA: 2,2-bis[4-(2-hydroxy-3-methacryloxypropoxy)phenyl]propane.

of the most important physical properties is surface roughness.[14] The presence of roughness or surface irregularities could affect esthetics, plaque retention, discoloration, and gingival inflammation.[15-17] Previous studies have indicated that some chemicals and acidic foods, particularly acidic beverages, can cause surface degradation of not only the tooth but also the restorative materials.[12,18-23] Beverages tested in previous studies have included carbonated soft drinks and orange and apple juices, which contain phosphoric and carbonic acids, citric acid, and malic acid, respectively.[12,20,23-26]

Generally, the behavior of eating and chewing sour fruits, such as green mangoes, pineapples, and limes, is most commonly found in tropical countries such as Australia, New Zealand, Cuba, and countries in southeast Asia.[27-30] A study in southern Thailand showed the associated factors of tooth wear to include age, gender, number of teeth lost, frequency of alcohol consumption, and carbonated drinking and sour fruit intake.[30]

Even though previous studies have reported that certain beverages and fruit juices, such as carbonated soft drinks and orange and apple juices, have a softening effect on restorative materials, sour fruits, such as green mangoes and pineapples, may have an effect as well. Unfortunately, little is known about the effect of eating these sour fruits on restorative materials. The purpose of this *in vitro* study was to investigate the erosive potential of acidic agents (sour fruit juices) on the surface roughness and characteristics of four restorative materials (metal-reinforced glass ionomer cement, resin-modified glass ionomer cement, resin composite, and amalgam). The hypothesis was that the acidic agents under investigation would cause significant changes in surface roughness of the restorative materials evaluated.

Table 2. Surface roughness parameters used and their meanings.

Roughness parameter	Meanings
R_a	The arithmetical average of surface heights
R_{max}	The magnitude of the peak-to-valley height in all cutoff lengths
R_z	The average height difference between the 10 highest peaks and 10 lowest valleys within each cutoff length
S_m	The arithmetical average spacing between peaks at the mean line over the cutoff length

Materials and methods

Four types of restorative materials were selected for this study: a metal-reinforced glass ionomer cement (Ketac Silver Aplicap [Ketac-S]); a resin-modified glass ionomer cement (Fuji II LC); a composite resin (Filtek Z250); and amalgam (Valiant-PhD) (see Table 1). Fuji II LC supplied as a powder/liquid type was used as the hand-mixing material. The powder/liquid ratio used was 1.0 g to 0.3 mL. Ketac-S and Valiant-PhD were supplied as preloaded capsules and were mixed using an electrical amalgamator at 4,300 Hz (ProMix, Dentsply International) for 10 seconds. Fuji II LC and Filtek Z250 were polymerized for 40 seconds with a photoactivated polymerization unit. The light intensity was verified with a measuring device (Cure Rite, Dentsply Caulk).

Fifty-two disc specimens of each restorative material were made using

Table 3. Means and standard deviations of roughness parameters (R_a, R_{max}, R_z, and S_m) of Ketac-S immersed in various storage media for different intervals.

Roughness parameters	Storage media	Time (hours) 1	6	24	48	72	96	168
R_a (μm)	Deionized water	0.02 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.02 ± 0.01	0.02[c] ± 0.01
	Citrate buffer	0.01 ± 0.01	2.40* ± 0.51	3.13* ± 1.25	4.47* ± 0.64	5.87* ± 0.92	7.13* ± 1.28	7.67*,[b] ± 1.63
	Mango juice	0.02 ± 0.01	3.40* ± 0.63	8.80* ± 1.74	9.20* ± 0.77	9.20* ± 1.74	11.87* ± 1.22	12.07*,[a] ± 1.98
	Pineapple juice	0.02 ± 0.01	0.05 ± 0.02	2.47* ± 0.52	3.13* ± 0.74	4.07* ± 1.03	4.20* ± 1.15	6.93*,[b] ± 1.39
R_{max} (μm)	Deionized water	7.73 ± 0.96	7.73 ± 1.96	7.67 ± 1.89	7.80 ± 2.57	7.93 ± 2.63	7.73 ± 2.68	8.13[d] ± 2.23
	Citrate buffer	7.60 ± 0.99	29.07* ± 8.69	54.67* ± 12.96	100.07* ± 16.67	144.93* ± 10.97	213.33* ± 19.98	281.4*,[b] ± 35.05
	Mango juice	7.40 ± 2.03	45.47* ± 12.58	153.80* ± 18.55	210.93* ± 47.67	244.20* ± 40.58	246.53* ± 37.72	314.4*,[a] ± 57.4
	Pineapple juice	6.80 ± 1.32	12.07* ± 1.44	35.93* ± 9.65	50.27* ± 7.43	75.6* ± 17.48	83.87* ± 10.56	142.8*,[c] ± 26.34
R_z (μm)	Deionized water	3.40 ± 0.51	3.40 ± 0.91	3.33 ± 0.98	3.46 ± 0.52	3.40 ± 0.51	3.33 ± 0.89	3.40[c] ± 0.83
	Citrate buffer	3.47 ± 0.52	19.73* ± 5.22	21.13* ± 6.92	32.20* ± 5.47	42.33* ± 5.98	59.20* ± 4.41	81.13*,[a] ± 10.47
	Mango juice	3.33 ± 0.62	26.80* ± 3.84	44.93* ± 5.68	66.53* ± 12.96	75.47* ± 14.09	83.53* ± 14.76	91.33*,[a] ± 16.28
	Pineapple juice	3.20 ± 0.86	9.67* ± 1.29	21.20* ± 2.62	25.81* ± 3.03	30.80* ± 6.79	28.87* ± 6.51	41.8*,[b] ± 7.66
S_m (mm)	Deionized water	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.02[c] ± 0.01
	Citrate buffer	0.02 ± 0.01	0.05 ± 0.03	0.16* ± 0.04	0.21* ± 0.04	0.24* ± 0.09	0.28* ± 0.06	0.40*,[a] ± 0.09
	Mango juice	0.03 ± 0.01	0.11* ± 0.02	0.35* ± 0.08	0.44* ± 0.14	0.39* ± 0.13	0.46* ± 0.13	0.37*,[a] ± 0.13
	Pineapple juice	0.02 ± 0.01	0.14* ± 0.01	0.12* ± 0.02	0.13* ± 0.04	0.15* ± 0.03	0.17* ± 0.05	0.22*,[b] ± 0.04

*Indicates a significant difference compared to 1 hour for each group and parameter (in rows) according to Tukey's HSD test ($p < 0.05$).

[a, b, c, d] Indicate significant differences among four storage media for each parameter (in columns) according to Tukey's HSD test ($p < 0.05$).

a polytetrafluoroethylene cylindrical mold, 12 mm in diameter and 2.5 mm thick. Each mold was covered with a glass cover slip to obtain a flat surface of the specimen. The specimens were allowed to mature in their molds in an incubator at 37°C for one hour after mixing. No mechanical preparation or abrasions of specimens were performed.

Four storage media were used in this study: deionized water (as a control); citrate buffer solution (as a benchmark); green mango juice (*Magnifera indica* L.); and pineapple juice (*Ananas comosus* L.). These juices were prepared from fresh pineapples and mangoes using a juicer machine and then sieved with double layers of filter cloth. The pH of each storage agent

(except deionized water) was determined using a pH meter (Orion 900A, Thermo Fisher Scientific). Ten pH readings of each storage agent, except deionized water, were performed to provide a mean value and standard deviation (SD) of the solution.

The 52 discs of each restorative material were divided into four subgroups (n = 13). After one hour in the incubator, the specimens of each material, still in their molds, were transferred into the storage media. Each specimen was stored in an individual plastic storage pot containing 25 mL of the storage medium, which was filled to a sufficient volume to completely cover both the specimen and the mold. The immersed specimens were retained in their molds at 37°C for the appropriate test period.

A period of immersion was performed to examine the extensive effect of each media. During the test period, the plastic storage pots containing the specimens were kept in an incubator at 37°C before surface roughness was measured. To maintain a constant pH for the storage solutions, each storage agent was changed daily.

Each subgroup was subjected to surface roughness measurement for baseline data (prior to immersion). Surface roughness determinations (4.0 mm in evaluated length) were measured by a profilometer (Surfcorder model SE-2300, Kosaka Laboratory Ltd.) with force 4 mN, speed of stylus 0.5 mm/s, and a cutoff of 0.8 mm. The surface roughness parameters used (R_a, R_z, R_{max}, and S_m [see Table 2]) were examined.[31] Five evaluations per specimen (1.5 mm apart) were taken, both before and after immersion in storage agents for 168 hours. Testing for surface roughness was carried out first one hour after mixing (prior to immersion) and then at 6, 24, 48, 72, 96, and 168 hours. Changes in surface roughness were recorded at each time interval.

To determine the effect of each storage agent on surface characteristic changes, three specimens from each of the four storage agents for each restorative material tested were examined using scanning electron microscopy (SEM). Specimens were rinsed with distilled water for five minutes, dried, and fixed to an aluminium cylinder (13 mm in diameter and 10 mm in height). Consequently, the specimens were sputter-coated with a gold-palladium alloy (SPI module sputter, SPI Supplies) and examined using a scanning electron microscope (JSM model 5800LV, JEOL USA, Inc.).

Statistical analysis

The data were statistically analyzed with the Statistical Package for the Social Sciences (SPSS), version 11.5 (SPSS Inc.). A two-way repeated ANOVA was performed for each of the four roughness parameters to assess the influence of different storage agents and restorative materials on surface roughness. Tukey's HSD multiple comparison test was used in each of the parameters for comparing differences for each time interval as well as for the storage agents (α = 0.05).

Results

The mean pH and SD of all storage media (except deionized water) were as follows: green mango juice, 2.56 ± 0.08; pineapple juice, 3.68 ± 0.08; and citrate buffer solution, 5.00 ± 0.02. Both freshly prepared juices used in this study showed highly acidic solutions.

The results of the two-way ANOVA with repeated measurement revealed statistically significant differences among the four types of materials and storage media, as well as interactions between the type of material and type of storage media ($p < 0.001$ for all comparisons). Means (± SD) of surface roughness parameters of the restorative materials immersed in storage media (see Tables 3–6) indicated increasing roughness for all materials tested after immersion for longer times in all three acidic solutions compared to the control (deionized water).

For Ketac-S (see Table 3), four surface roughness parameters had statistically significant changes. R_a had significant changes at 6 hours in citrate buffer solution ($p = 0.03$) and mango juice ($p = 0.001$) and also at 24 hours in pineapple juice ($p = 0.02$). R_{max} and R_z indicated changes at 6 hours in all acidic agents ($p < 0.001$ for all comparisons). S_m demonstrated changes at 6 hours when exposed to mango juice ($p = 0.02$) and pineapple juice ($p = 0.03$), and at 24 hours for citrate buffer solution ($p < 0.001$).

For Fuji II LC (see Table 4), R_a, R_{max}, and S_m had statistically significant changes after immersion in all acidic agents for 96 hours ($p < 0.001$ for all comparisons). R_z was found to have significant changes after immersion in mango juice at 48 hours ($p = 0.03$) and in citrate buffer solution ($p = 0.02$) and pineapple juice ($p = 0.03$) at 96 hours.

For Filtek Z250 (see Table 5), R_a, R_{max}, and S_m established significant surface changes when exposed to all acidic agents for 168 hours ($p < 0.001$ for all comparisons). R_z verified the surface changes statistically when immersed in mango juice and citrate buffer solution for 96 hours and in pineapple juice for 168 hours ($p < 0.001$ for all comparisons).

R_a, R_{max}, and R_z for Valiant-PhD (see Table 6) increased

Table 4. Means and standard deviations of roughness parameters (R_a, R_{max}, R_z, and S_m) of Fuji II LC immersed in various storage media for different intervals.

Roughness parameters	Storage media	Time (hours) 1	6	24	48	72	96	168
R_a (μm)	Deionized water	0.63 ± 0.02	0.62 ± 0.03	0.60 ± 0.05	0.61 ± 0.01	0.62 ± 0.02	0.60 ± 0.02	0.61[c] ± 0.01
	Citrate buffer	0.64 ± 0.02	0.69 ± 0.04	0.72 ± 0.04	0.78 ± 0.07	0.77 ± 0.04	1.03* ± 0.03	1.12*,[b] ± 0.14
	Mango juice	0.65 ± 0.05	0.71 ± 0.10	0.69 ± 0.12	0.72 ± 0.15	0.87 ± 0.26	1.13* ± 0.06	1.40*,[a] ± 0.51
	Pineapple juice	0.65 ± 0.03	0.67 ± 0.04	0.66 ± 0.05	0.67 ± 0.12	0.67 ± 0.09	1.02* ± 0.08	1.07*,[b] ± 0.35
R_{max} (μm)	Deionized water	8.53 ± 1.48	8.56 ± 1.15	8.60 ± 1.01	8.58 ± 1.02	8.62 ± 1.28	8.61 ± 1.19	8.59[c] ± 1.14
	Citrate buffer	8.53 ± 1.41	8.63 ± 1.32	8.65 ± 1.22	8.69 ± 1.19	8.73 ± 1.04	10.07* ± 0.37	11.13*,[b] ± 1.34
	Mango juice	8.60 ± 1.89	9.20 ± 1.62	10.6 ± 1.34	11.27 ± 1.65	13.87 ± 1.84	18.27* ± 1.08	23.53*,[a] ± 2.56
	Pineapple juice	8.57 ± 1.72	8.60 ± 1.09	8.67 ± 1.11	8.73 ± 1.03	8.80 ± 1.01	10.15* ± 1.01	11.02*,[b] ± 1.84
R_z (μm)	Deionized water	6.73 ± 1.35	6.60 ± 1.94	6.53 ± 1.22	6.46 ± 1.19	6.53 ± 1.83	6.60 ± 1.21	6.67[c] ± 1.11
	Citrate buffer	6.80 ± 1.45	6.81 ± 1.23	6.87 ± 1.31	6.97 ± 1.41	8.13 ± 0.16	9.02* ± 0.18	9.51*,[b] ± 1.10
	Mango juice	6.73 ± 1.08	6.80 ± 1.81	6.84 ± 0.25	7.62* ± 0.69	7.87* ± 1.42	10.53* ± 1.74	12.33*,[a] ± 1.69
	Pineapple juice	6.78 ± 1.41	6.79 ± 1.26	6.73 ± 1.36	6.73 ± 1.25	6.97 ± 0.14	7.96* ± 0.30	8.95*,[b] ± 0.35
S_m (mm)	Deionized water	0.25 ± 0.11	0.26 ± 0.05	0.24 ± 0.06	0.25 ± 0.05	0.28 ± 0.06	0.27 ± 0.04	0.26[c] ± 0.07
	Citrate buffer	0.26 ± 0.04	0.25 ± 0.09	0.27 ± 0.13	0.26 ± 0.09	0.28 ± 0.02	0.32* ± 0.05	0.35*,[b] ± 0.02
	Mango juice	0.27 ± 0.04	0.24 ± 0.19	0.28 ± 0.08	0.29 ± 0.05	0.28 ± 0.07	0.37* ± 0.08	0.39*,[a] ± 0.09
	Pineapple juice	0.28 ± 0.05	0.28 ± 0.05	0.29 ± 0.04	0.21 ± 0.08	0.22 ± 0.07	0.32* ± 0.04	0.36*,[b] ± 0.05

*Indicates significant difference compared to 1 hour for each group and parameter (in rows) according to Tukey's HSD test ($p < 0.05$)

[a, b, c] Indicate significant differences among four storage media for each parameter (in columns) according to Tukey's HSD test ($p < 0.05$)

slightly but did not illustrate any statistically significant changes ($p > 0.05$). However, S_m did have statistically significant changes when immersed for 168 hours in all acidic agents ($p < 0.001$ for all comparisons).

Tukey's HSD multiple comparison tests among the four storage agents for each material tested revealed that, for all parameters, the most statistically significant changes were found after being immersed in mango juice, followed by citrate buffer solution ($p < 0.001$ for all comparisons). The least significant value was found after immersion in deionized water ($p < 0.001$ for all comparisons).

After evaluating the four types of restorative materials for all four parameters, the changes in surface

Table 5. Means and standard deviations of roughness parameters (R_a, R_{max}, R_z, and S_m) of Filtek Z250 immersed in various storage media for different intervals.

Roughness parameters	Storage media	Time (hours) 1	6	24	48	72	96	168
R_a (μm)	Deionized water	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.02[c] ± 0.01
	Citrate buffer	0.03 ± 0.01	0.04 ± 0.02	0.03 ± 0.01	0.05 ± 0.02	0.04 ± 0.02	0.04 ± 0.01	0.06*,[a] ± 0.01
	Mango juice	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.02	0.02 ± 0.01	0.03 ± 0.02	0.02 ± 0.01	0.07*,[a] ± 0.01
	Pineapple juice	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.02	0.02 ± 0.01	0.04*,[b] ± 0.01
R_{max} (μm)	Deionized water	0.53 ± 0.02	0.55 ± 0.11	0.56 ± 0.05	0.56 ± 0.04	0.57 ± 0.06	0.58 ± 0.05	0.60[c] ± 0.11
	Citrate buffer	0.48 ± 0.11	0.60 ± 0.13	0.65 ± 0.06	0.68 ± 0.11	0.72 ± 0.12	0.78 ± 0.10	0.93*,[b] ± 0.09
	Mango juice	0.51 ± 0.11	0.53 ± 0.03	0.58 ± 0.11	0.59 ± 0.09	0.63 ± 0.11	0.72 ± 0.12	1.17*,[a] ± 0.16
	Pineapple juice	0.46 ± 0.11	0.47 ± 0.05	0.53 ± 0.06	0.58 ± 0.03	0.62 ± 0.12	0.68 ± 0.08	0.92*,[b] ± 0.08
R_z (μm)	Deionized water	0.29 ± 0.09	0.31 ± 0.11	0.30 ± 0.09	0.32 ± 0.11	0.34 ± 0.08	0.32 ± 0.11	0.31[d] ± 0.07
	Citrate buffer	0.31 ± 0.09	0.34 ± 0.05	0.36 ± 0.13	0.42 ± 0.12	0.46 ± 0.09	0.65* ± 0.08	0.73*,[b] ± 0.09
	Mango juice	0.29 ± 0.12	0.31 ± 0.06	0.43 ± 0.14	0.52 ± 0.09	0.55 ± 0.11	0.87* ± 0.10	1.07*,[a] ± 0.26
	Pineapple juice	0.28 ± 0.11	0.28 ± 0.09	0.32 ± 0.11	0.35 ± 0.08	0.37 ± 0.11	0.39 ± 0.12	0.58*,[c] ± 0.05
S_m (mm)	Deionized water	0.02 ± 0.01	0.03 ± 0.02	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.02[c] ± 0.01
	Citrate buffer	0.03 ± 0.01	0.03 ± 0.02	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.02	0.03 ± 0.01	0.06*,[b] ± 0.01
	Mango juice	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.02	0.03 ± 0.01	0.07*,[a] ± 0.02
	Pineapple juice	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.03 ± 0.02	0.03 ± 0.01	0.05*,[b] ± 0.01

*Indicates significant difference compared to 1 hour for each group and parameter (in rows) according to Tukey's HSD test ($p < 0.05$).

[a, b, c, d] Indicate significant differences among four storage media for each parameter (in columns) according to Tukey's HSD test ($p < 0.05$).

roughness could be ranked as Ketac-S > Fuji II LC > Filtek Z250 > Valiant-PhD. The ranking order of the erosive potential effect of the storage media was as follows: mango juice > citrate buffer solution > pineapple juice > deionized water.

The SEM photomicrographs (Fig. 1–4) illustrated the gradual surface degradation of the various restorative materials tested. Before immersion, Ketac-S and Valiant-PhD specimens demonstrated rough surfaces and the protrusion of filler particles (Fig. 1A and 4A, respectively). Fuji II LC specimens demonstrated a few rough surfaces (Fig. 2A), while Filtek Z250 specimens demonstrated the smoothest surfaces (Fig. 3A).

After immersion in various storage media for 72 and 168 hours, Fuji II

Table 6. Means and standard deviations of roughness parameters (R_a, R_{max}, R_z, and S_m) of Valiant-PhD immersed in various storage media for different intervals.

Roughness parameters	Storage media	Time (hours) 1	6	24	48	72	96	168
R_a (μm)	Deionized water	1.24 ± 0.15	1.23 ± 0.12	1.25 ± 0.19	1.26 ± 0.15	1.24 ± 0.09	1.25 ± 0.11	1.26 ± 0.12
	Citrate buffer	1.26 ± 0.16	1.25 ± 0.11	1.27 ± 0.35	1.27 ± 0.16	1.28 ± 0.26	1.28 ± 0.16	1.29 ± 0.22
	Mango juice	1.27 ± 0.16	1.28 ± 0.19	1.29 ± 0.21	1.30 ± 0.12	1.31 ± 0.19	1.31 ± 0.16	1.33 ± 0.11
	Pineapple juice	1.27 ± 0.14	1.27 ± 0.26	1.28 ± 0.15	1.28 ± 0.26	1.27 ± 0.13	1.28 ± 0.00	1.29 ± 0.26
R_{max} (μm)	Deionized water	12.27 ± 1.43	12.27 ± 2.55	12.30 ± 3.54	12.29 ± 2.61	12.28 ± 2.63	12.29 ± 2.57	12.30 ± 3.10
	Citrate buffer	12.26 ± 1.60	12.27 ± 1.76	12.28 ± 1.71	12.28 ± 1.79	12.29 ± 1.89	12.30 ± 1.49	12.32 ± 1.13
	Mango juice	12.27 ± 1.22	12.40 ± 1.04	12.51 ± 1.14	12.58 ± 1.33	13.31 ± 2.97	13.42 ± 2.02	13.17 ± 2.11
	Pineapple juice	12.28 ± 1.43	12.30 ± 1.58	12.31 ± 1.48	12.31 ± 1.66	12.33 ± 1.61	12.33 ± 1.73	12.34 ± 1.57
R_z (μm)	Deionized water	8.95 ± 1.46	8.99 ± 2.65	8.98 ± 1.72	8.98 ± 1.49	8.99 ± 1.42	9.01 ± 1.52	8.99 ± 1.49
	Citrate buffer	8.97 ± 1.05	9.03 ± 1.12	9.10 ± 1.38	9.09 ± 1.24	9.11 ± 1.09	9.12 ± 1.14	9.15 ± 1.13
	Mango juice	8.93 ± 1.43	9.03 ± 1.37	9.06 ± 1.45	9.08 ± 1.43	9.11 ± 1.74	9.30 ± 1.79	9.45 ± 1.25
	Pineapple juice	9.00 ± 1.51	9.02 ± 1.81	9.05 ± 1.81	9.07 ± 1.15	9.08 ± 1.08	9.12 ± 1.16	9.13 ± 1.31
S_m (mm)	Deionized water	0.10 ± 0.02	0.11 ± 0.02	0.11 ± 0.03	0.11 ± 0.02	0.12 ± 0.02	0.10 ± 0.00	0.11[b] ± 0.02
	Citrate buffer	0.12 ± 0.03	0.11 ± 0.02	0.12 ± 0.02	0.11 ± 0.02	0.10 ± 0.01	0.12 ± 0.03	0.17*,[a] ± 0.02
	Mango juice	0.11 ± 0.02	0.11 ± 0.03	0.11 ± 0.02	0.10 ± 0.01	0.12 ± 0.01	0.11 ± 0.02	0.18*,[a] ± 0.02
	Pineapple juice	0.11 ± 0.02	0.13 ± 0.04	0.12 ± 0.02	0.13 ± 0.05	0.12 ± 0.04	0.13 ± 0.05	0.16*,[a] ± 0.02

*Indicates significant difference compared to 1 hour for each group and parameter (in rows) according to Tukey's HSD test ($p < 0.05$).

[a,b] Indicate significant differences among four storage media for each parameter (in columns) according to Tukey's HSD test ($p < 0.05$).

LC specimens displayed more rough surface pits that increased with time in citrate buffer solution (Fig. 2D and 2E, respectively) and mango juice (Fig. 2F and 2G, respectively). Roughening patterns also increased with time for Ketac-S (Fig. 1D–1G) and Valiant-PhD (Fig. 4D–4G), after citrate buffer solution and mango juice immersion for 72 and 168 hours. Filler particles were more clearly seen at 168 hours than at 72 hours. For Filtek Z250 (Fig. 3), even after 72 and 168 hours in all storage media, the specimen surfaces still showed mostly smooth surfaces. After the materials were immersed in pineapple juice (Fig. 1I, 2I, 3I, and 4I), the specimen surfaces seemed to have a "plaque-like" covering.

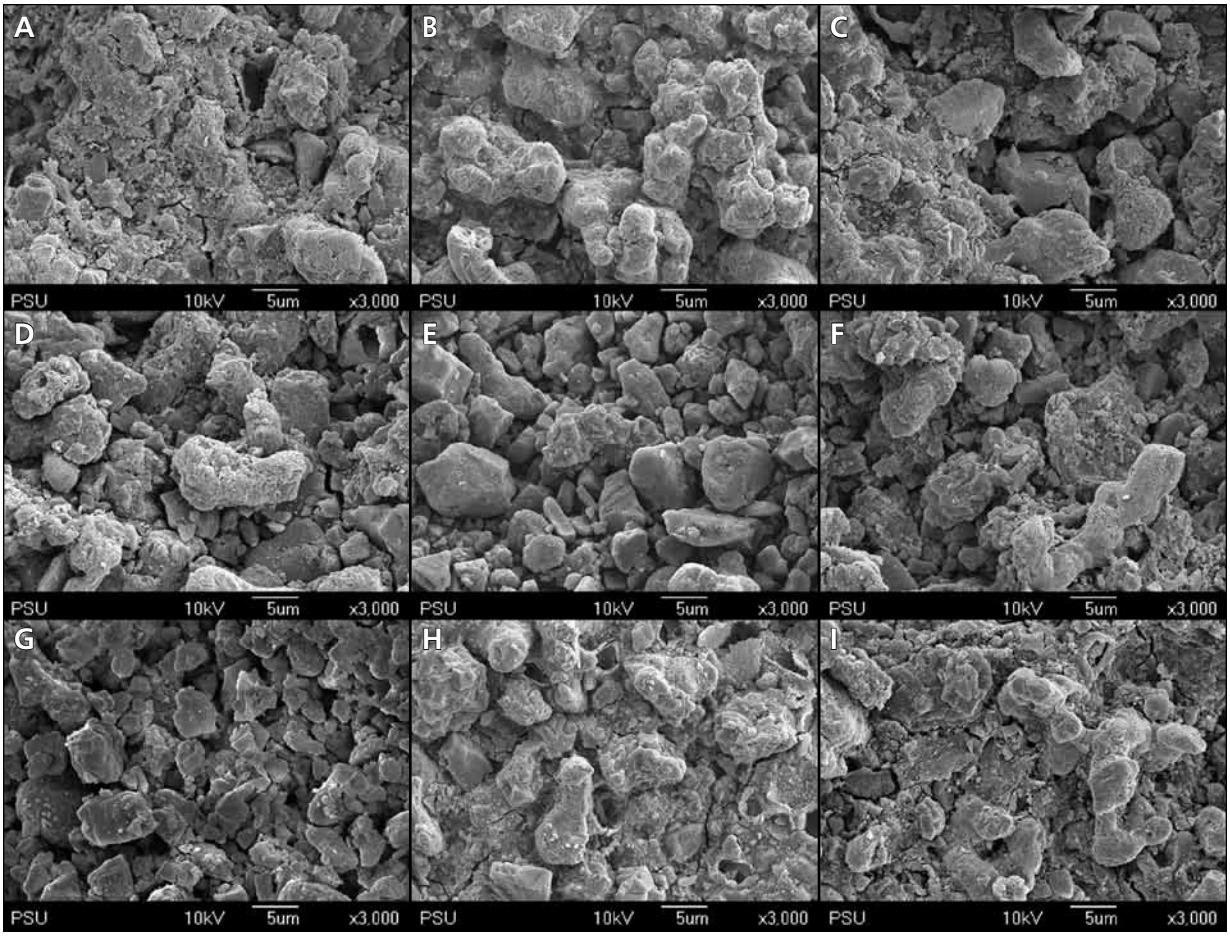

Figure 1. SEM photomicrographs of Ketac-S before and after immersion in various storage media (5,000x magnification). *A:* Before immersion. *B:* After immersion in deionized water for 72 hours. *C:* After immersion in deionized water for 168 hours. *D:* After immersion in citrate buffer solution for 72 hours. *E:* After immersion in citrate buffer solution for 168 hours. *F:* After immersion in mango juice for 72 hours. *G:* After immersion in mango juice for 168 hours. *H:* After immersion in pineapple juice for 72 hours. *I:* After immersion in pineapple juice for 168 hours.

Discussion

The results of this study support rejection of the null hypothesis because the acidic agents used could lead to significantly changed surface roughness of the materials evaluated. This study concentrated solely on erosion by static immersion of restorative materials in solutions over a period of 168 hours. The effect of attrition from chewing habits was not measured.

The oral cavity is a complex environment, and it is difficult to simulate clinically. For this reason, a long immersion time was used to simulate the extensive effect of acidic solutions.

Currently, there are two methods used to measure surface roughness in dentistry: contact methods and noncontact methods.[32] Noncontact methods use a light beam or a laser beam to receive a surface profile. One of the disadvantages of this method is that shiny surfaces, which can be found in composite resin and glass ionomer cement surfaces, are sometimes difficult to measure because of the scattering effect of reflected light. This can result in false values being recorded.[32] For this reason, the current study used a profilometer, which is a contact method. Although it has been claimed that the stylus tip used in contact methods can damage or alter the surfaces, no scratches were observed in SEM analysis because the stylus tip traced on specimen surfaces with very little force (4 mN).[31]

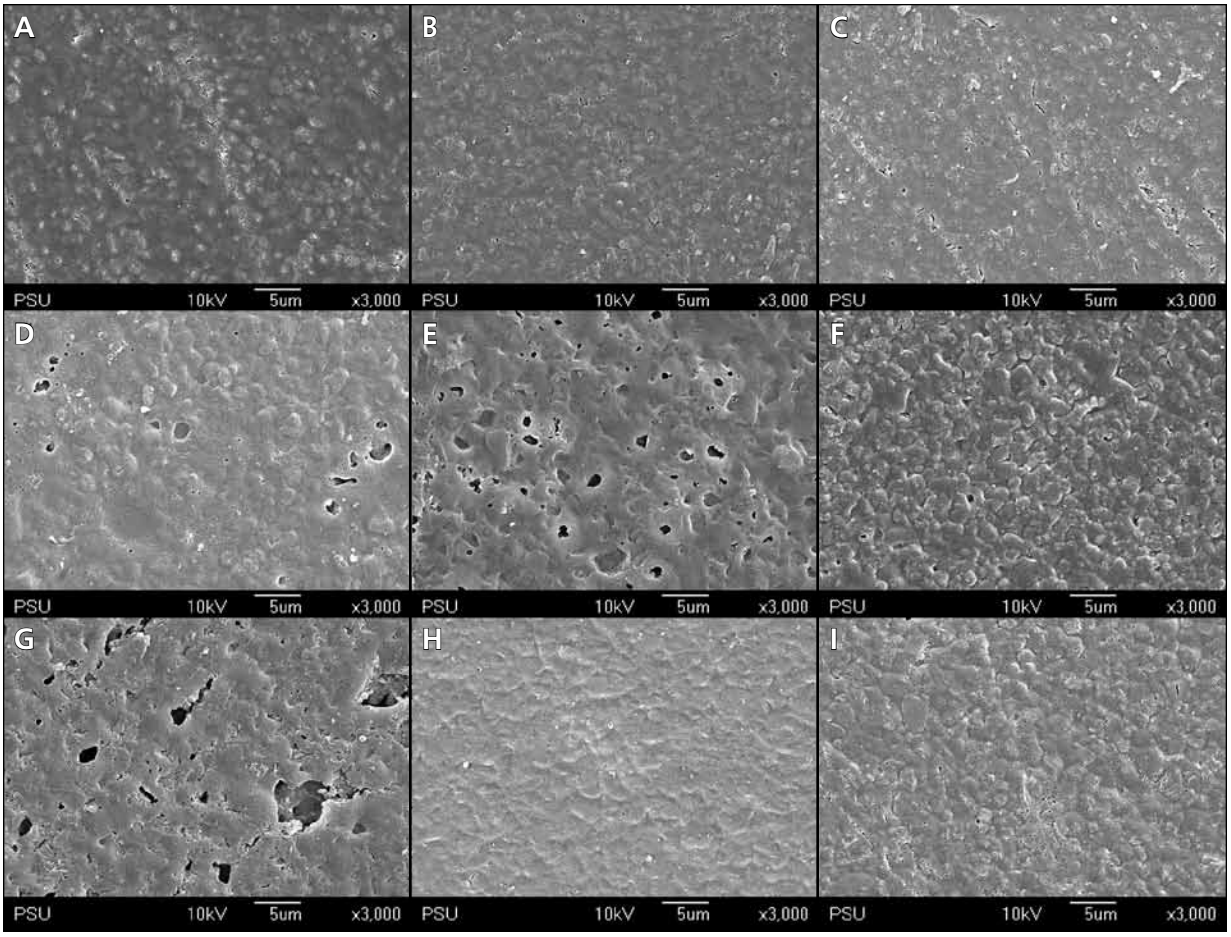

Figure 2. SEM photomicrographs of Fuji II LC before and after immersion in various storage media (5,000x magnification). *A:* Before immersion. *B:* After immersion in deionized water for 72 hours. *C:* After immersion in deionized water for 168 hours. *D:* After immersion in citrate buffer solution for 72 hours. *E:* After immersion in citrate buffer solution for 168 hours. *F:* After immersion in mango juice for 72 hours. *G:* After immersion in mango juice for 168 hours. *H:* After immersion in pineapple juice for 72 hours. *I:* After immersion in pineapple juice for 168 hours.

The most common roughness parameter used in both dentistry and engineering is the R_a value.[33] However, the R_a value is limited in that it is two-dimensional and it only allows information about the average roughness height. It also provides no information regarding the surface profile.[31] To resolve this limitation, the current study used three additional roughness parameters—R_z, R_{max}, and S_m—to provide a qualitative result in three dimensions. The combination of quantitative measurements and qualitative data by SEM supports an obvious characterization of the surfaces tested.[32-34] In addition, roughness measurements obtained from relatively short scans might not be representative of the entire surface, so many measuring scans would be necessary when using a profilometer, as in the current study. The roughness values of the materials tested were in agreement with the other findings.[35-38]

The current study revealed that the acidic agents tested created rough surfaces on the restorative materials. Previous studies have reported that increasing the surface roughness of restorative materials could promote plaque accumulation.[15-17] The critical mean R_a for the adhesion and colonization of bacteria on restorative materials has been reported to be 0.2 μm, which matches the results of the present study.[39] These results may lead to bacterial colonization, which would result in clinical failure of restorations; however, the current

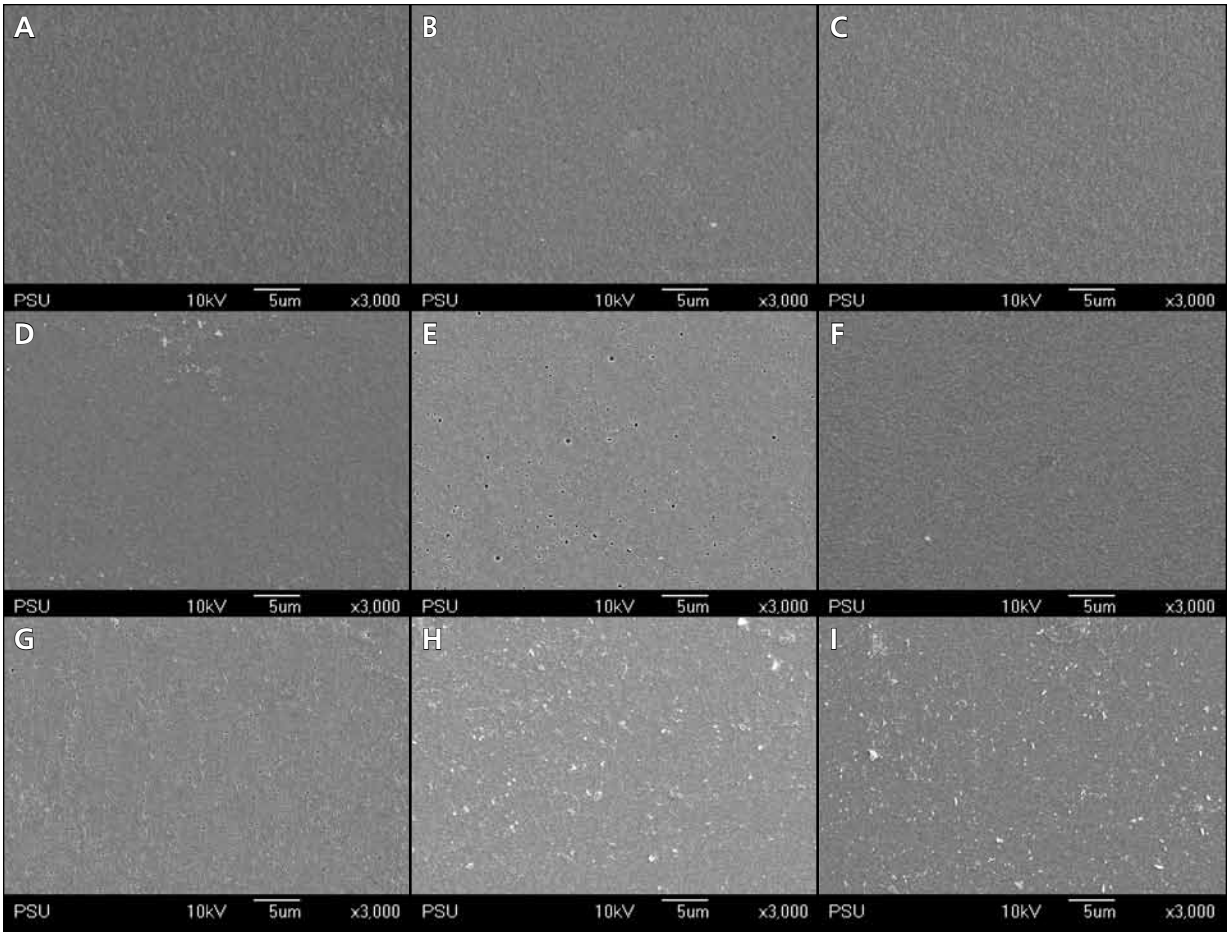

Figure 3. SEM photomicrographs of Filtek Z250 before and after immersion in various storage media (5,000x magnification). *A:* Before immersion. *B:* After immersion in deionized water for 72 hours. *C:* After immersion in deionized water for 168 hours. *D:* After immersion in citrate buffer solution for 72 hours. *E:* After immersion in citrate buffer solution for 168 hours. *F:* After immersion in mango juice for 72 hours. *G:* After immersion in mango juice for 168 hours. *H:* After immersion in pineapple juice for 72 hours. *I:* After immersion in pineapple juice for 168 hours.

study did not examine this particular relationship, so further studies are required to examine this correlation.

The four restorative materials selected for this study are those most commonly used for restoring eroded teeth.[3] The results proved that immersing these restorative materials into acidic agents could cause surface roughness at different intervals. Ketac-S and Fuji II LC, which are modified from conventional glass ionomer cement, displayed changes in surface roughness over a shorter time period compared to amalgam and composite resin. The results indicated that Ketac-S, a metal-reinforced glass ionomer cement, degraded more than Fuji II LC, a resin-modified glass ionomer cement. One reason for this could be the effect of acid on interfacial bonding between the silver alloy fillers and the polyacrylate matrix of Ketac-S, causing the dissolution of the metal ion.[14] Another reason could be the chelating effect of the acid in acidic agents. This phenomenon takes place by complex binding of chelating acids to dissolved metal ions from Ketac-S and results in more ion dissolution and degradation of Ketac-S to maintain electrical neutrality. These results could illustrate that acidic agents could degrade Ketac-S more than the other materials tested.

In fact, there are many types of acids and other components that can have the chemical erosive effect of sour fruits on dental materials. Citric, malic, ascorbic, and fumalic

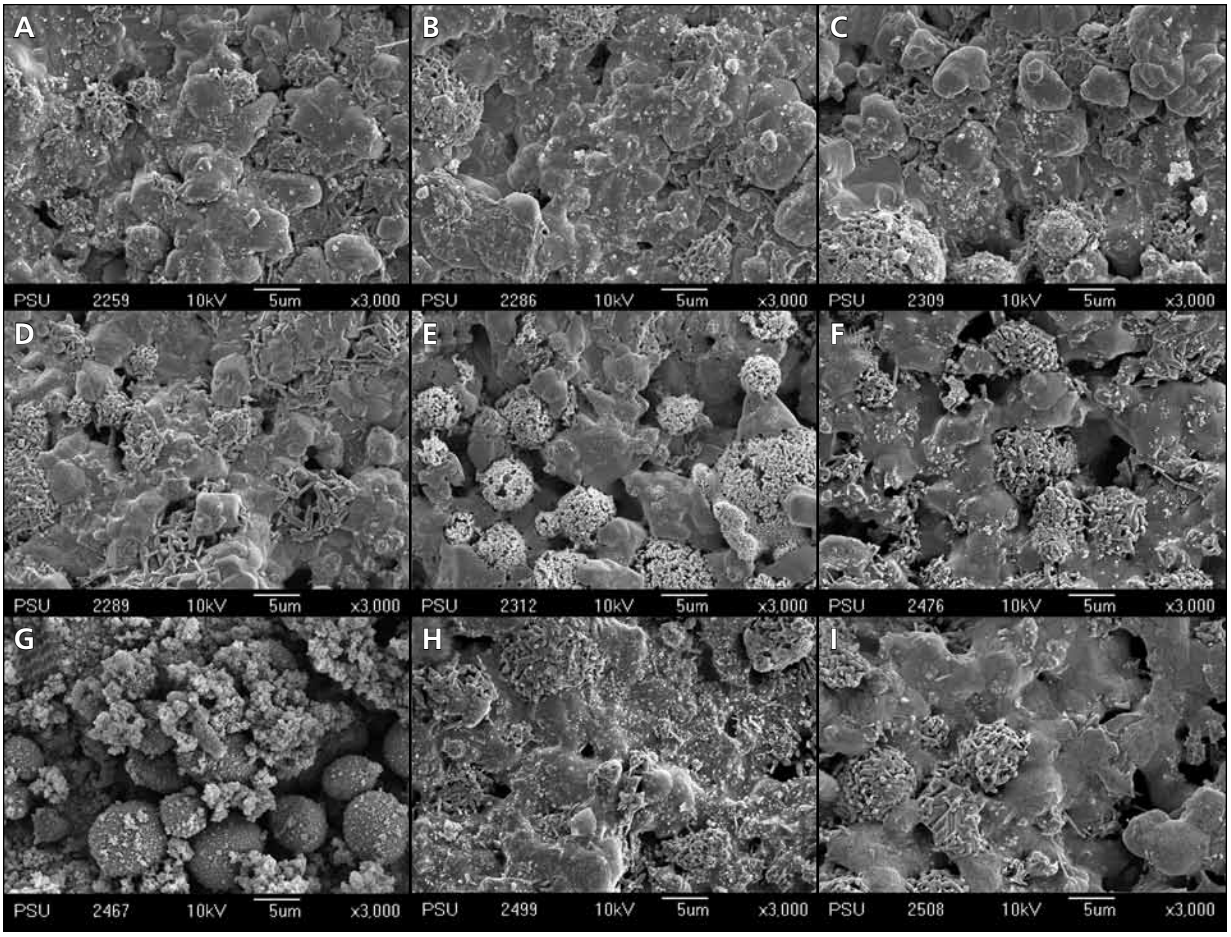

Figure 4. SEM photomicrographs of Valiant-PhD before and after immersion in various storage media (5,000x magnification). *A:* Before immersion. *B:* After immersion in deionized water for 72 hours. *C:* After immersion in deionized water for 168 hours. *D:* After immersion in citrate buffer solution for 72 hours. *E:* After immersion in citrate buffer solution for 168 hours. *F:* After immersion in mango juice for 72 hours. *G:* After immersion in mango juice for 168 hours. *H:* After immersion in pineapple juice for 72 hours. *I:* After immersion in pineapple juice for 168 hours.

acids are the major organic acids in mangoes, while citric acid and malic acid also are the major acids in pineapples.[25] A previous study reported that citric acid (pH = 2.5) is the most aggressive storage medium for glass ionomer cement and compomer, as compared with phosphoric acid (pH = 2.1) and lactic acid (pH = 2.7).[23] In the current study, green mango juices at a pH of 2.56 were harmful to restorative materials, especially Ketac-S. It also was noted that pineapple juice (pH = 3.68) also degraded the restorative materials. However, pineapple juice showed a lower chemical erosive effect on surface roughness compared to the citrate buffer solution (pH = 5.00). It is possible that other components in pineapple juice provide protection against erosion. This is consistent with the SEM photomicrographs, which displayed a "plaque-like" layer covering the specimens that had been immersed in pineapple juice. Further investigation of this finding is required.

The most significant discovery of this *in vitro* study was that amalgam and composite resin could endure acidic solutions more successfully than metal-reinforced glass ionomer cement and resin-modified glass ionomer cement. Therefore, when restoring teeth from the effects of erosion, amalgam or composite resin could be the most suitable materials.

However, it must be noted that the current study had some limitations. Elements of saliva, such as flow rate and buffering capacity,

could alter the results. Also, while the current study attempted to duplicate the oral environment, the presence of water, temperature changes, and a varying pH level in the oral cavity could considerably affect the properties of restorations. In addition, the present study evaluated only the *in vitro* effect. Further studies are required to elaborate the effect of acidic agents or sour fruit juice on restorative materials *in vivo*.

Conclusion

Within the limitations of this study, it can be concluded that acidic agents (citrate buffer solution, green mango juice, and pineapple juice) affect surface roughness changes of dental restorative materials. Amalgam (Valiant-PhD) and composite resin (Filtek Z250) were less affected by acid damage than both types of glass ionomer cement (Ketac-S and Fuji II LC).

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COMMENT

Cast metal bases as an economical alternative for the severely resorbed mandible

Luis Rueda, DDS, MSD ▪ Fong Wong, DDS, MSD ▪ Marissa Cooper, DMD ▪ Andrew Clark, DMD

Resorption of the alveolar ridge is a common problem in edentulous patients and can compromise the stability and function of dentures. Resorption and its consequences can be minimized when strategically placed implants are used; however, this option is financially out of reach for many patients.

The article discusses a more cost-effective alternative (metal-based dentures) for patients with ridge resorption. In certain environments, like a dental school, where patients are looking for solutions to their dental problems at a reasonable price, cast metal bases can be a feasible economical alternative for edentulous patients. Both cases presented here demonstrated a significant improvement in stability, phonation, and mastication.

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Many patients who lose their natural teeth adapt to complete dentures as a result of the accommodation factors inherent to the oral cavity. However, problems can arise when patients have been edentulous for many years and the residual alveolar ridges have undergone extensive resorption.[1] The severely resorbed mandible is associated with most problems encountered by edentulous patients.[2] The lack of retention and stability of the mandibular denture makes the normal functions of mastication and phonation extremely difficult for many of these patients.

The introduction of dental implants has created new treatment options for patients who have advanced resorption. Implant-supported overdentures have become the standard of care for cases of mandibular edentulism.[3] However, for many patients, the greatest obstacle to implant therapy is the high cost. In a dental school environment, where most of the patient population faces financial limitations, implants may not be a viable option.

Metal bases have been used in dentistry for many years; however, despite certain advantages, they are not widely used in clinical practice. Advantages of metal-based dentures include increased retention; less occlusal discrepancy; fewer sore spots; a reduced incidence of fracture; more comfort for the patient; better thermal conduction; increased stability; a thinner palate, which facilitates speech; improved preservation of the residual alveolar ridge; decreased porosity; decreased deformation during lateral mandibular function; and more accurate tissue detail.[1,2,4,5] Regli and Kydd found that a metal denture base was eight times more resistant to deformation than dentures with an acrylic resin base.[6]

In a subsequent study, Regli and Gaskill concluded that the ability of the denture base to resist deformation is an important factor in the adequate distribution of stress to the supporting tissue.[7] Their study indicated that during mastication, acrylic resin denture bases exhibited greater deformation compared with metal denture bases or denture bases with metal inserts. Added strength and increase accuracy of fit complement the reduction in base deformation and may help to prevent excessive loss of the supporting structures.[2,8]

Of course, there also are disadvantages to metal bases, including increased cost, especially if the clinician uses noble metal alloys or more technique-sensitive metals, such as titanium.[5-7,9] Allergies to nonprecious alloys have been reported, with a frequency of 10% in women and 1% in men.[4]

Many authors have identified relining and rebasing procedures as a problem when using metal bases. However, several articles describe sandblasting the metal base and applying a metal primer to condition and bond the relining acrylic material.[10-13]

A number of dental alloys have been used to fabricate metal bases. Gold use was described in classic articles by Grunewald and Lang.[1,5] Aluminum has been used for maxillary metal bases due to its light weight.[14-16] Recently, titanium has been used due to its positive physical properties of excellent corrosion resistance, light weight, and biocompatibility.[8] However, titanium is difficult to cast due to its high melting point, and milled frameworks can be expensive to fabricate. The current price of gold is so high that it cannot be considered when

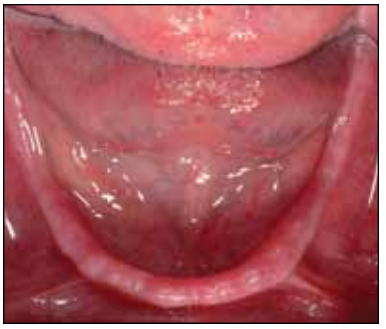

Fig. 1. Severely resorbed mandibular ridge.

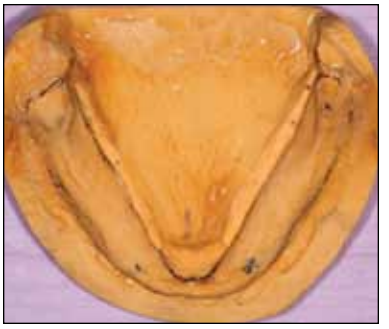

Fig. 2. Metal base design on the master cast.

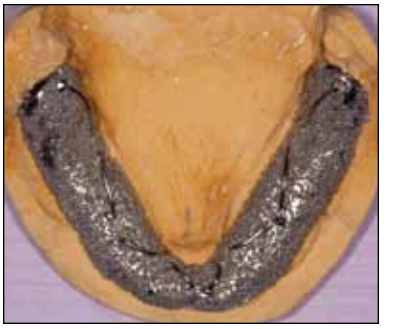

Fig. 3. Metal base on the master cast.

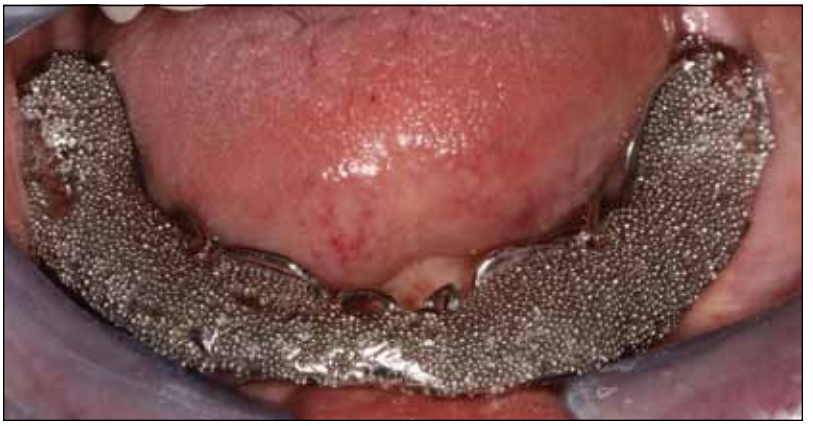

Fig. 4. Metal base framework evaluated in the patient's mouth.

patients have financial constraints. Chrome-cobalt alloys have been used extensively in the fabrication of removable partial denture frameworks due to their reasonable cost, and the fabrication technique is commonly used in most dental laboratories.[8]

Case reports

Case report No. 1

A 57-year-old woman in good overall health sought dental treatment at the predoctoral clinical program at the University of Florida College of Dentistry. Her chief complaint was difficulty using her existing complete dentures, especially the mandibular denture, which had no retention, making it extremely challenging for her to chew and speak. The only way she could tolerate the dentures was to use dental adhesive.

During the intraoral examination, she was classified as a completely edentulous Type III patient (Fig. 1), according to the Prosthodontic Diagnostic Index.[17] She reported having the greatest difficulty with her mandibular complete denture. Her dental history revealed that all of her maxillary and mandibular teeth were extracted in 2007 due to advanced periodontal disease. Immediate dentures were placed at the time of extraction. The patient reported that she continued to be uncomfortable with her dentures, even after several adjustment appointments.

Based on the patient's prior dental experience, an implant-retained overdenture with two implants was presented as the ideal treatment option. However, the high cost of this option caused the patient to reject it. A metal-based complete denture was presented as an alternative treatment option to attempt to reduce the problems she was experiencing with a conventional acrylic-based denture. The treatment plan was approved and informed consent was obtained.

Alginate impressions (Jeltrate, Dentsply Caulk) were taken using plastic stock trays, (Coe, GC America Inc.). The preliminary impressions were poured immediately with a fast-setting dental stone (Snap Stone, Whip-Mix Corporation) so that preliminary casts could be fabricated at the first appointment. This was done to evaluate the cast, to determine areas of tissue displaced by the stock tray, and to fabricate an accurate custom tray.

On this preliminary cast, the areas of attached tissue were determined by manipulating the lips, cheeks, and tongue and were delineated on the cast. This outline was used to fabricate a custom tray (Triad, Dentsply Trubyte). The custom tray was evaluated for overextension in the mouth, and border molding was

accomplished using green modeling plastic impression compound (Kerr Corporation), a Bunsen burner, an alcohol torch, and a water bath set at 140°F.

Polysulfide impression material (Permlastic, Kerr Corporation) was used to make the maxillary and mandibular final impressions. These impressions were boxed using boxing wax strips (Henry Schein, Inc.) and poured using Microstone (Whip-Mix Corporation). After the stone cast was separated from the impression, the extension of the metal base borders was defined on the master cast (Fig. 2). A surveyor (Deringer-Ney Inc.) was used to determine areas of undercuts, especially in the posterior lingual area. The final impression and the master cast were sent to a commercial dental laboratory for the fabrication of a chrome-cobalt metal base (Fig. 3).

The metal base was evaluated on the master cast and in the patient's mouth (Fig. 4). Extension, retention, and stability were evaluated while the patient performed different movements with her tongue and cheeks. A wax rim was adapted on the mandibular metal base to make a centric relation record using Blu-Mousse (Parkell) (Fig. 5). A face-bow record was taken. It was observed that, with the metal base, the occlusal record could be made in a more stable manner.

Teeth were selected using the Blue-line shade and mold guides (Ivoclar Vivadent Inc.). Anterior teeth were selected according to manufacturer's guidelines. Orthoplane zero degree teeth (Ivoclar Vivadent Inc.) were selected for the posterior teeth. A wax try-in was completed, patient approval was obtained, and the dentures were sent to the laboratory for processing (Fig. 6).

When the dentures were delivered to the patient, pressure-indicating paste (Henry Schein, Inc.) was used to note pressure spots and adjustments were made using a metal polishing kit. The occlusion was checked using Surgident articulating paper (Heraeus Dental North America) (Fig. 7). The patient was evaluated again after 24 hours and after one week.

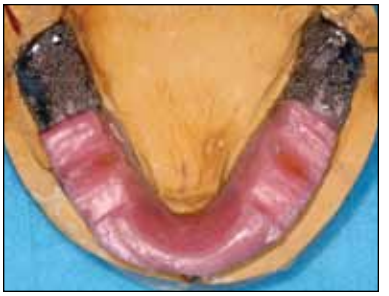

Fig. 5. Metal base occlusal rim on the master cast.

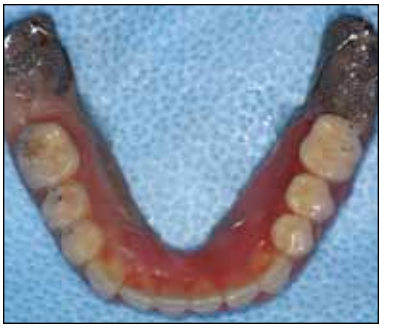

Fig. 6. A wax try-in in the patient's mouth.

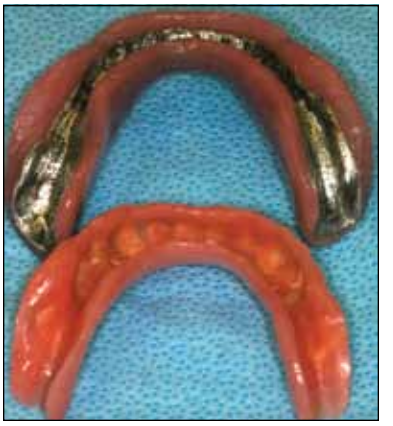

Fig. 7. The intaglio surface of the metal-based mandibular denture.

At a six-month recall appointment, the patient reported a significant improvement in stability, phonation, and mastication; she was extremely satisfied with the final result.

Case report No. 2

A 71-year-old woman presented with multiple medical problems, which were being treated by her primary care physician. She was taking several medications for hypertension, hypercholesteromia, diabetes, and antidepressants. No contraindication for dental treatment was found. The patient had been treated in the predoctoral clinic six months earlier, when she was fitted with a maxillary and mandibular acrylic-based denture. The patient returned on several occasions for adjustments, reporting that she had multiple sore spots, that the mandibular denture was unstable, and that she was unable to eat while wearing it. Flanges were reduced to correct overextensions and Coe-Soft (GC America Inc.) was used on several occasions.

After six months of unsuccessful results, it was decided to replace the acrylic-based mandibular denture with a metal-based mandibular denture. The denture was fabricated using the procedures outlined in case report No. 1. Special attention was given to the design of the custom tray in order to limit the extension of the impression to the attached tissue. At the try-in appointment, special care was taken to avoid impingement of the tissue and overextension.

The patient was evaluated after 24 hours and after one week, and

minor adjustments were made to the occlusion and the base. This patient also reported a significant improvement in stability, phonation, and mastication and was extremely satisfied with the final result.

Summary

This clinical report describes the use of metal-based mandibular complete dentures in two patients for whom conventional acrylic dentures were less than ideal. The lack of retention and stability of the mandibular denture made it extremely difficult for these patients to eat and speak normally.

The mandibular two-implant overdenture has become the standard of care for edentulous patients, especially for those with advanced resorption. However, the high cost of implant therapy remains an obstacle, and implants may not be a viable option for many patients in a dental school environment. Cast metal bases could be a more economical option for patients experiencing problems with conventional acrylic dentures.

Acknowledgments

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Disclaimer

None of the authors have any affiliation with or interests in any of the manufacturers mentioned in this article.

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Manufacturers

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COMMENT

Effect of fiber posts with different emerging diameters on the fracture strength of restored crownless teeth

Paolo Baldissara, DDS ▪ Francesca Zicari, DDS ▪ Luiz Felipe Valandro, DDS, MS, PhD

The relatively low elastic modulus of fiber posts reduces the risk of root fracture, but it also decreases composite core stabilization. To compensate for the lack of rigidity, larger post sizes can be necessary when restoring crownless teeth that have significant internal destruction of the root canal. This study evaluated the effectiveness of fiber posts with different emerging diameters and shapes on composite core stabilization as measured by fracture strength testing.

Fracture strengths ranged from 262.6 ± 81 N to 422.8 ± 56 N. A one-way ANOVA test showed that fracture strength was affected by type of post ($p < 0.0001$); single-tapered posts were weaker than double-tapered posts. Pearson's linear correlation test showed that the fracture strength results appear to have a direct correlation to the emerging diameter of the post ($p < 0.0001$; $r^2 = 0.6191$).

The emerging diameter of fiber posts is important to stabilize the core. When restoring crownless teeth, it is advisable to use fiber posts with large emerging diameters; no additional preparation of the internal root dentin is necessary to enlarge the post diameter.

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In clinical practice, endodontically treated teeth often completely lose their crowns. In these cases, a composite core must be rebuilt completely around the fiber post.[1] Subsequently, a crown must be applied to completely cover the restoration so that the prosthetic margins are brought as close as possible to the dentin tissue, the load is transferred better on the root, and the possibilities of fracture through the ferrule effect are reduced.[1] However, teeth restored in this manner often are subject to failure with core detachment and post yielding; this happens primarily when the crowns supported by fiber posts are anchors for removable partial dentures.[2]

During mastication loading, stress is concentrated strongly at the cervical zone, and mechanical features of the fiber post are crucial to establishing the restoration.[1,3,4] For instance, post diameter or type of post fiber can influence the value of stiffness.[1,5,6] Aird determined that the stiffness varies according to the cube of the thickness, so if the thickness is doubled, the resistance to buckling increases eight times.[7] Asmussen *et al* demonstrated that an increase in diameter generally increases the value of stiffness, while additionally showing that the type of fiber and resin used to fabricate the post could change the stiffness.[8]

These findings indicate that different fiber posts could perform differently from a mechanical standpoint by changing the pattern of stress distribution. The percentage of fibers used also could influence the stiffness value of fiber posts.[9] The aim of this study was to evaluate the fracture strength of roots restored with fiber posts with different shapes and emerging cervical diameters. The hypothesis was that wider fiber posts would have higher fracture strength.

Materials and methods

Eighty single-rooted human teeth (maxillary central incisors, canines, and mandibular premolars) that had not been previously submitted for endodontic treatment were selected. The teeth were cleaned with periodontal curettes, stored in 1.23% chlorexidine for two hours for disinfection, and stored in water at 37°C until use. All of the crowns were sectioned using a diamond disc under cooling, with the length of specimens standardized at 16 mm.

The 80 specimens were allocated into eight test groups ($n = 10$) (Table 1). The canals of the specimens were prepared at 10 mm, using the preparation burs of each post system. After preparation, each root was embedded in a plastic cylinder (height = 25 mm; diameter = 12 mm) filled with an epoxy resin (Araldite MY721, Huntsman) as follows: The preparation bur of the post system was placed inside the prepared root canal; the bur (with the root) was attached to an adapted surveyor, with the long axes of the bur, specimen, and cylinder parallel to each other and perpendicular to the ground; and the acrylic resin was prepared and

Table 1. Fiber posts tested in this study.

Group	Emerging diameter (mm)	Fiber post	Manufacturer	Features
1	1.08	Endo Light-post	Recherches Techniques Dentaires (RTD)	Quartz fiber Conic Smooth surface
2	1.14			
3	1.24	D.T. Light-post	RTD	Quartz fiber Double-taper Smooth surface
4	1.46			
5	1.00	Compaq	Innotech SRL	Glass fiber Parallel side Macroretentions on the surface
6	1.20			
7	1.30	Premier	Innotech SRL	Glass fiber Conic-cylindrical Macroretentions on the surface
8	1.50			

Table 2. Results of one-way ANOVA test.

Source	Degree of freedom	Sum of square	Mean of square	F	*P*
Between	7	258178	36882.6	7.17	<0.0001
Within	72	370219	5141.9		
Total	79	628397			

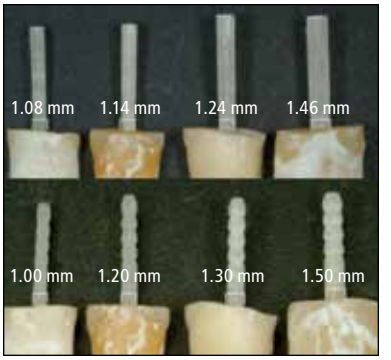


Fig. 1. Groups 1–4 are shown from left to right in the top row, while Groups 5–8 are shown from left to right in the bottom row.

Fig. 2. *Top:* Fracture strength test. *Bottom:* Specimen after testing.

poured inside the cylinder up to 3.0 mm of the most coronal portion of the specimen (Fig. 1).

Post cementation

The fiber posts were etched with 32% phosphoric acid for one minute, then rinsed and dried. For root/crown dentin, a multiple-bottle etch and rinse adhesive system (All Bond 2, Bisco, Inc.) was used. Posts were etched with 32% phosphoric acid for 30 seconds, then washed with 10 mL of water in a disposable syringe. Excess water was removed with No. 80 absorbent paper points. Primer A and Primer B (All Bond 2) were mixed and applied to the posts; excess material was removed using a CaviTip brush (Directa AB). Pre-Bond resin (All Bond 2) was applied; excess material was removed using a brush.

For post cementation, the A and B pastes of a resin cement (Duo-Link, Bisco, Inc.) were measured and mixed. The cement was applied to the post and root canal with a No. 40 lentulo spiral (Dentsply Maillefer). The top surface was photocured for 40 seconds using an XL 3000 unit (3M ESPE) at a light intensity of 450 mW/cm^2.

After post cementation, the core was made with a hybrid composite resin (Light-Core, Bisco, Inc.), using plastic matrixes that were standardized in dimensions (height = ±6.0 mm). The composite was packed inside the matrix, which then was positioned on the post and the top surface of the tooth and photocured (XL 3000) for 20 seconds through the vestibular, lingual, medial, and distal surfaces.

Fracture strength test

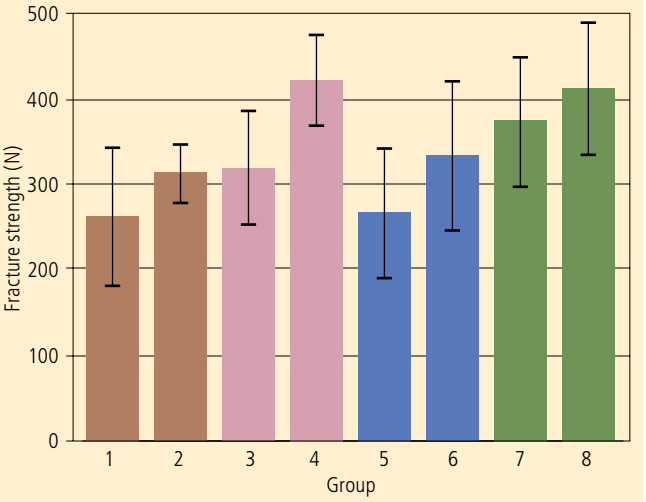
The specimens were placed in a metallic base at a 45 degree angle (to simulate clinical conditions as closely as possible) so that a

Table 3. Means (± SD) of the facture strength results.

Group	Fiber post	Emerging diameter (mm)	Fracture strength (N)*
1	Endo Light-Post	1.08	262.6 ± 81^{c}
2		1.14	314.7 ± 35^{bc}
3	D.T. Light-Post	1.24	318.2 ± 69^{bc}
4		1.46	422.8 ± 56^{a}
5	Compaq	1.00	269.2 ± 77^{c}
6		1.20	334.4 ± 89^{abc}
7	Premier	1.30	375.5 ± 72^{ab}
8		1.50	414.6 ± 80^{ab}

*Different superscript letters indicate a statistically significant difference.

Chart 1. Means and SDs of the fracture strength data (N).



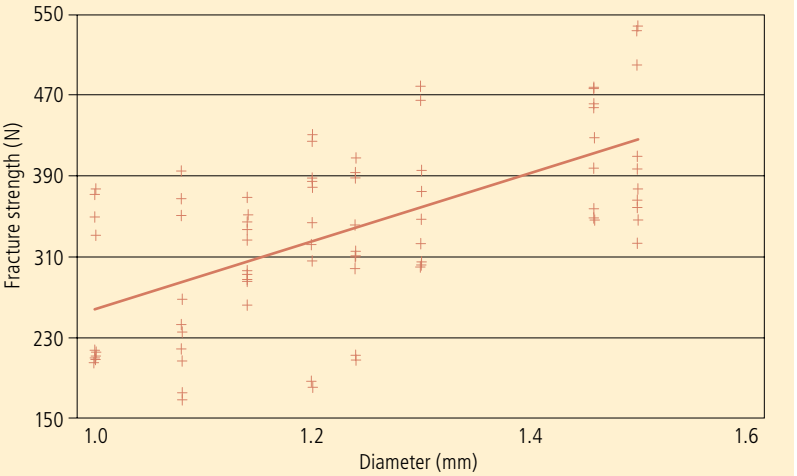
point with a 1.6-mm diameter tip from a universal testing machine (Instron Corp.) could induce load up to fracture. The maximum force required to fracture was considered to be the fracture strength (Fig. 2). One-way ANOVA and Tukey's tests were used to compare the groups ($\alpha = 0.05$), while Pearson's linear correlation test was used to correlate the post diameter and fracture strength results.

Results

The one-way ANOVA showed that fracture strength was affected by the type of post ($p < 0.0001$) (Table 2). Means and standard deviations (Tukey's test) are shown in Table 3 shown in Chart 1. In general, the wider fiber post promoted higher fracture strength values, but only the D.T. Light-Posts (Groups 3 and 4) demonstrated statistically significant differences.

Pearson's linear correlation test demonstrated a direct correlation between fiber post diameter and fracture strength results ($p < 0.0001$; $r^2 = 0.6191$) (Chart 2).

Chart 2. Scatter plot of post diameter versus fracture strength values ($p < 0.0001$; $r^2 = 0.6191$).



Discussion

One advantage of fiber posts is a modulus of elasticity (E = 30–40 GPa) similar to that of dentin (E = 18 GPa), permitting a better dissipation of masticatory loads under clinical function.[10-14] However, this low modulus of elasticity permits greater flexion of the fiber posts, producing tension at the interface of the post/resin core, thus reducing the adhesive resistance.[15] A possible way to avoid this deflexion could be to utilize a post with a larger diameter at the canal entrance, because maximum equivalent stress occurs at the vestibular side of the cervical cement layer (interface between post and cement).[16]

In the present study, it was observed that the greater the post diameter, the higher the fracture strength of the dentin post and core setup. Similarly, in 2004, Lassila *et al* showed a linear increasing resistance against loading force in addition to an increase in diameter.[6] Both carbon/graphite and glass fiber-reinforced posts behaved similarly. According the authors, from a clinical perspective, this suggests that thick posts contribute more favorably than thin posts to the fracture resistance of the root-post-core-crown system.

The findings of the current study also corroborate the results obtained by Amaral *et al* in 2009.[17] In that study, the fracture resistance of teeth restored with fiber posts with different cervical diameters and surface characteristics (macro-retentions) was tested; it was noted that wider fiber posts promoted higher fracture strength.

Another factor related to the resistance of a restoration is the post structure. A 2007 study tested the hypothesis that the fiber diameter and the surface occupied by fibers per square millimeter of post surface (fiber:matrix ratio) is directly related to the physical properties of a fiber post.[18] This factor can explain the differences between the two types of posts used in the current study.

According to the methodology used and the results, it is advisable to use fiber posts with large emerging diameters when restoring crownless teeth; however, additional preparation of the internal root dentin is not advisable for enlargement of the fiber post diameter. Minimal intervention is essential in restoring crownless teeth. The results of the current study suggest that a minimum diameter of 1.5 mm is key for optimizing the clinical performance of teeth restored with fiber posts.

Further studies should be conducted using mechanical fatigue testing, especially to correlate the increase of the fiber post diameter and the weakening of the root. Fatigue failure is a multi-stage process involving creation of microfractures at the interfaces, growth and coalescence of microscopic flaws into dominant cracks, and stable propagation of the dominant macrofractures according to the combination of open, tear, and shear modes occurring in a multi-axial stress condition. In this manner, fatigue testing can simulate masticator conditions.[16]

Conclusion

The findings of the present study suggest that, in crownless teeth, fiber posts with a wider cervical emerging diameter can provide higher fracture strength and a more mechanically stable setup. Additional preparation of the root dentin to increase the post diameter is not advised.

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Disclaimer

The authors have no relationship with any of the manufacturers listed in this article.

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18. Seefeld F, Wenz HJ, Ludwig K, Kern M. Resistance to fracture and structural characteristics of different fiber reinforced post systems. Dent Mater 2007;23(3):265-271.

Manufacturers

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COMMENT

Using cone beam computed tomography to determine safe regions for implant placement

Sayde Sokhn, BDS, DUA, DUB ▪ Ibrahim Nasseh, DCD, DSO, FICD ▪ Marcel Noujeim, DDS, MS

This study sought to identify and follow the course of the incisive canal in the mental interforaminal region of the human mandible and to describe other anatomical landmarks present in this region. Cone beam computerized tomography (CBCT) studies for 40 patients were collected from the database at the Department of Oral & Maxillofacial Radiology, School of Dentistry, Lebanese University. Ten patients had edentulous mandibles; the other 30 had partially or completely dentate mandibles. Axial native images and panoramic and cross-sectional reconstructions were examined to assess the anatomical landmarks in the anterior mandible. Multiple neurovascular canals and foramina were clearly detected on CBCT studies of the mandible. Numerous foramina were seen on the internal surface of the mandible, even distant from the midline. The incisive canal was identified in 97.5% of the images. These anatomical landmarks should be evaluated carefully during preoperative planning.

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For most dental practitioners, the use of advanced imaging has been limited due to cost, availability, and radiation dose considerations. Cone beam computed tomography (CBCT) is capable of providing submillimeter resolution in images of high diagnostic quality, with short scanning times and radiation dosages notably lower than those of conventional CT scans.[1] The introduction of CBCT for the maxillofacial region provides opportunities for dental practitioners to request the most advanced and detailed images needed for adequate diagnosis and treatment planning.

During surgical procedures in the mandible, the mental interforaminal region usually is considered to be a safe region, with no significant risk of damaging vital anatomical structures. Common surgical procedures performed in this region include insertion of endosseous implants, bone harvesting from the chin, genioplasty in orthognatic surgery, and screwing with or without plating after trauma to the anterior mandible.

Even so, the precise anatomy of the interforaminal region, with its potential clinical implications, is still controversial. The mandibular incisive canal is described mainly as a prolongation of the mandibular canal anterior to the mental foramen (MF), containing a neurovascular bundle.[2]

The lingual foramen (LF) is usually situated in the midline of the internal surface of the mandible at the level of or superior to the mental spines.[3,4] The lingual canal (LC) and LF are important considerations for surgical placement of dental implants in this region. The inferior alveolar artery provides some branches to the medial portion of the mental region at the anterior mandible and may pass through the LC to the LF, where they emerge to enter the mylohyoid or anterior belly of digastric muscles. However, previous studies have reported life-threatening conditions caused by profuse bleeding following interforaminal implant placement. If this complication remains unnoticed during a surgical procedure, it could create an upper airway obstruction due to the development of a large hematoma within the mouth floor. Surgical, radiographic, and anatomical measures should be taken to prevent severe bleeding and other complications during surgery.[5-7]

In addition, Tepper *et al* mentioned the existence of numerous foramina on the internal surface of the mandible, even distant from the midline (premolar region).[8] Unfortunately, the extent to which these foramina play a role in the neurovascular supply of the mandible and/or teeth has not been documented.

This study was designed to evaluate the presence and course of the incisive canal (IC), LF, and innominate foramina in panoramic and axial reconstructions generated from CBCT data, and to discuss their clinical significance. Many studies neglect the presence of a true IC and usually suggest that placing dental implants in this

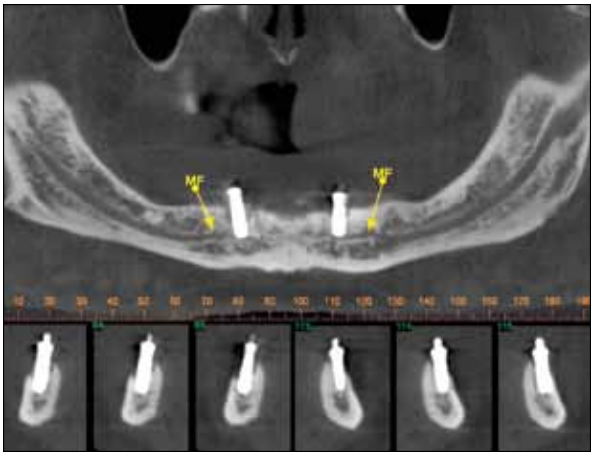

Fig. 1. Panoramic and cross-sectional reconstructions revealed an implant situated in the IC. The patient had experienced pain and sensory disturbances of the lower lip for three months.

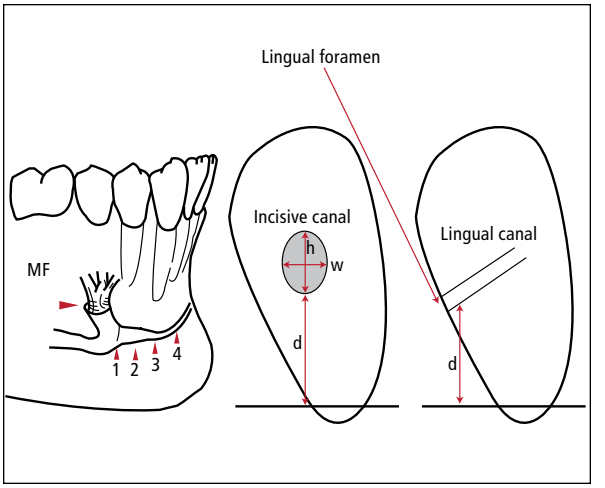

Fig. 2. The course and location of the IC, with a cross-sectional schematic drawing illustrating the IC, LF, and LC.

region cannot cause damage to vital anatomical structures; however, in this study, patients who underwent implant surgery in the incisive canal demonstrated a neurosensory disturbance (Fig. 1).[9,10]

The aim of the present study was twofold: to assess the appearance of the IC and other anatomical landmarks (MF, LF, innominate foramina, and anterior looping) in the mental interforaminal region on CBCT images of patients referred for implant placement in the mandible; and to radiographically establish the location and course of the incisive canal, if present, and to determine its dimensions (Fig. 2).

Materials and methods

This retrospective study included mandibular CBCT images from 40 patients (26 women and 14 men) aged 20–60. Patients were examined for mandibular implant planning. Conventional panoramic radiographs were available for some patients. All CBCT volumes were taken using a standard exposure with an exposure time of 20 seconds and a voxel size of 0.3 mm. Panoramic reconstructions were obtained with 0.3 or 0.4 mm slice thicknesses. Reformatted cross-sectional views were generated as well, with 1.0 mm spacing.

Axial, coronal, and sagittal views as well as the reconstructed images were reviewed carefully for the presence and course of an anterior prolongation of the mandibular canal. In addition, linear measurements were performed.

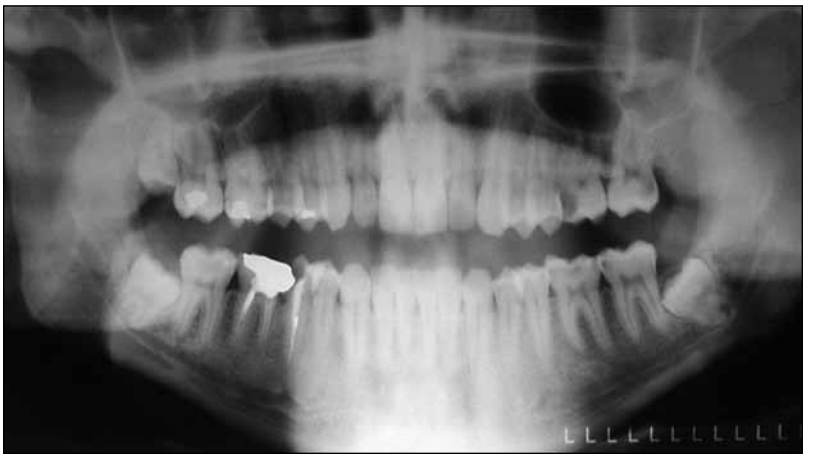

Fig. 3. A conventional panoramic image illustrating a well-defined anterior looping of the mental canal.

Results

Conventional panoramic radiographs can be used to visualize the MF and a potential anterior looping but not to locate the mandibular IC (Fig. 3). A portion of the IC was observed by Jacobs *et al* in 11% of cases after the anterior loop of the MF.[11] CBCT imaging modalities are preferred to verify the existence of the IC for preoperative planning purposes.

On CBCT images, the lingual canal(s) and foramina were observed

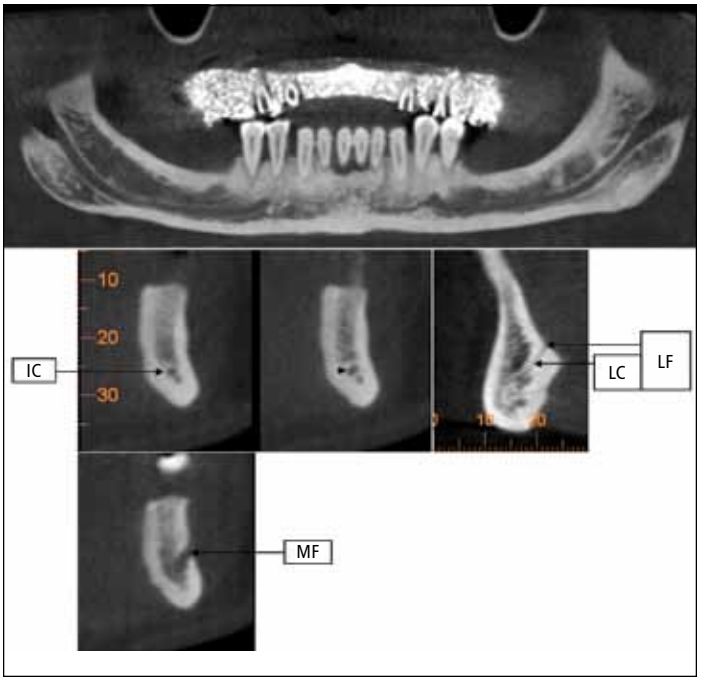

Fig. 4. Cross-sectional images illustrating the MF, LF, and LC.

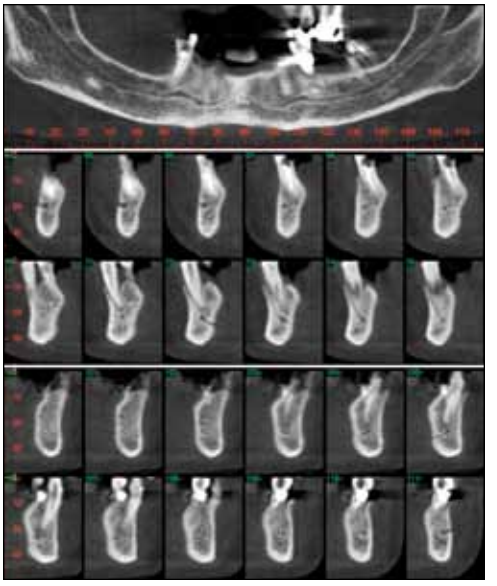

Fig. 5. A well-defined innominate foramina situated between the MF and LF with a large (significant) diameter, cross-sectional numbers 72 and 105. (The number of the cross-sectional image is indicated in the panoramic reconstruction.)

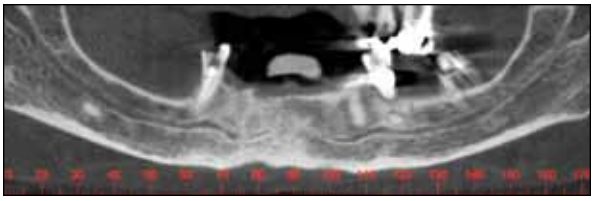

Fig. 6. The structure of bony walls recorded as complete bony cortical walls.

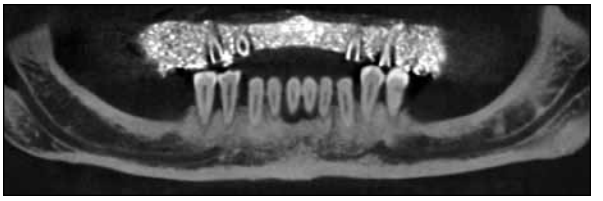

Fig. 7. The structure of bony walls recorded as cortical bony borders and areas of medullary bone in part of the canal.

in 97.5% of the cases. The MF could be seen in 100% of the cases (Fig. 4). The innominate foramina was identified in three patients; it is symmetrical and has a diameter of 1.6 ± 1.0 mm (Fig. 5). The IC was observed in 97.5% of the cases, with a diameter ranging from 0.45–2.9 mm.

The structure of the bony walls was recorded as follows: Complete bony cortical walls throughout the canal (25% of cases) (Fig. 6); cortical bony borders and areas of medullary bone in part of the canal (60% of cases) (Fig. 7); and no cortical walls observed, and the bundle traveling through the medullar bone (15% of cases) (Fig. 8).

Discussion

The inferior alveolar nerve runs an entirely intraosseous course from its entry into the mandibular canal at the mandibular foramen. The nerve is accompanied in the mandibular canal by the inferior alveolar artery, a branch of the maxillary artery. These neurovascular structures supply the teeth and periodontium on both sides of the mandibular arch. At the MF, the inferior alveolar nerve and inferior alveolar artery diverge from the mental nerve and mental artery, respectively, to supply and innervate the skin of the lower lip, the alveolar mucosa, and the gingiva as far posterior as the second premolars. The incisive nerve has been described as one of the terminal branches of the inferior alveolar nerve and appears to run in a clearly defined IC in the mental interforaminal bone.[2,3,12,13]

Olivier was the first to describe the course of the incisive nerve as a

continuation of the inferior alveolar nerve traveling in a canal or through the vacuoles of the spongy bone.[14] The observations of Mardinger *et al* and Bavitz *et al* strengthened this theory.[12,15] Mardinger *et al* anatomically observed an IC in 80% of mandibles.[12] Other studies, however, did not detect the presence of a true IC.[9,10]

The present study confirmed the existence of the IC, as it was visible in 97% of the cases. The present findings also are in accordance with the results from a CT scan observational study.[2] They also support the results reported by Mraiwa *et al,* Bavitz *et al,* and Uchida *et al.*[3,15,16]

No difference was noted between the widths of the IC in edentulous or dentate subjects in this or other studies.[13] The diameter of the IC appears to be large enough to support the presence of a neurovascular bundle. In the present study, the diameter of the IC was 0.45–2.9 mm, which is in agreement with other studies.[2,16] However, it should be noted that the IC does not appear unless the thickness of the panoramic reconstruction is smaller than the diameter of the IC (Fig. 9).

The presence of a well-defined LF on the midline of the lingual aspect of the mandible was confirmed in the present study, as an LF could be seen in a majority of cases. Because of the two-dimensional projection of intraoral radiographs, the LF is often perceived between the mental spines. McDonnell *et al* investigated the radiographic appearance of the canal and concluded that the radiopaque rim is caused by the lingual canal wall, not the mental spines.[17] That group also found that periapical radiographs do not always depict the LF and LC, depending on the projection geometry. When the X-ray beam is parallel to the canal, visualization may be more likely.

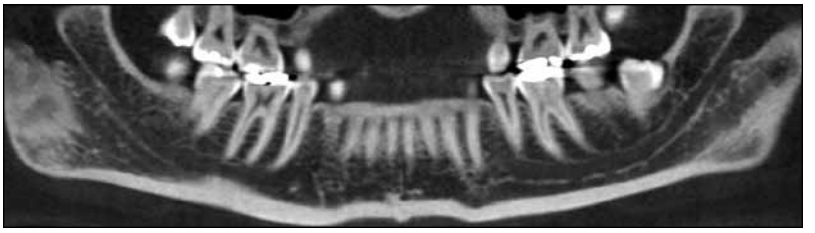

Fig. 8. The structure of bony walls recorded as no corticals walls observed.

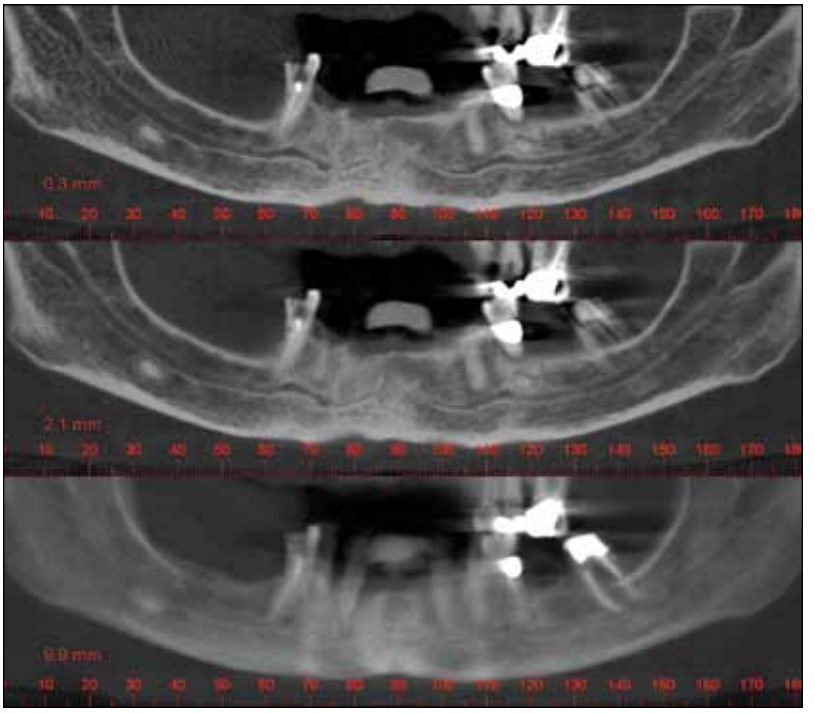

Fig. 9. The IC did not appear in the panoramic reconstruction if the thickness exceeded the diameter of the canal.

Jacobs *et al* added that conventional radiography often fails to demonstrate the presence of the LF, due not only to technical limitations of the image but also to observer limitations.[18] Indeed, observers require certain skills and knowledge of basic information to recognize anatomical landmarks such as the LF. The fact that such features are not described in anatomy textbooks could prevent clinicians from gaining knowledge regarding these structures.

In contrast to two-dimensional imaging, CT scans have the advantage of not being sensitive to beam orientation. For this reason, it was easier to visualize the superior and inferior genial spinal foramina and their bony canals with CT scans than has been reported with conventional radiographic results. Hofschneider *et al* were the first to mention the possibility of visualizing bone canals by means of CT scans.[19] Tepper *et al* and

Gahleitner *et al* also clearly demonstrated the high incidence of such bone canals.[20,21]

The visualization on CT scans reported by Liang *et al* (81%) actually is lower than what has been reported during anatomical studies.[5] This may be related to the reformatting procedure, with some CT scans lacking a reformatted cross-sectional slice exactly at the mandibular midline. Also, it is possible that the 1.0 mm slice thickness masked smaller diameter structures on the mandibular midline.[12,16]

CBCT is the most advantageous technique for visualizing the IC. Visibility of this canal in two-dimensional images (such as intraoral and panoramic radiographs) is limited and dependent on the projection geometry, in addition to other factors such as degree of cortication of the canal wall. The anatomical variations in this region can be detected in the majority of reconstructions from CBCT. The findings from the present study are in agreement with other anatomical reports on the occurrence of multiple innominate foramina, LCs, and lingual foramina.[5,7,8]

Anatomical features and variations should be considered during surgical procedures in the mandible, such as during placement of endosseous implants. Whether neural and/or vascular structures are present in the IC and LF is the subject of further research; however, based on the results of the present study, it can be stated that a well-defined IC appears to be an intraosseous extension of the inferior alveolar canal, so any surgical procedure could be considered to present a risk of traumatizing a neurovascular bundle. Doing so could result in sensory disturbances caused by direct trauma to the incisive canal bundle.

In a case in which a patient had pain and discomfort resulting from implant placement in the interforaminal region, postoperative CBCT images revealed that implants were placed through a large lumen of the IC (Fig. 1). Sensory disturbances also could be related to indirect trauma to the IC bundle, causing a hematoma in a closed chamber, spreading to the main mental branch and resulting in neurosensory disturbances.

Sensory disturbances of the lower lip have also been reported. These could be the result of direct trauma to the anterior looping of the mental nerve during implant site preparation, especially when implants are placed adjacent to the MF or after bone harvesting from the chin. It is possible that an implant could fail to integrate in a gap of 2.0 mm, the average diameter of the IC.[22] Rosenquist found that the incisive bundle caused implant failure by migration of soft tissue around the implant, preventing osseointegration.[23]

With the increased interest in developing a thorough operative plan prior to oral implant surgery in the anterior mandible, cross-sectional images may be considered for obtaining more detailed information about the appearance, location, and course of the foramina and canals and their relation to other anatomical structures in the mandible. CBCT may be the preferred option when a balance is needed between requirements for quality and information on one hand and costs and radiation doses on the other.[24]

Conclusion

CBCT has changed the way clinicians approach dental diagnosis and treatment planning, particularly when knowledge of the anatomy of the maxillofacial complex is essential. CBCT has enabled dental professionals to better visualize the anatomy of the IC. Whether clinicians are looking at the position of the IC with respect to the anteroinferior teeth or treatment planning for implants, viewing the mandible in all three dimensions helps to extract the maximum information needed for diagnosis and treatment. The present study confirms that the recent advances in imaging equipment and technology have increased the applicability of cross-sectional and panoramic reconstructions for visualization of critical structures prior to surgery.

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COMMENT

Recurrence of central odontogenic fibroma: A rare case

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Central odontogenic fibroma (COF) is a rare, benign, painless, slow-growing tumor associated with expansion of the bone cortex. Histologically, it consists of fibrous connective tissue that contains multiple islands of odontogenic epithelium. Some lesions have diffuse spherical calcifications that usually are related to islands or cords of epithelium. The majority of cases respond well to conservative treatment such as enucleation and the prognosis is favorable; recurrences are rare. This article presents a rare case of COF that was located in the anterior region of the maxilla and treated with enucleation; the case recurred five years following the initial treatment.

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The World Health Organization (WHO) defines *central odontogenic fibroma* (COF) as a benign tumor originating from the odontogenic ectomesenchyma, characterized by fibrous tissue with variable cellularity and density, a variable quantity of apparently inactive odontogenic epithelium, and the presence of calcifications similar to dysplastic dentin, cementum, or bone.[1] COF occurs only in jaw bones and accounts for 0.1–5% of all tumors of odontogenic origin.[1,2]

COF occurs in similar proportions in the anterior region of the maxilla and the posterior region of the mandible.[3] It can be a small, asymptomatic tumor or it can reach large proportions that cause bone expansion. An association with impacted teeth occurs in one-third of the cases. COF occurs more frequently between the second and fourth decades of life, but it has been reported in children and the elderly.[3]

The radiographic image of the tumor can be either unilocular or multiocular and either radiolucent or mixed, depending on the amount of mineralized material; the margins are well-defined.[4] COF must be differentiated from other odontogenic tumors or even endodontic lesions. Although the tumor does not have a capsule, its growth is limited, which favors its complete removal through enucleation and rigorous curettage. Recurrences are rare and the prognosis is very favorable.

This article presents a rare case of COF located in the anterior region of the maxilla that was treated with enucleation; the tumor recurred five years following the initial treatment.

Case report

A 16-year-old boy sought treatment at the Oral Maxillofacial Surgery Unit of the Hospital Geral de Areias in Recife, Brazil, complaining of a painless increase in gingival volume in the region of the maxillary right canine (Fig. 1). The patient was in good health, with no allergies to medications and no relevant medical history.

Approximately five years earlier, the patient underwent a surgical procedure to remove a tumor from the same site. The description of the surgery reported that the procedure was performed under local anesthesia without complications. The tumor was removed whole and had a rubbery, gelatinous aspect. The impacted maxillary right canine was maintained in the site, with no bone coverage of the incisal portion of the crown. The diagnosis determined by histopathological analysis was odontogenic fibroma. Five years later, the patient noticed a new increase in volume that was progressing slowly in the same region, so he returned to the same oral maxillofacial surgery unit.

The extraoral examination of the head and neck revealed no

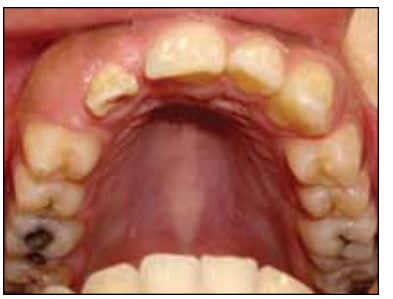

Fig. 1. Intraoral image of a swelling in the buccal region of the maxillary right canine and the presence of a primary maxillary right lateral incisor.

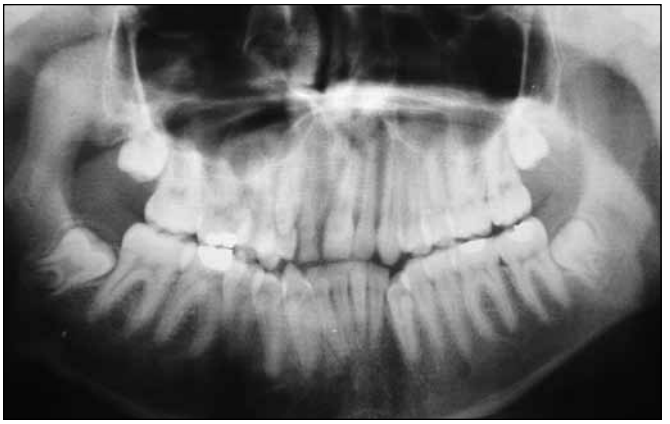

Fig. 2. Panoramic radiograph demonstrating the presence of the maxillary right canine.

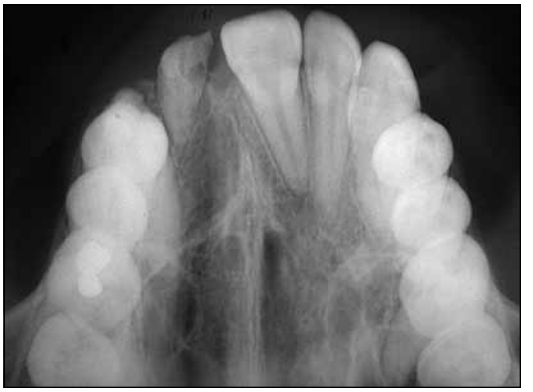

Fig. 3. Maxillary oclusal radiograph. Note the ill-defined radiolucent image related to the maxillary right canine and the primary maxillary right lateral incisor.

abnormalities. The intraoral examination revealed an increased volume of the vestibular cortex in the region of the maxillary right canine extending to the region of the right lateral incisor and first premolar. The mass had a hard, nonfloating consistency, was painless on palpation, and was covered by mucosa with normal texture and coloration. Aspiration was negative for liquids, suggesting a solid lesion. The radiographic examination revealed an impacted maxillary right canine and a poorly defined radiotransparent unilocular tumor between the canine and the primary lateral incisor, apparently without the involvement of the apical region of these teeth (Fig. 2 and 3).

After incison and mobilization of the total thickness of the flap, the vestibular bone cortex was removed, the maxillary right canine and the primary maxillary lateral incisor were extracted, and a tumor of a gelatinous aspect was removed in fragments. Peripheral ostectomy was performed with a high-speed drill under abundant irrigation.

A photomicrograph of the tumor revealed islands of odontogenic epithelium that at times were inactive and at times deposited a mineralized intracellular matrix similar to that of cementum or bone (Fig. 4). The presence of hypercellularized connective tissue with intensive deposition of complete collagen fibers confirmed the diagnosis of odontogenic fibroma (WHO type).

The patient has made follow-up visits for three years with no clinical signs of recurrence.

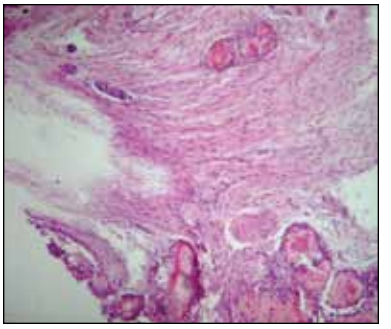

Fig. 4. Odontogenic fibroma characterized by a matrix of fibrous connective tissue showing islands and cords of inactive odontogenic epithelium. Several foci of calcification are seen in odontogenic epithelium islands (H&E stain; magnification 100x).

Discussion

COF is a rare tumor. Older studies attribute a 23% frequency to COF due to interpretations that hyperplastic dental follicles represented cases of odontogenic fibroma.[2] A large number of publications report isolated occurrences with the peculiarities or specificities of each case.[5-7] The two largest series published consisted of 24 and 19 cases.[8,9] For this reason, it is not possible to obtain concrete data on the epidemiology of this condition or reach conclusions regarding its treatment and prognosis.

The age at which COF has been diagnosed varies considerably in the literature, ranging from 5–80.[1,6] The most frequently encountered clinical characteristics are a painless increase in volume that progresses slowly, covered by mucosa that appears normal.[7,9] The clinical characteristics of the patient in the present case report matched those described in the literature.

The radiographic aspect of COF varies from case to case, but it is commonly characterized as a unilocular radiolucent tumor (55%) with well-defined edges (73.3%).[1,3,6] Although calcifications

Table. Characteristics of WHO-type COF recurrences.

Author	Heimdal *et al* (1980)	Svirsky *et al* (1986)	Jones *et al* (1989)	Kinney *et al* (1993)	Present case
Patient age	20	45	51	66	16
Gender	Female	Female	Female	Female	Male
Site	Apex of the mandibular left first molar	Right mandible between the first and second premolar	Mandibular symphysis	Apex of the mandibular right second molar	Between the maxillary right canine and the primary right lateral incisor
Initial treatment	Enucleation; extraction of related tooth	Curettage	Curettage	Enucleation; extraction of related tooth; curettage	Enucleation
Recurrence	Nine years	Two years	16 months	One year	Five years

are determined through histological analysis in approximately 19% of cases, they are not always seen in the radiograph. Small tumors generally have a unilocular image, while larger tumors may have a multilocular aspect.

Radiographic characteristics of COF can be similar to those exhibited by other conditions, such as periapical tumor, traumatic bone cyst, odontogenic cyst, central giant cell tumor, ameloblastoma, and myxoma.[4,7] Pathologists unfamiliar with odontogenic tissues and tumors could have difficulty distinguishing COF from other odontogenic tumors and normal components of odontogenesis. The predilection for the anterior region of the maxilla diverges from many other odontogenic tumors, which tend to affect the region of the third molars, and is an important data point for the differential diagnosis of this tumor.[9] The tumor has no adherence to adjacent bone and tooth structures, which favors conservative treatment.[7]

Although rare, recurrences can occur. The first was reported by Heimdal *et al* in 1980.[10] Since then, three other cases of recurrence of WHO-type COF and three cases of recurrence of COF with a giant cell granuloma component have been published.[5,11-14] The table illustrates the lack of common characteristics that would allow for the identification of a more aggressive pattern or the prediction of recurrence. Errors in the histological diagnosis of the tumor and inadequate surgical techniques are considered to be possible causes of recurrence.[6,12] A probable explanation for the recurrence in the case reported here would be the maintenance of the impacted maxillary right canine and its periodontal ligament as a reactivating factor for the tumor.

Summary

The findings of this study underline the importance of follow-up and periodic clinical and radiographic examinations for COF. The majority of cases respond well to conservative treatment such as enucleation and the prognosis is favorable; recurrences are rare.

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COMMENT

Flexural bond strength of repaired composite resin restorations: Influence of surface treatments and aging

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The objective of this study was to evaluate the effect of storage in deionized water at room temperature, for seven days and six months, on the flexural strength of a repaired photocured microhybrid composite resin, using different surface treatments. After each surface treatment, the adhesive interface was analyzed with a surface roughness tester. The flexural strength of samples from each group was determined by three-point bending in a testing machine at a crosshead speed of 0.5 mm/min with a 50 N load cell. Data were analyzed using ANOVA ($p = 0.0001$) and compared with the Newman-Keuls multiple comparison test.

It was verified that flexural strength of the unrepaired specimens, after both seven days and six months, was similar ($p > 0.05$) and was in accordance with ISO specifications (minimum of 50 MPa), with values ranging from 52–63 MPa. The authors concluded that the use of an unfilled resin agent is necessary prior to the repair to increase the adhesive strength. Further, the use of a silane agent prior to use of the unfilled resin agent is unnecessary, since it does not increase the adhesive strength.

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Composite resin materials and adhesive techniques have become the basis of modern restorative dentistry. The clinical application of composite resins encompasses everything from the restoration of the initial caries process and cosmetic corrections through full prosthetic rehabilitation.[1] Current adhesive techniques allow dental preservation because only the carious areas are removed during dental preparation. It is recognized, however, that composite resins have both inconvenient and attractive properties as a restorative material.

Despite recent significant improvements in composite resin restoration resistance, problems still exist regarding wear, color change, fracture, and superficial pigmentation over time.[2-4] However, when an existing composite resin restoration presents a defect, it is not always necessary to replace it; sometimes a repair can be made.[5-7]

Current knowledge of the biological risks of restorative materials requires reflection on repair techniques. The interfacial adhesive resistance of repaired restorations is clearly affected by some factors, including the age of the initial layer; superficial condition of the initial layer; cure; contamination of the surface of the initial layer with saliva; use of an adhesive agent; use of both a silane and an adhesive agent; characteristics of the resinous adhesive agent when applied, mainly its viscosity and wetting; composite viscosity; particle load of the composite; and time of storage of repaired specimens in water.[8-16] A variety of superficial mechanical and chemical treatments have improved the adhesive strength between old and new composite layers.

The purpose of the current study was to evaluate the effect on flexural strength of photocured microhybrid composite resin TPH Spectrum (Dentsply Caulk) restorations, repaired using different surface treatments and stored in deionized water at room temperature for seven days and six months.

Materials and methods

Specimen preparation

Control group (Group 1)

All specimens were prepared using a stainless steel split mold that was 25 mm long, 2.0 mm wide, and 2.5 mm deep. Each specimen, protected by a polyester matrix, was polymerized three times, once from above and once from each side. Each application lasted 40 seconds and used a device (Optilight 600, Gnatus) that emitted a light intensity between 400 mW/cm^2 and 500 mW/cm^2, as verified by a radiometer.

After initial polymerization, the 30 control specimens were stored in distilled and deionized water in a black container at room temperature for seven days. Silicon

sandpaper with grits ranging from 320–600 was used to prepare specimens to dimensions of 25 mm long, 2.0 mm thick, and 2.0 mm wide. Fifteen specimens were randomly chosen for roughness testing after one week, while the remaining 15 were kept in storage under the same conditions for six months, with the water changed every seven days.

Test groups

The same stainless steel split mold that had been used for the control group was used to create 120 repaired specimens. However, the central depression was one-third filled, then immersed in distilled and deionized water for seven days. Next, the specimens were marked with a pencil at a length of 12.5 mm, where the surface treatments were applied before repairing. The preparation protocol for each test group is described below.

Diamond bur mechanical treatment (Group 2)

A 4138 medium grit diamond bur (KG Sorensen), adapted in a SUPERtorque turbine (KaVo America Corporation), was used five times under water cooling. The specimens then were dried by air spurts and placed in the depression of the stainless steel split mold to receive the resin repair.

Phosphoric acid treatment (Group 3)

These specimens received the diamond bur mechanical treatment, then were conditioned with 37% phosphoric acid (Denstsply International) for one minute and washed under flowing water for two minutes. The specimens then were dried by oil- and water-free air spurts and placed in the depression of the stainless steel split mold to receive the resin repair.

Treatment with resinous adhesive (Group 4)

These specimens received the diamond bur mechanical treatment and the phosphoric acid treatment. Next, two layers of Prime & Bond 2.1 adhesive (Dentsply Caulk) were applied, using the provided applicator tips, for 30 seconds. The surfaces then were dried with light water- and oil-free air spurts for five seconds and polymerized for 10 seconds. The specimens then were placed in the stainless steel split mold to receive the resin repair.

Silane treatment (Group 5)

These specimens received the diamond bur mechanical treatment and the phosphoric acid treatment. Next, the specimens received a silane layer, prepared with a drop from Silane Primer (Dentsply International) mixed with a drop of Silane Activator (Dentsply International) in a special receptacle. After five minutes, the silane treatment was applied, using applicator tips, in two fine layers on the surface to be repaired, then air-dried. The specimens then received two layers of Prime & Bond 2.1 adhesive for 30 seconds. The surfaces were dried with light spurts of air for five seconds and polymerized for 10 seconds. The specimens then were placed in the stainless steel split mold to receive the resin repair.

Surface roughness and flexural strength analyses

A previously calibrated surface roughness tester (SJ-201P, Mitutoyo America) was used to perform 10 readings on each specimen. This was regulated to cover a distance of 0.3 mm, scaled in micrometers (μm). The average surface roughness (R_a) was measured in micrometers and the data were compared using ANOVA, with the tabulated results used to calculate the effect of storage in water and the action of the mechanical and chemical treatments made before repairing.

Flexural strength was evaluated according to ISO 4049. The specimens were tested on a computer-controlled universal testing machine (DL 500, EMIC Ltd.) at a cross-head speed of 0.5 mm/min with a 50 N load using a chisel-shaped tool 1.0 mm thick and 10 mm in length. The specimens were taken to an aluminum device on the table of the universal testing machine, with 20 mm between supports, which was programmed to provide compression in the center of the specimen until it ruptured. Data were transmitted to a dedicated computer with a special program (TESC version 1.8, EMIC Ltd.) and tabulated for later statistical analysis.

Results

The compressive strength results for the seven-day and six-month groups and their respective subgroups (adhesive methods) are presented in Table 1 and Chart 1. For both time frames, Groups 2 and 3 showed statistically significant differences in relation to the other groups ($p < 0.001$), although they did not differ from each other. When comparing the seven-day and six-month specimens, there was a statistically significant difference between Groups 2 and 3 ($p < 0.001$).

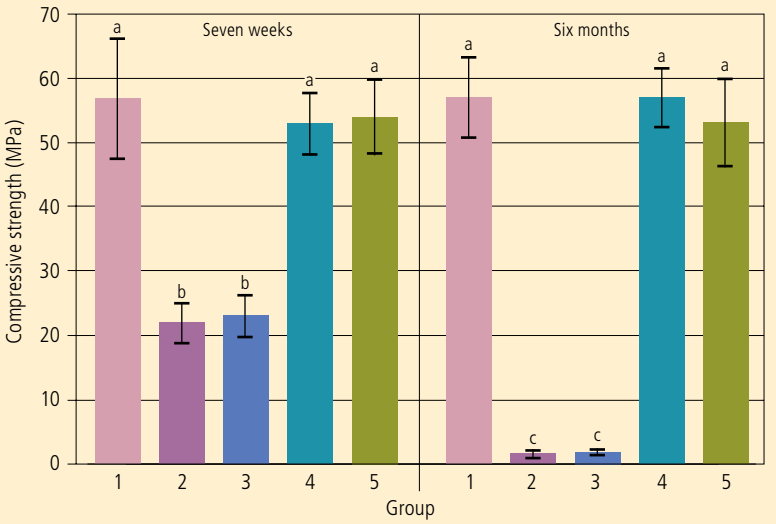
Discussion

The thorough removal of a composite resin restoration is not always necessary or desirable.[17] The advantages of repairing a composite resin restoration include increasing the restoration's longevity, reduced cost, and less pulpal trauma.[7,18-20] Repairs can be conducted in cases of fracture, discoloration, old restorations with a rough surface, marginal

Table 1. Compressive strength analysis according to time (seven days and six months). Statistical differences were verified via one-way ANOVA and Newman-Keuls *post-hoc* tests.

	Mean value ± SD (MPa)		Statistical difference
Group	Seven days	Six months	($p < 0.05$)
1 (control)	57 ± 9.4	57 ± 6.30	No
2	22 ± 3.1	1.7 ± 0.78	Yes
3	23 ± 3.2	1.9 ± 0.49	Yes
4	53 ± 5.0	57 ± 4.60	No
5	54 ± 5.9	53 ± 7.00	No

Chart 1. Mean (± SD) compressive strength values (in MPa) at both time intervals. Different letters indicate a statistically significant difference ($p < 0.05$).



defects or secondary caries, and partial preparation of deep or complex restorations.[3,7,17,18,20]

The adhesive strength of a composite resin to enamel varies from 15–30 MPa.[4,18] Based on the fact that composite resins rarely fail mechanically with acid-conditioned enamel, it is estimated that the adhesive strength of a repaired composite resin should be in this same range.[21] However, results in the literature vary from 2–85 MPa.[4,8-11,15,16] These results could be influenced by many factors, such as the age of the initial layer, the superficial condition of the initial layer, contamination of the surface of the initial layer with saliva, the chemical treatment before the repair, the composite resin viscosity, particle load of the composite, and the duration of water storage for the repaired specimens.[8-14,18]

This study sought to evaluate adhesive strength by varying the conditions of the adhesive surfaces and to evaluate superficial roughness based on surface treatment. The surface roughness was measured at seven days or six months after the composite resin repair and after each superficial treatment. The roughness average (R_a) was evaluated for each specimen. Through the surface roughness analysis in Group 1, the authors conclude that the six-month specimens demonstrated an increase in roughness. This increased roughness could be caused by hydrolytic degradation, which could start in the organic matrix, exposing the fill particles that can disrupt the material body.[10,22] Also, material characteristics and the length of time stored in deionized water could influence this process, causing an increase in surface roughness.

In the present study, the importance of the surface's mechanical preparation to be repaired was considered to increase the micromechanical and/or chemical adhesive surface area of the repairing material. A medium grit diamond bur (between 90 µm and 120 µm) was used because it promotes an increase in surface area, has a low cost, and eliminates the need for other devices, such as micro air-abrasive devices. The use of diamond burs also exposes fresh composite resin that has not yet been contaminated by the oral environment.[3,8,23] Many studies have shown that surface roughness, caused by surface abrasion, was more important than chemical treatment in affecting the adhesive strength of repaired composites.[24,25]

Enamel etching with 37% phosphoric acid increased the average rugosity of the seven-day specimens and decreased it for the six-month specimens, although this difference

was not statistically significant. The acid used in this study is a low-cost material that is widely recognized by clinicians and easy to use. It also can remove superficial debris and ionizate the substrate surface, increasing the surface free energy, which creates a surface more receptive to the next material to be used.[24]

No statistically significant differences in superficial rugosity were found in the control group, regardless of whether the silane agent was used prior to application of the unfilled adhesive agent.

The cohesive resistance in the control group, where there was no repair, was the parameter of maximum flexural resistance of the used material and served as a benchmark to compare the adhesive strength of the repaired groups.

The lowest adhesive strength values were found in Group 2; this was more evident in the six-month specimens. This could be caused by the low wettability of composite resins combined with their high viscosity, which means that a low-viscosity, unfilled resin is necessary to penetrate the microcracks of the old composite resin, thereby increasing micro-mechanical retention.[4,11,17] The wettability is controlled by the difference of superficial free energy between the substrate and the adhesive resin and by its viscosity.[4] The phosphoric acid allows a modest increase in the flexural strength, but this was not statistically significant.

The best flexural resistance results were indicated when an unfilled adhesive resinous agent with high superficial wettability ability was used. Previous studies have shown some advantages of adhesive agents in composite resin repairs, such as increasing mechanical retention, which is important in the repair resistance.[4,9,10,18] The application of unfilled adhesive between the increments is essential to obtain an adequate adhesive resistance.[8,14,15]

One of the objectives of the use of silane in composite resin repairs is to obtain covalent links between the monomer in the adhesive agent and the glass particles that lost the silane covering after mechanical treatment.[26,27] Denehy *et al* believe that this procedure improves hydrolitic stability and mechanical properties in the repair; however, its use in the present study did not affect adhesive resistance, indicating that it is unnecessary.[28]

Conclusion

Based on the results of this *in vitro* study, the authors conclude that aging unrepaired composite resin in deionized water for six months did not decrease its flexural strength. There was a statistically significant decrease in flexural strength of repaired composite resin when only mechanical treatment was used prior to the repair. Further, the use of an unfilled resin agent prior to the repair is required to increase the adhesive strength. Finally, the use of a silane agent prior to the use of the unfilled resin agent is unnecessary, since it does not increase the adhesive strength of the repair.

Disclaimer

The authors have no relationship with any of the manufacturers mentioned in this article.

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