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The TDSC Marketplace and You

Kerry K. Carney, DDS, CDE

When I was a child, we would order our shoes from the Sears, Roebuck and Company catalog. I can remember my mother tracing around my foot to record my footprint on a piece of paper that she would then send to the mail-order company. After some weeks, the box would arrive with my new penny loafers. It was easy and convenient. We did not have to drive into a big city to purchase shoes.

Sears and Roebuck began as a watch and jewelry mail-order company in 1893. Rural areas at that time offered a limited variety of items at prices that varied according to the vendor’s inclination. The mail-order company expanded and became successful because it offered a wide selection of products at set, listed prices. In 1906, Sears went public and was the first major retail IPO in American financial history. In the three decades between 1925 and 1955, Sears expanded into brick-and-mortar stores and the sales from those stores eventually exceeded the mail-order revenue. In 1993, Sears discontinued its catalog. The company continued to expand and its profits peaked at $1.5 billion in 2006. However, just four years later, their profits plummeted to virtually nothing.

The irony here is that in 1994, just one year after Sears discontinued its catalog business, Jeff Bezos incorporated the company that would eventually be known as Amazon. The mail-order business that had been abandoned by Sears was reinvented and became the online immediate-gratification machine and the e-commerce gargantua that it is today.

And now for my confession: I love to shop online. It is easy and convenient. I can compare prices before buying. I can shop at any hour and free shipping and easy returns make me a loyal customer.

The Dentists Service Company is striving to recreate that experience for our CDA members when we order dental supplies through the TDSC Marketplace. The Marketplace was established to provide CDA members with the same advantage that large group practices enjoy in securing favorable pricing. The price-negotiating power of CDA’s 27,000 members can translate into reductions in overhead and overall cost of providing patient care.

For the Marketplace to succeed and support our members, CDA members need to support the Marketplace by using it to buy supplies. This sounds easy. The pricing is very good and the shipping is free. If they do not have the item you are looking for, they will try to source it for you so it will be available in the future. They are eager for your feedback and will adapt to your needs and suggestions. It is easy to reach a human to speak to for customer support and they strive for excellence in every customer interaction. But I want to advise you of one hurdle that you must overcome.

When I talk with colleagues about the Marketplace, they “get it” right away. They understand how it can help their practices and they want to support an endeavor designed by CDA to benefit CDA members. They sign in and take a look at the site. They see the advantageous pricing and they are sold. Then comes the hurdle: Usually, the dentist is not the team member who does the ordering.

The staff member who does the ordering will have to change the way she or he has ordered for years. This can be difficult. There are issues of friendship, trust, loyalty, ease and familiarity. They may have had the same dental supply representative for years. It can feel like a betrayal of a friend. Also, in some offices the dental supply rep does the inventory and restocking, thereby saving the staff member the physical effort. But though this cooperation on the part of the rep may seem like it is free, we all know the cost is part of the calculus that determines the supply prices. Sometimes the supply ordering may be the job of a staff member who does not feel comfortable with the computer. This can make it hard to switch over to the online site. Therefore, it may be necessary to assign the job to another more computer-savvy member of the office team. Sometimes the hard job of changing gets in the way.

In my office, I was very excited about the Marketplace. I introduced my staff to it and said, “This is where we want to place our orders.” I checked in a few days later and asked, “Did you order this from TDSC?” The answer was no. I explained again that we wanted to support TDSC and place our orders there. I checked again a few days later and found they were still using the familiar suppliers. So I had to crack down and say, “From now on, you must first check the price of the item we need on the Marketplace and if it is lower, order it there.”
Finally, because my staff loves to flaunt a retail bargain, they started coming to me to brag about how much money they had saved by ordering a certain item through TDSC. When they finally became familiar with the process, they were sold. They now have their favorite customer service representatives at TDSC. They know them by name. They do not hesitate to tell TDSC reps what our office needs. If a product is not yet available through the Marketplace, our customer service rep will add it to their acquisition list and let us know when it becomes available. My staff members investigate the site specials and popular alternatives to the items we usually order and take great pleasure in racking up the savings. Your role in the success of TDSC is as clear as Newton’s First Law of Motion. A body at rest will remain at rest unless acted upon by an external force. Each of us needs to be that external force. We need to give our staff members that little persistent push to make sure that we support TDSC’s group buying site, the Marketplace. The more successful TDSC is, the more TDSC can help us succeed.

The Journal welcomes letters
We reserve the right to edit all communications. Letters should discuss an item published in the Journal within the last two months or matters of general interest to our readership. Letters must be no more than 500 words and cite no more than five references. No illustrations will be accepted. Letters should be submitted at editorialmanager.com/jcaldentassoc. By sending the letter, the author certifies that neither the letter nor one with substantially similar content under the writer’s authorship has been published or is being considered for publication elsewhere, and the author acknowledges and agrees that the letter and all rights with regard to the letter become the property of CDA.

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3. Can I sell my practice and continue to work on a part time basis?
4. How can I most successfully transfer my patients to the new dentist?
5. What if I have some reservation about a prospective Buyer of my practice?
6. How can I be certain my Broker will demonstrate absolute discretion in handling the transaction in all aspects, including dealing with personnel and patients?
7. What are the tax and legal ramifications when a dental practice is sold?

QUESTIONS MOST OFTEN ASKED BY BUYERS:

1. Can I afford to buy a dental practice?
2. Can I afford not to buy a dental practice?
3. What are ALL of the benefits of owning a practice?
4. What kinds of assets will help me qualify for financing the purchase of a practice?
5. Is it possible to purchase a practice without a personal cash investment?
6. What kinds of things should a Buyer consider when evaluating a practice?
7. What are the tax consequences for the Buyer when purchasing a practice?

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Bacteria Live Under Treated Caries

Your readers may be fascinated by a set of experiments recently described by Rella Christensen, RDH, PhD, and her colleagues at Technologies in Restoratives and Caries (TRAC) Research in a study published in Clinicians Report. They have shown beyond a reasonable doubt that living bacteria reside under all manner of treated carious lesions. For a couple of years, TRAC Research has documented numerous vital microbes under fillings. They harvested loads of bugs after fresh cavity preparation performed with the most aseptic techniques. Now they announce the same following treatment with silver diamine fluoride (SDF). These results pry open a question that would be easier for us dentists to ignore: What are our treatments actually doing?

Dr. Christensen and colleagues went to extraordinary means to confidently reach their conclusions. During my recent visit to TRAC Research, I was spellbound by the measures they took. Dr. Christensen and her colleague Brad Ploeger generously showed me their clinical laboratory and walked me through each excruciating step. This was the most careful microbiological study I have ever seen — and coming from someone in a world-class infectious disease lab at the University of California, San Francisco, that means something. Through physical isolation, decontamination, upward negative pressure and putting the microbiology workstations at the foot of the dental chair, they made possible the cultivation and quantification of live bacteria from microgram samples taken in progressive excavations — each from one turn of a new quarter-round bur. Moreover, they identified each isolate genetically. Each tooth contained its own positive and negative control. All studied lesions they showed me had several completely sterile samples at the very end, after the thousands of bacteria in each step prior.

Dr. Christensen’s study shows that there is work left to do. For now, if no treatment of caries actually arrests all bacterial growth (neither Gordon J. Christensen-quality fillings or SDF), then what do our treatments actually accomplish? The caring dentist would hope that operative or topical approaches debulk the bacterial infection of a carious lesion and limit access to nutrients for the remaining microbes, such that bacterial growth and therefore the progression of lesions is slowed so much that it would rarely be clinically relevant. Until we have more effective treatments, it seems that all dentistry may rely upon a race against time, for the tooth to exfoliate or the patient to pass before the bacteria overcome the pulpal defenses.

JEREMY HORST, DDS, PHD
Postdoctoral Fellow
UCSF DeRisi Lab
Innovative education.  
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CDA. THIS IS WHERE VISION MEETS VALUE.
Frankly, I have had enough of alt-truths. In the end, the facts are not determinative: It is the interpretation that counts. Most of us know where to get the facts we want, conveniently packaged in our favorite interpretations. And as for the other guy’s supposed facts, here are some convenient defenses: “It might be premature to comment,” “probability is not certainty,” “the sample size is too small” and “beware of overgeneralizing.”

Information is a combination of the facts and the assumptions we make about what they would mean for us if true. When we witness a car accident or get an exposure, we say “Oh, no.” It is instinct to deny unwanted facts. The evaluation is instantaneous as though we were shielding ourselves from something we do not acknowledge as the case.

If we don’t like the facts, we can make adjustments for the source. It is easy enough to say the radiograph is not diagnostic. Insurance will not cover this. Dentists do not choose a staff member or associate exclusively on the information about the candidate or they would all be after the same ones. Dentists typically diagnose the condition of a tooth by combining what they see with their years of clinical wisdom regarding “these kinds of teeth.” It is human nature to combine real, particular data with information about cases of a general nature. The sophisticated name for this is evidence-based dentistry.

The critical question is how much weight should be placed on the facts and how much on generalizations about where the facts came from and what they mean. Typically, decisions that are based on an honest combination of facts and their sources are better than decisions that undervalue either. There are formal techniques for this. So it may be correct to say “beware of generalizations,” but it is incorrect to say we can get rid of them. Better by far to say “be aware of generalizations.” It is unethical to use logic that misleads others by protecting our generalizations at the expense of inconvenient facts.

What makes this an ethical matter is picking only the facts we want or distorting them to match our generalizations. The patient who declines the obvious best health options does so either because he or she has not been given full informed consent or because the common facts are placed in different contexts. Change the context rather than the facts. A colleague who engages in what you may consider to be questionable treatment may have diagnosed the case exactly as you have. What is needed before judgment is comparing the contexts.

The nub:
1. All facts are alt-facts; it is the interpretation that matters.
2. If dentistry were reducible to objective reality, staff or computers would replace dentists.
3. Agreement with others is a matter of perspective; unless we can see as others do, we are pretty certain to disagree.

David W. Chambers, EdM, MBA, PhD, is a professor of dental education at the University of the Pacific, Arthur A. Dugoni School of Dentistry, San Francisco, and the editor of the American College of Dentists.
Hot Tea, Smoking and Alcohol: A Cancer Cocktail

Drinking hot tea, when combined with heavy alcohol and tobacco use, increases the risk of esophageal cancer by fivefold, according to a China-based study published recently in the journal *Annals of Internal Medicine*.

The study followed tea-drinking habits of more than 450,000 people aged 30 to 79 over the course of about nine years. Researchers asked participants about their tea-drinking habits, along with other lifestyle choices, through a questionnaire.

Research findings suggest that those who reported drinking hot or burning-hot tea regularly in addition to excessively drinking alcohol or smoking (two already known causes of cancer) increased their chances of developing esophageal cancer. Excessive drinking was defined as having 15 grams of pure alcohol (slightly more than a 12-ounce glass of beer or 5-ounce glass of wine) every day. Researchers noted that more studies are needed to confirm these findings and tea’s possible link to cancer.

In response to the study, the Tea Association of the USA released a statement pointing to the health benefits of tea, including research suggesting it could actually prevent cancer, and stating that “alcohol and tobacco appear to remain risk factors for esophageal cancer.”

The International Agency for Research on Cancer (IARC), which is part of the World Health Organization, and the National Toxicology Program do not recognize tea as a carcinogen. But the IARC did find that hot beverages (at least 149 degrees) “probably” cause cancer of the esophagus.

Learn more about this study in the *Annals of Internal Medicine* (2018); doi: 10.7326/M17-2000.

Bacterial Fats Not Dietary Fats May Cause Heart Disease

New evidence suggests that fatty molecules might come not only from eating fatty, cholesterol-rich food but from bacteria in the mouth, which may explain why gum disease is associated with heart trouble, according to a report in the *Journal of Lipid Research*.

For decades, doctors and researchers assumed that the lipids that can lead to heart attacks and strokes came from eating fatty food. But the research hasn’t borne this out. Some people who eat large amounts of fatty food don’t necessarily develop heart disease.

However, University of Connecticut researchers believe they may have solved part of this puzzle. Using careful chemical analysis of atheromas — growths that form in the walls of blood vessels — collected from patients, they found lipids with a chemical signature unlike those from animals. Instead, these strange lipids come from a specific family of bacteria called *Bacteroides*, which make distinctive fats.

The chemical differences between bacterial and human lipids result in subtle weight differences between the molecules, which might be the reason they cause disease, according to the study. The immune cells that initially stick to the blood vessel walls and collect the lipids recognize them as foreign, react to the lipids and set off alarm bells.

The research team showed that the *Bacteroidetes* lipids could be broken down by an enzyme that processes lipids into the starting material to make inflammation-enhancing molecules. So the *Bacteroidetes* lipids have a double whammy on the blood vessels: The immune system sees them as a signal of bacterial invasion and then enzymes break them down and supercharge the inflammation. Usually the *Bacteroidetes* bacteria stay in the mouth and gastrointestinal tract. If conditions are right, they can cause gum disease in the mouth but not infect the blood vessels.

The next step in the research is to analyze thin slices of atheroma to localize where the bacterial lipids are accumulating. If they are found within the atheroma but not in the normal artery wall, that would be convincing evidence that these lipids are associated specifically with atheroma formation and therefore contribute to heart disease.

Learn more about this study in the *Journal of Lipid Research* (2017); doi: 10.1194/jlr.M077792.
Squamous cell carcinoma of the tongue is an aggressive form of cancer that generally affects older people. Patients with the disease often find it difficult to eat, swallow food or speak. Reasons for its generally poor prognosis include late detection.

But a new study published in the journal *Oncotarget* found that bacterial diversity and richness and fungal richness are significantly reduced in tumor tissue compared to their matched nontumor tissues. This raises the prospect that certain bacteria and fungi, in sufficient amounts and in possibly interactive ways, may play a part in the development of oral tongue cancer, according to the study conducted by a team of researchers from the Case Western Reserve University School of Medicine, the Cleveland Clinic and the University Hospitals Cleveland Medical Center.

While the bacteriome is increasingly recognized as playing an active role in health, the role of the mycobiome has never before been studied in the case of oral tongue cancer. In the new study, the researchers extracted tissue DNA from 39 paired tumor and adjacent normal tissues from patients with the cancer. Analyses showed that *Firmicutes* was the most abundant bacterial phylum and was significantly increased in tumors compared to nontumor tissue (48 percent versus 40 percent, respectively).

In total, the abundance of 22 bacterial and seven fungal genera types was significantly different between the tumor and adjacent normal tissue, including *Streptococcus*, which was significantly increased in the tumor group (34 percent versus 22 percent in normal tissue.)

“Our findings mean that it may be possible to perform precautionary testing in patients at high risk for oral tongue cancer,” said the study’s co-senior author Mahmoud A. Ghannoum, PhD, professor at the Case Western Reserve School of Medicine and the University Hospitals Cleveland Medical Center. “If the patterns that we found are present in people who are not yet showing signs of lesions, we could begin treatment early, offering the possibility of better patient outcomes.”

Researchers say additional research is needed to understand how these two communities influence or are influenced in disease settings such as oral tongue cancer.

Learn more about this study in *Oncotarget* (2017); doi.org/10.18632/oncotarget.21921.

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**Tooth Enamel Determines Sex of Human Remains**

A new method for determining the sex of human remains using tooth enamel has been discovered by researchers in the United Kingdom and Brazil, according to a study published in the journal *Proceedings of the National Academy of Science* in December 2017.

Determining the sex of human remains has applications in archaeological and legal contexts, among others. DNA sequencing can be used for sex determination, but the approach is often expensive, time-consuming and depends on the quality of the DNA sample. In the study, researchers used peptides from tooth enamel, a durable human body tissue, to develop a method for determining the sex of human remains.

To extract peptides from tooth enamel, the method uses a minimally destructive acid-etch procedure. Sex chromosome-linked isoforms of amelogenin — an enamel-forming protein — are identified from the acid-etch sample using nanoflow liquid chromatography mass spectrometry, according to the study.

The authors tested the method on the remains of seven adult individuals from the late 19th century as well as male and female pairs from three archaeological sites ranging from 5,700 years ago to the 16th century in the United Kingdom. In each context, the method successfully determined the sex of the individuals, as confirmed by comparison with coffin plates or standard osteological analyses.

According to the authors, the method might help improve techniques for sex determination of human remains with potential applications in bioarchaeology and medical-legal science.

Read more of this study in the *Proceedings of the National Academy of Science* (2017); doi: 10.1073/pnas.1714926115.
Blasting Dental Plaque With Microbubbles

A research team from Tohoku University and Showa University in Japan discovered that using a cavitating jet to clean dental implants was more efficient and thorough than a water jet, which has been used for a long time to remove plaque from dental implants to keep them clean, according to a study published in the journal Implant Dentistry. A cavitating jet uses a nozzle to inject high-speed fluid through water to create very tiny bubbles of vapor. When these bubbles collapse, they produce strong shockwaves that are able to remove contaminants.

Researchers conducted the study to look for better ways for dentists to remove the plaque that builds up on the screws that hold dental implants in place. While the plaque sticks mainly to the crown, it also adheres to the microgrooves of the exposed parts of the screws and are much harder to clean.

To compare the cleaning effect of a cavitating jet to that of a water jet, the team grew a biofilm within the mouths of four volunteers. After three days, they used the two different methods to clean the mouths, measuring the amount of plaque remaining at several time intervals.

While there was little difference between the amounts of dental plaque removed by both methods after one minute of cleaning, that changed after longer exposure. After three minutes, the cavitating jet had removed about a third more plaque than the water jet did, leaving little plaque stuck to the implant at the end of the experiment. The cavitating jet was also able to remove the plaque not only from the root section of the screws, but also from the harder-to-reach crest section.

Previous research has shown that water flow exerts shear stress to remove the biofilm. In addition to this shear effect, the cavitating jet also produces a considerable force when the bubbles collapse that is able to remove particles from the biofilm and carry them away. The researchers suggest that the two processes probably work in synergy to make the cavitating jet superior to the water jet.

Read more of this study in Implant Dentistry (2017); doi: 10.1097/ID.0000000000000681.
Scotland Launches Oral Health Improvement Plan

The Scottish government recently launched a nationwide Oral Health Improvement Plan (OHIP) to provide a framework for improving the oral health of “the next generation,” according to a news article on the website fluoridealert.org.

As part of the OHIP, the government will introduce a system of monitoring to ensure that all dental practices provide preventive treatment for children. This system will include oral health risk assessments (OHRA). Patients will be seen according to their OHRA results, meaning they may be recommended to visit the dentist once every 24 months.

The OHIR will also implement ways to meet the needs of Scotland’s aging population. The Scottish government predicts that the number of people aged over 65 will increase by 53 percent by 2039 and has therefore decided to introduce arrangements to accredited general dental practitioners to provide care in elderly care homes. Additionally, dental practices will be required to display the government oral health information on self-care, treatments available, costs and services and to communicate this information clearly to patients.

In response to the 46 percent increase in the number of dentists working under Scotland’s national health system — from 2,474 in March 2007 to 3,613 in March 2017 — the OHIP will establish a dental workforce planning forum, which will make recommendations for workforce requirements, morale and issues affecting dental teams. Promotional programs will also be developed to encourage dentists to work in rural areas of Scotland, and a European Union (EU) dentists’ network will be established for after Brexit, providing an opportunity for dentists from the EU to engage with Scotland’s chief dental officer.

While the government admits OHIP is an ambitious program of work, it has pushed on to establish a number of short-term working groups to take it forward. In the meantime, a biannual newsletter will be produced to provide updates on the progress that is being made toward implementation and a number of “roadshow” events will be held to discuss the implementation arrangements.

Read more about Scotland’s Oral Health Improvement Plan at fluoridealert.org/news/30322.

Wine Polyphenols Could Benefit Oral Health

Abundant and structurally diverse polyphenols have been attributed to the healthy effects of wine on the colon and heart, but new research reported in the American Chemical Society’s Journal of Agricultural and Food Chemistry in February 2018 shows that wine polyphenols might also be good for oral health.

Polyphenols are antioxidants, meaning they likely protect the body from harm caused by free radicals. However, recent work indicates polyphenols might also promote health by actively interacting with bacteria in the gut. That makes sense because plants and fruits produce polyphenols to ward off infection by harmful bacteria and other pathogens, according to research.

M. Victoria Moreno-Arribas, who studies wine chemistry, and research colleagues from the University of Madrid in Spain wanted to know whether wine and grape polyphenols would also protect teeth and gums, and if so, how this could work on a molecular level. The researchers checked out the effect of two red wine polyphenols, as well as commercially available grape seed and red wine extracts, on bacteria that stick to teeth and gums and cause dental plaque, cavities and periodontal disease.

Working with cells that model gum tissue, they found that the two wine polyphenols in isolation — caffeic and p-coumaric acids — were generally better than the total wine extracts at cutting back on the bacteria’s ability to stick to the cells. When combined with the Streptococcus dentisani, which is believed to be an oral probiotic, the polyphenols were even better at fending off the pathogenic bacteria. The researchers also showed that metabolites that formed when digestion of the polyphenols begin in the mouth might be responsible for some of these effects.

Learn more about this study in the Journal of Agricultural and Food Chemistry (2018); doi: 10.1021/acs.jafc.7b05466.
Evolution of Endodontic Treatment

Leif K. Bakland, DDS

Current evolving aspects of endodontic treatment are connected to many historical efforts to save and preserve teeth. An oft-quoted recommendation in Miguel de Cervantes’ novel, Don Quixote, is still good advice 400 years later: “Because I’ll have you know, Sancho, that a mouth without teeth is like a mill without its stone, and you must value a tooth more than a diamond.”

To appreciate the treatment advances that have been and continue to be made in patients with endodontic problems, one may look at the evolving understanding of the etiology and diagnosis of pulpal and periapical disease. That understanding has led to improvements in treatment outcomes making endodontic treatment a quite predictable treatment modality.

This issue of the Journal contains reports on current advances in endodontic treatment procedures in four areas: Management of bacterial contamination in the root canal system; improvement in visualization of the tooth-bone complex through cone beam computed tomography; replacement of necrotic pulpal tissue in developing immature teeth; and enhanced understanding of the balance between endodontics and dental implants in a patient-centered environment.

Root Canal Disinfection

The pulp spaces in human teeth are complex. That notion is not new — a century ago Hess examined 2,800 extracted teeth and described the anatomy of the root canal system; his images show pulp spaces with numerous variations in shapes and sizes. In recent years, the advent of microcomputed tomography (microCT) has allowed an even more detailed examination of the complexity of the root canal system (Figure 1). From such micro-CT images one can only wonder how root canal treatment can be done and how such treatment can succeed.

From the beginning of human history and through subsequent millennia until the last couple of centuries, dental pulp infections from caries and trauma have been major medical problems. Bacteria are for the most part prevented from penetrating through the skin and mucous membranes into underlying tissues. But when they gain access to the dental pulp, they can grow in a protected environment not accessible to the body’s defense system and stimulate inflammatory reaction in tissues surrounding the tooth and even invade these tissues and the bloodstream. The result can be disastrous (Figure 2).
Until modern times, the most common treatment for infected, painful teeth was usually extraction, often a crude and painful procedure. There were, however, according to Ingle et al., some innovative approaches to treatment based on the notion that “tooth worms” were responsible for the dental problems — an idea that first seemed to have originated in China perhaps as long as two millennia ago. The Chinese then started applying arsenicals to carious lesions, a procedure that much later was also adopted in Europe and subsequently in the U.S.

A more invasive approach was reported by Zias and Numeroff. They discovered, in a mass grave in the Negev Desert, a skeleton from 200 BCE with a maxillary lateral incisor that had a 2.5 mm bronze wire inserted in the root canal. Radiographically, the tooth apex was associated with a large bony lesion, likely of endodontic origin, and the wire was inserted in a way suggesting some learned skills on the part of the person performing this ancient root canal treatment.

More recent efforts to address pulpal disease probably began about 250 years ago when the father of modern dentistry, Pierre Fauchard, recommended removal of diseased pulp tissue, a procedure that sometimes was accomplished by cauterization with red-hot wires. It is not known when the first root canal filling was placed, but McQuillen reported seeing a patient who had a root-filled tooth that likely was treated in the early part of the 1800s. The root canal filling material apparently was gold foil. Later in the 19th century, further progress in endodontics saw the introduction of the rubber dam for dental procedures, root canal instruments, intracanal antiseptics, gutta-percha and local anesthesia.

By the end of the 19th century, the technical aspects of cleaning, preparing and filling root canal spaces were aided by the innovations described. Of equal importance was the growing understanding of the biological basis for root canal treatment. Contributing to this understanding was the work done by Willoughby D. Miller, MD, DDS, who had studied microbiology under Dr. Robert Koch (of Koch’s postulate fame) in Berlin. Dr. Miller laid the foundation for modern endodontics with the publication of his classic 1890 textbook Microorganisms of the Human Mouth. Thus, the technical and the biological concepts were coming together to help form a sound basis for saving teeth through root canal therapy.

Recognizing that bacteria play an important role in many diseases, including dental disease, researchers began to speculate that bacteria had a special selective affinity for certain tissues and organs. That concept became the basis for the focal infection theory, which led to physicians blaming dental diseases for such diverse conditions as rheumatism, appendicitis and ulcers. Contributing to this concept was a seminal event in the history of dentistry that took place in 1910 when a physician...
from the United Kingdom, Dr. William Hunter, gave a stirring speech at McGill's University in Montreal entitled “The role of sepsis and antisepsis in medicine.” Dr. Hunter had observed in the U.K. a dismal state of dental health in the population at large — patients with rampant caries and periodontal disease, a condition he called “oral sepsis.” What made it worse was that in many cases patients had gold crowns and bridges sitting on top of rotting teeth. Incidentally, in Europe this type of dentistry — that is gold crowns and bridges — was often called “American dentistry.”

Dr. Hunter’s speech contributed to the notion that foci of infection could disseminate bacteria to tissues and organs all over the body. It apparently made sense in the medical community, thus leading to what Dr. Louis I. Grossman later described as a national furor that resulted in people running to their physicians to inquire whether illnesses they had were the result of bad teeth and then to their dentists to have the teeth taken out. Dr. Grossman summarized the problem by observing: “The focal infection theory that created dissensions among dentists, and between dentists and physicians, was destined to die a slow, reluctant death, but leaving many people edentulous.”

Dr. Grossman, who was able to demonstrate that endodontic treatment was safe and valid, who were also the first to use radiography for root canal therapy was Dr. C. Edmund Kells in New Orleans in 1899. The obvious benefits included the ability to visualize the canals and to monitor treatment outcomes.

Advances in radiographic equipment and X-ray films proceeded over the following decades with the next major progress being the development of digital radiography. Again, endodontic treatment benefitted from this technical advance with the ability to get instant imaging of a tooth and convenient enhancement of the image quality.

The latest development in dental imaging is the application of cone beam computed tomography (CBCT). Endodontists were quick to recognize the benefits of three-dimensional imaging and have adopted its use extensively. The increasing role of CBCT in endodontic treatment is explored by author Robert S. Roda, DDS, MS, in this issue.
Treatment Options for Diseased Pulps

The specialty of endodontics is involved with the physiology and pathology of the dental pulp. Historically that meant recognizing pulps that were diseased and needed to be removed and replaced with a filling material such as silver points or gutta-percha. Preserving pulp tissue, however, was promoted by some dentists; the first to recommend that idea was probably Dr. B.W. Hermann nearly a century ago when he published his report on the use of calcium hydroxide (CH). Dr. Grossman paid tribute to Dr. Hermann by pointing out that his purpose for suggesting CH as a medicament was “not to destroy but to heal the pulp.”

In subsequent decades, CH became a much relied-upon medicament for treatment of the pulp. For the most part, however, treatment with CH was confined to immature, developing teeth with traumatic crown fractures; the procedure became known as a Cvek-type pulpotomy. It was rarely used in teeth with carious pulp exposures. The expected response to exposing pulp tissue to CH was development of a hard tissue barrier (dentin bridge) to protect the underlying pulp tissue. One of the problems with the use of CH in these cases is that CH gradually neutralizes and loses its ability to kill bacteria. If microleakage of the coronal restorations occurs, bacteria may then penetrate through the CH-generated dentin bridge through which they can cause pulpal disease.

A new era in pulp treatment began when the first bioceramic material, mineral trioxide aggregate (MTA), was shown to be useful for pulp capping in traumatically exposed teeth. It was subsequently shown that it could also be successfully used in teeth with carious pulp exposures (FIGURES 6). Further, a recent study showed MTA to be more predictable than CH in treatment of teeth with carious exposures. Preserving vital pulps has now become an important component of general dentistry as well as pediatric dentistry and endodontics.

A new era of pulp therapy arrived with the clinical report published in 2001 by Iwaya et al. They demonstrated that teeth with dens evaginatus could be treated in a way that would preserve uninfected pulp tissue in the root canal and permit continued root formation. Dens evaginatus is an anomaly of odontogenesis in which a central cusp develops on the occlusal surface of a tooth, and during eruption, when contact is made with the opposing tooth, the cusp can fracture and expose the underlying pulp providing a pathway for bacteria to enter. In the case presented by Iwaya et al., the bacteria had stimulated a periapical response resulting in an apical abscess. The authors decided to attempt to preserve as much pulp tissue as possible and limited the treatment to removal of infected tissue and allowing a blood clot to form in the space where the infected pulp tissue had been removed. They sealed the occlusal access and monitored the outcome, which was continued root formation along with healing of the apical abscess.

The Iwaya report generated an immense interest among endodontists. Could diseased pulp tissue be replaced with new pulp tissue — pulp regeneration? While that question stimulated case reports, professional lectures and research projects, it is reasonable to conclude that at this time “pulp regeneration” is not clinically feasible. But techniques for managing teeth in young patients to allow continued root development continue to be developed. Author Paul V. Abbott, BDS, MDS, discusses the topic in this issue.

Endodontics and Dental Implants

Dental implants have a long history. The ancient Mayans apparently successfully placed dental implants. In 1913, Dr. E.J. Greenfield from Kansas presented a lecture on the “…implantation of artificial roots…” made from iridio-platinum to which crowns could be attached. But it was not until the 1970s that root-formed implants, as developed by Per-Ingvar Brånemark in Sweden, again appeared. During the preceding years, other types of implants, such as the blade and the subperiosteal implants, had gained prominence.
Endodontists became interested in endodontic endosseous implants when Orlay suggested their use in splinting endodontic endosseous implants when indicated, endodontists also began placing them. In this issue, authors Tory Silvestrin, DDS, MSD, and Charles J. Goodacre, DDS, MSD, report on the coexistence of endodontics and implant dentistry.

Root canal therapy has evolved over the past two centuries to where treatment outcomes are highly favorable.

In this issue, we describe evolving aspects of endodontic treatment that may further promote efforts to preserve natural dentition.

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**OSHA Review**

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Can We Eliminate Microorganisms From the Root Canal System?
Markus Haapasalo, DDS, PhD

ABSTRACT Bacteria in the root canal system are the causative factor of apical periodontitis (AP). Therefore, removing and killing these bacteria is the goal of endodontic treatment of AP. So far, none of the materials, methods and strategies employed has allowed elimination of all microbes in the root canal system. Emerging materials and equipment are moving us closer to predictable elimination of all root canal microbes.

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Conflict of Interest Disclosure: Dr. Haapasalo has commercial interest in two products named in the article: QMiX (Dentsply Tulsa Dental) and GentleWave (Sonendo).

Microbial invasion through the protective layers of the tooth, enamel, root surface cement and dentin into the pulp is the most common cause of pulpal and periapical inflammation and infection. Other pathways for the microbes include leaking fillings, exposed dentin, trauma, cracks, lateral canals and even invaginations and evaginations (FIGURE 1). Pulp inflammation starts before the invading bacteria enter the pulp from penetration of bacterial antigens released from the carious lesion through the dentinal tubules toward the pulp (FIGURE 2). These antigens are recognized by the defense system of the pulp, first by antigen presenting dendritic cells, followed by a wider participation of the immune system and inflammatory apparatus.1-3 Infection starts when bacterial cells enter the pulp. If left untreated, caries and bacterial invasion thus lead to pulp inflammation, infection and eventually necrosis and apical periodontitis (FIGURE 3).

When the pulp has become necrotic, there are no defense mechanisms left in the root canal. The newcomers, microbes, quickly develop biofilm ecosystems throughout the root canal system, attached to the root canal wall and to the necrotized pulp tissue (FIGURE 4). Periapical inflammation starts when antigens start spreading through the apical foramina into the periapical tissue (FIGURES 5A and 5B), similar to what happened when bacteria in carious dentin sent antigens (e.g., bacterial surface structures) toward the pulp.4 There is strong consensus based on classical studies that apical periodontitis is caused by microbes in the necrotic root canal, not by necrotic tissue per se (FIGURE 6).5,6 The pathogenesis of pulpitis and apical periodontitis differ, however, in one very important aspect: The pulp has no collateral circulation and is therefore vulnerable to irreversible inflammation and necrosis to occur. The periapical area is different; collateral circulation secures continuing presence...
of apical periodontitis the root canal is occupied dominantly by strictly anaerobic bacteria (FIGURE 8). Typically, a few to several dozen different species are found, and combining different cases together, several hundred different microbial species of which >99 percent are bacteria can be found in infected, necrotic root canals of teeth with apical periodontitis. The flora of root canals that have become reinfected has shifted to a more facultative microbiota (“semi-aerobic,” facultative bacteria tolerate both lack and presence of oxygen) instead of the strong anaerobic dominance typical of primary infections.

Treatment Strategy Part I

From a clinical point of view, should the composition of the flora be reflected in the treatment strategy? Since the 1960s and even before, there have been numerous reports of the different virulence potential of various bacteria found in necrotic root canals, and frequently, new studies suggest that certain species can be regarded as “important pathogens.” There is probably much unnecessary confusion of the host defense system, with a variety of different defense cell populations and active angiogenesis (FIGURE 7), which in most cases successfully fights the invading bacteria and prevents them from establishing biofilm communities outside the root canal system. Therefore, the goal of root canal treatment is to eliminate the microbes from the root canal system, ending the continuous feeding of antigens into the periapical area. Following this, normal wound healing mechanisms will usually take over and the periapical soft tissue inflammatory lesion is gradually replaced again by healthy bone tissue.

The key questions are: How predictably and with what methods can we eliminate the microbes from the root canal system? If not all microbes can be eradicated, is there some threshold limit or other specific conditions under which complete healing can be obtained? Is prevention of reinfection of the root canal system different from prevention of the primary infection?

In this review, the nature of root canal infection is discussed, together with existing and potential future strategies to maximally reduce or even completely eliminate microbes from the root canal system. Extraradicular infections, where biofilms have established their presence on root surface or in the periapical lesion requiring endodontic surgery for successful completion of the treatment, will not be discussed in this review.

Infection Part I

Before the development of anaerobic culturing techniques for bacteria in the late 1960s and 1970s, many necrotic teeth with apical periodontitis were thought to be sterile. Developments in anaerobic microbiology eventually led to the current understanding that every tooth with necrotic pulp and periapical lesion has microbes (mostly bacteria) in the root canal space and that in most cases of apical periodontitis the root canal is occupied dominantly by strictly anaerobic bacteria (FIGURE 8). Typically, a few to several dozen different species are found, and combining different cases together, several hundred different microbial species of which >99 percent are bacteria can be found in infected, necrotic root canals of teeth with apical periodontitis. The flora of root canals that have become reinfected has shifted to a more facultative microbiota (“semi-aerobic,” facultative bacteria tolerate both lack and presence of oxygen) instead of the strong anaerobic dominance typical of primary infections.
related to pathogenicity and virulence. Pathogenicity is the ability to cause a disease while virulence is related to the severity of the infection. Virulent bacteria cause more serious, symptomatic, even spreading infections. Less virulent bacteria more often cause symptom-free local infections. Bacteria with both low and high virulence are pathogenic, but they can all cause periapical inflammation.

Critical analysis of studies on endodontic microbiology shows that whenever bacteria survive the ecological conditions of the root canal, a periapical lesion will develop. In other words, development of the lesion (pathogenesis) is not dependent on the presence of certain specific, more pathogenic or virulent microbial species. Rather, the lesion develops as a response to any microbiota established in the canal space. It seems therefore that the endodontic infection (and the “pathogenic” lesion) differs from some other common host-parasite interactions in the oral cavity: Tooth surface plaque may or may not cause disease (caries) on the enamel and gingival crevice plaque may or may not cause gingivitis. Microbiota in the necrotic root canal, however, will always cause apical periodontitis. Therefore, the target in endodontic treatment is the elimination of any microbes in the root canal system, with no specific focus on certain microbial groups or species.

**FIGURES 5.** Schematic illustration of bacteria in the apical canal of a necrotic tooth facing a zone of defense cells (5A). Interaction between the root canal microbes and host defense cells initiates a variety of immunological chain reactions (5B). One result of this is activation of osteoclast cells, which remove the bone around the apical foramen.

**FIGURE 6.** Classical studies have shown that sterile necrosis (tooth with necrotic pulp but with no bacteria) does not create a periapical lesion (left). Only when the necrotic canal contains microbes will a lesion will appear.

**FIGURE 7.** Histological specimen from a periapical lesion shows a small arteriole and great numbers of defense cells.

**FIGURE 8.** A cultured sample from the tooth in Figure 3 shows a mixed flora of mostly anaerobic bacteria, including at least two different “black pigmented” species.

**FIGURE 9.** An SEM image of the surface of a multispecies oral biofilm. Many different types of bacteria can be seen. However, extracellular polymeric substance (EP) between cells is not visible in a conventional SEM image.

**FIGURE 10.** A special FIB-SEM image of a biofilm shows structures not seen in a conventional SEM image: blue arrows: EPS between cells; yellow arrows — microscopic water channels; green arrows — debris (waste) on biofilm surface.
Infection Part II: Biofilm

Bacteria in nature and in infections exist either as planktonic, i.e., individual, single cells floating in a liquid medium, or as biofilms, which are complex ecological structures usually attached to solid surfaces. It has been estimated that approximately 80 percent of human infections are biofilm infections. Most oral infections are also biofilm infections: caries, gingivitis, periodontitis, implantitis and apical periodontitis. The two states, planktonic and biofilm, have great and clinically important differences: Planktonic bacteria are sensitive to common antimicrobial substances, whereas biofilm bacteria are much more resistant. In other words, in endodontics the dentist is treating a resistant biofilm infection.

The key characteristics of a biofilm are as follows: The biofilm is attached (often firmly) to a solid surface, the cells inside biofilm are surrounded by a gel consisting of different organic molecules and extracellular polymeric substance, and the metabolic activity of the microbial cells in the biofilm is low and some may even be in a dormant state (viable but nonculturatable). Figures 9 and 10 were taken with a regular scanning electron microscope (SEM) and a specialized focused ion beam SEM technique shows some key structural features of a multispecies bacterial biofilm.

Anatomy, Advantages and Disadvantages

The root canal system in a tooth is where the effort to eliminate endodontic biofilms takes place. This environment is a very special area of the human body, which can be both good and bad. The big advantage from the treatment point of view is that the root canal offers a space surrounded by hard, mainly inorganic walls of dentin. This allows use of harsh, even caustic disinfecting solutions such as concentrated sodium hypochlorite (NaOCl). Although the root canal system is not completely isolated from the surrounding soft tissues and bone, the limited connections via small apical foramina usually allow solutions to be kept inside the tooth; only rarely do large volumes of liquid escape to the exterior. However, even though the chance of an NaOCl accident is small, the mere possibility may result in excessive caution for fear of the dramatic, negative consequences of an NaOCl extrusion accident. Disadvantages of the root canal anatomy include the frequent presence of narrow, deep fins, tiny anastomoses and connecting isthmuses, which cannot be reached with instruments and are also difficult to access by conventional irrigation (Figures 11–13). Further, the microanatomy of dentin, the 1–2.5 μm wide dentinal tubules (Figure 14), allows bacterial penetration deep into dentin (Figure 15) and renders them beyond the reach of endodontic instruments.
Treatment Strategy Part II: Sterilization vs. Disinfection

Effective sterilization methods include the use of autoclave or dry heat at more than 100 degrees Celsius or high-energy gamma radiation. These methods are not suitable for infected root canals. Therefore, sterilization is not a correct word to describe the methods of reducing and eliminating microbes from infected root canal spaces. Instead, disinfection and antisepsis better describe what is done in endodontics. Antiseptis means destruction or prevention of proliferation of (pathogenic) microorganisms in order to prevent infection: the state of being free from living pathogenic organisms. Antiseptic compounds (such as iodine) are designed to be used in direct contact with living tissue, therefore their toxicity level is low.25,26 Disinfecting agents, such as NaOCl, are antimicrobial agents that are applied to the surface of nonliving objects to destroy microorganisms that are present.25-27 Disinfectants work by destroying the cell wall of microbes or interfering with the metabolism, but they will not necessarily kill all microorganisms. By definition, disinfecting solutions are not used in contact with living tissue, usually meaning “inside the human body.” As mentioned earlier, the mainly inorganic dentin walls create a special exception to the rule by effectively limiting the spreading of the solutions to living tissue where cells, vital connective tissue, nerves and the circulatory system are present. Bacterial spores are often resistant to disinfectants, but the challenge in endodontics to obtain a completely bacteria-free canal is not primarily related to the presence of bacterial endospores in the root canal. It is more a matter of the microanatomical conditions in the root canal system, the chemical nature of the tooth structures (in activation of disinfecting agents)28,29 and to some extent the necessary caution in the endodontic procedures to avoid disinfection complications.

FIGURE 16. Smear layer on the wall of the main root canal after instrumentation. Several bacteria can be seen embedded in the layer.

FIGURE 17. Dentin debris packed by rotary files into the isthmus area between two canals in the same root. Even after 20 minutes of syringe-needle irrigation the debris had not been removed.

Treatment Strategy Part III: Elimination of Root Canal Bacteria

Microorganisms, mostly bacteria, are killed or removed from the contaminated root canal system by a combination of methods and approaches. These include mechanical removal of necrotic and infected pulp tissue along with some of the root canal wall dentin by hand and rotary instruments and the washing action by irrigation solutions. Other methods are chemical dissolution and flushing of intradental soft tissues and dentin, removal of soft tissue and biofilms by NaOCl and ultrasonic and other sound energies, chemical killing of microbes by disinfecting solutions and interappointment medication such as calcium hydroxide, killing by direct antimicrobial effect from some sealers and killing by long-term blocking of nutrients by a high-quality root filling and proper restoration of the tooth.20,24

Mechanical Instrumentation

Instrumentation by hand and rotary instruments impacts the root canal bacteria/biofilms mainly in two ways. Firstly, infected pulp tissue and dentin is removed and secondly, space is created for effective irrigation. Together with antibacterial root canal fillings, it is expected that most of the microbes will be eliminated. It is recognized that mechanical instrumentation cannot remove all microbes from the root canals.30,31 The classic studies in Sweden in the 1970s showed that while the number of bacteria in the canal was reduced even a thousandfold, sterility (complete elimination of bacteria) was not achieved even after five appointments of mechanical instrumentation and irrigation with saline.30,31 Newer studies have confirmed these findings.32,33 While these more recent studies confirmed earlier findings, they did show that increasing the size of apical preparation would further reduce the number of bacteria or colony forming units of bacteria on culture plate counts.

Many of the above studies have indicated that some of the canals can be rendered bacteria free by instrumentation. However, it is generally understood that the negative cultures reflect more the lack of sensitivity of the sampling and culturing methods rather than true, complete absence of bacteria.34 It should be emphasized that sampling is usually done in areas of the main canal where instrumentation and irrigation have the strongest effect. New studies where dentin of the whole tooth has been crushed into powder and sensitive molecular biological methods have been used, much more bacteria are found than with traditional paper point and culturing methods.35,36

Irrigation With Antimicrobial and Other Solutions

Irrigation of the root canals can reach areas that instruments cannot.21,27 The “flexibility” of liquids allows them, in theory, to penetrate into all areas in the canal system, many of which had not been touched by metallic files. Also, in the instrumented areas, the files have created a smear layer (FIGURE 16) and debris (FIGURE 17) that
contains not only dentin but remnants of pulp tissue and bacteria and their antigens in all cases where the canal has been infected. Irritants with specific properties can remove the smear layer and its contaminating microbial material. NaOCl followed by ethylene diaminetetraacetic acid (EDTA) will predictably and usually quite easily remove the smear layer; NaOCl removes the organic portion and EDTA the inorganic portion of the smear layer.\(^3\),\(^4\) Although not conclusively shown by studies, it is likely that if any part of the root canal system is bacteria free after chemomechanical preparation, it would be the main root canal. However, the few studies that have focused on removal of dentin debris from fins, isthmuses, lateral canals and apical foramina have shown that the available methods for cleaning canals and apical foramina have shown the inorganic portion of dentin biofilm (bacterial biofilm in dentin). Biofilm grown from a mixture of bacteria (FIGURE 18). In a recent study of dentin biofilm (bacterial biofilm in dentinal tubules), 6% NaOCl used for 30 minutes and refreshed every 5 minutes killed only >70 percent of the microbes in dentin. Importantly, there was very little additional killing after 10 minutes of exposure, despite refreshed NaOCl.\(^9\) Other studies have suggested that long-term NaOCl irrigation weakens dentin structure,\(^4\) therefore it is quite clear that long exposure to high-concentration NaOCl will not be the ultimate answer to obtain bacteria-free root canals.

However, there are indications that 5–6% NaOCl can detach biofilms from the dentin surface, which can then be more easily flushed out of the canal by the continuing irrigation. Biofilm detachment by conventional syringe-needle NaOCl irrigation works only in the main root canal, not in dentinal tubules. Whether it can detach biofilms in isthmus areas or lateral canals is not currently known.

Chlorhexidine (CHX) kills planktonic and biofilm bacteria, but its effectiveness is at best the same as that of NaOCl and in many instances CHX is weaker.\(^7\) CHX does not dissolve tissue and has not been shown to be able to detach biofilms attached to the dentin surface. With respect to the ability of EDTA to kill microbes, most evidence shows it has little if any antimicrobial activity.\(^2\),\(^7\) The role of EDTA is important as it helps to remove the smear layer and at least some of the dentin debris with all the microbes contained in it. EDTA or citric acid combination products intend to combine smear layer removal with antimicrobial activity.\(^2\),\(^7\) So far, the highest documented antimicrobial effect has been demonstrated with QMIX (Dentsply Tulsa Dental, Tulsa, Okla.), which killed about 65 percent of dentinal tubule bacteria in three minutes, same as 6% NaOCl (FIGURE 19).\(^4\),\(^1\)

**Negative Pressure and Agitation of Irrigants**

Several methods of agitation of the irrigating solutions in the root canals have been developed.\(^2\) It is likely that such emphasis to improve irrigation will have a positive effect. However, so far none of the methods have been shown to completely and predictably eliminate microbes from root canals. One of the newer methods includes the use of negative pressure irrigation (EndoVac, Kerr Dental, Orange, Calif.), which allows more effective irrigation of the apical canal space than traditional positive pressure syringe-needle irrigation.\(^4\) In negative pressure irrigation, there is no risk of irrigant extrusion to the periapical area, which
makes it possible to maximize the chemical cleaning and killing of microbes in this key location of the canal. Comparative studies have shown improvement by EndoVac over positive pressure irrigation in reducing bacteria but complete absence of the microbes remains a challenge.

EndoActivator (Dentsply Tulsa Dental) uses sonic vibration to facilitate irrigation. Again, while any valid method to improve cleaning is commendable, complete disinfection cannot be accomplished with sonic activation of irrigation solutions. Ultrasound uses higher frequency vibration than sonic activation, usually in the range of 20,000–35,000 Hz. Ultrasound used with an irrigant in the canals and pulp chamber works in two ways, cavitation and acoustic streaming. In cavitation, high-energy vacuum bubbles are formed, which in theory have the ability to release a concentrated energy burst at their target and cause a breakdown such as cell death. The difficulty in endodontic cavitation so far has been that the vacuum bubbles have been estimated to last only for a few micrometers from the surface of the oscillating file. Acoustic streaming extends further in the canal system but many studies with equipment using so-called passive ultrasonic irrigation (PUI) show limited effect on bacterial reduction as compared to syringe-needle irrigation. ProUltra PiezoFlow (Dentsply Tulsa Dental) ultrasonic irrigation is active/continuous ultrasonic irrigation because in addition to the ultrasonic energy there is a simultaneous flow of irrigant through the needle into the root canal (FIGURE 20). Detailed studies on reduction of intracanal bacteria are too few to draw conclusions. EndoUltra (Vista Dental, Racine, Wis.) is another new high-energy ultrasonic device with an optionally attached prefilled irrigant canister (FIGURE 21).

Recently, a new type of endodontic cleaning device was introduced. The instrument (FIGURE 22) GentleWave (GW, Sonendo, Laguna Hills, Calif.) uses a wide spectrum of sound waves, including ultrasonic frequencies. The GW action is based on three main mechanisms. First, high flow velocity (45 mL/min) of NaOCl hits an end plate of a nozzle in a treatment instrument, just above the pulp chamber floor. The liquid then spreads all around the pulp chamber and the root canal system.48 Second, the liquids (NaOCl, EDTA and water) are all degassed to remove micro air, which is known to reduce or eliminate the effects of cavitation. Third, GW irrigant flow happens under slight negative pressure in the canals, eliminating the risk of irrigant extrusion.48 A study on tissue dissolution by GW, ultrasound and conventional syringe-needle irrigation indicated that cavitation may in fact be contributing to the much faster (8 x) tissue dissolution by GW as compared to all other systems.48
Other studies have shown the ability of GW to clean the main canal, isthmuses and lateral canals from pulp tissue remnants or from calcium hydroxide to allow high-quality root filling.\textsuperscript{49,50} The latter, complete calcium hydroxide removal, was only accomplished by GW but not by PUI or syringe-needle irrigation.\textsuperscript{50} A recent in vitro study comparing the effectiveness of GW and continuous ultrasonic irrigation to reduce bacterial numbers in contaminated root canals showed that GW predictably produced the highest level of cleanliness (FIGURES 23 and 24).\textsuperscript{51} A 12-month follow-up study after GW cleaning reported approximately 96 percent healing rate, thus clinically supporting the results of superior effectiveness in the in vitro studies.\textsuperscript{52}

Interappointment Medicaments

In multiappointment treatment, the root canals are usually filled with a medicament with antimicrobial activity. Calcium hydroxide, CHX and iodine potassium iodide (IPI) or combinations of these are the most commonly used.\textsuperscript{20,34,53} The many studies of the efficacy of such medicaments have clearly shown that they fail to predictably remove or kill all microbes from infected root canals.\textsuperscript{34} Studies comparing the reduction of bacteria after one and two appointment treatments have shown varying results.\textsuperscript{54}

Root Filling, Sealers

Root canal sealers have been known to have antibacterial effects, depending on the type of sealer.\textsuperscript{55} Direct in vitro contact experiments showed variable killing of planktonic bacteria by sealers, but the effect usually faded away after a few hours or days. As seen previously with irrigation solutions, tests with planktonic bacteria have limited value in predicting the efficacy of the compound against biofilms. New studies using confocal microscopy and viability staining have indicated killing of 30–50 percent of bacteria in dentinal tubules by sealers after 30 days of incubation. This is an important contribution in the elimination of residual microbes.\textsuperscript{56} Follow-up studies using 5% NaOCl and AH+ sealer (Dentsply Tulsa Dental) or bioceramic sealers reported up to 80 percent killing of biofilm bacteria in root canals.\textsuperscript{57}

Other Emerging Strategies

Nanoparticles made of a wide variety of materials are particles with a size between 1 and 100 nm. Many materials in the size of nanoparticles can have properties that are quite different from their usual characteristics. The appearance of the “new,” different properties may happen when the relative surface area of the material (due to small particle size) becomes much higher than the volume of the material. In medicine and in endodontics, antibacterial properties of nanomaterials are of particular interest. Nanoparticles could be part of irrigating solutions and intracanal medicaments and sealers.\textsuperscript{58} Research in use of nanoparticles in endodontics is likely to grow strongly in the next few years. Currently, the use of nanoparticles in root canal treatment is experimental. Another relatively new group of antibacterial materials is antimicrobial peptides (AMPs). Recent publications on oral biofilms and antimicrobial peptides have shown antibiofilm effect stronger than reported for 2% chlorhexidine and even 6% NaOCl. A study where AMP was used alone or mixed with EDTA showed 80–90 percent killing of oral biofilm bacteria in just minutes.\textsuperscript{59} It is possible that in the near future combination products will be available where nanoparticles and/or antimicrobial peptides are combined with conventional endodontic materials to boost their antimicrobial effect.\textsuperscript{60}

Conclusions

None of the materials, equipment and strategies currently available for endodontics can predictably create a completely microbe-free root canal. Although 100 percent sterility is not required for complete healing of apical periodontitis, a high level of bacterial reduction is desirable. While this can often be achieved with currently available methods and materials, implementation of emerging new technology seems necessary in order to predictably obtain the highest level of cleaning and disinfection and thereby healing. 

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Can Use of Cone Beam Computed Tomography Have an Effect on Endodontic Treatment?

Robert S. Roda, DDS, MS

ABSTRACT Cone beam computed tomography (CBCT) has revolutionized endodontic diagnosis and treatment planning over the past decade. It allows the clinician to detect dental anatomy and disease states with much greater accuracy than regular two-dimensional radiography and is recommended as the imaging modality of choice for use in most aspects of endodontics. This paper reviews the most updated guidelines for use of CBCT to illustrate the effects this has on clinical endodontic practice.

Over the 122 years since Professor Otto Walkhoff exposed the first dental radiograph, radiography has become an integral part of all aspects of dentistry, including endodontics. Recently, cone beam computed tomography (CBCT) has been added to the armamentarium for endodontic therapy. As with any new technology, there has been a rapid growth in knowledge along with changes in implementation strategies that require clinicians to continually review all aspects of this new three-dimensional radiography.

Three-dimensional radiographic imaging began to be widely used in the 1980s in medicine, and ongoing developments in imaging have revolutionized the process of medical diagnosis. Progress in adapting medical CT imaging to dentistry was somewhat slow with initial uses being mainly restricted to imaging craniofacial abnormalities and to aid in planning very complex oral and maxillofacial surgeries. This limited use of conventional CT in dentistry was due to the relatively high X-ray dosages of medical CT scanners and the high cost of imaging. The advent of cone beam CT in the late 1980s resulted in dramatically lower radiation exposure to patients, higher spatial resolution and lower costs. The technology soon became widely used in diagnostic imaging for dental implant placement and complex oral surgery procedures. It was the recent development of restricted or small field of view (FOV) CBCT that brought it to the fore in endodontics. The much higher resolution of these smaller-imaged volumes allows detection of many of
the fine details in tooth structures and surrounding tissues and that information can have an impact on clinical decision-making. The impact of CBCT in endodontics is reflected in the scientific literature. Each year for the last decade, there have been an increasing number of articles published regarding CBCT. A quick search of scientific articles and case reports in the Journal of Endodontics revealed that in 2006 only three articles mentioned CBCT. In 2011, that number had risen to 39; in 2016, there were 64 articles. The interest in this topic is clearly increasing.

What Is Cone Beam Computed Tomography?

Traditional 2-D radiography produces a flat image on a film or sensor that is made up of the shadows of all of the structures between the X-ray source and the detector (film or digital sensor). These structures appear as overlapped and, while the image resolution is excellent, the geometries are distorted and true sizes of biological structures are not discernable. Superimposed anatomic structures impede visualization of subjacent structures and disease-related changes. In dentistry, this renders diagnosis difficult especially in the maxillary posterior region. By making multiple 2-D images from differing incident beam angles, three-dimensionality can be inferred but the distortions of the image still make definitive diagnosis difficult and sometimes impossible.

Three-dimensional radiography was developed to overcome these disadvantages. Hounsfield introduced computed tomography in the 1970s and the technology has been advancing ever since. Conventional medical CT scanners produce a fan-shaped beam that rotates around the patient multiple times in a helical or spiral motion to create image slices that are stacked one upon the other. This process is time-consuming and results in a large radiation exposure to the patient and artifacts induced by patient movement. CBCT reduces the time of acquisition of the image and reduces exposure of the patient to X-rays by using a cone-shaped beam that rotates between 180 and 360 degrees around the patient with the beam hitting a detector on the opposite side of the patient’s head similar to panoramic radiography. A third type of 3-D radiography is the micro-CT (μCT). It produces 3-D images of exceedingly fine detail and clarity, and it is widely used in endodontic research but is not adaptable to the clinical setting.4

The imaged area is called a volume that is made up of voxels. Voxels are isotropic units (cubes) that make up the image. Generally, the smaller the voxel, the higher the spatial resolution of the imaged volume.4 Commonly used voxel sizes in endodontics range from 0.076 to 0.6 mm. Because a computer in the scanner processes the data, the limitations on resolution imposed by larger voxel sizes can often be overcome with sophisticated algorithms.

Other parameters that affect image quality include the peak kilovoltage (kVp), milliampere seconds (mA-s) and FOV that is imaged. Of these, the FOV is of critical importance. Generally, the smaller the FOV, the better the resolution of the images produced, which, in endodontics, allows for more accurate diagnosis and treatment planning decisions because many of the factors leading to better outcomes are too small to detect on larger FOV images (FIGURES 1). In addition, smaller FOV volumes expose the patient to less radiation.

Rather than the overlapped shadows in 2-D radiography, CBCT produces a 3-D image that is made up of slices. But unlike medical CT devices, these slices are combined into a volume that can be inspected in many ways. The structures in the imaged area can be seen from any of the three traditional anatomic planes of view (sagittal, coronal and axial).
but also, depending on the rendering software, the structures can be viewed from any angle because the voxels are isotropic. These structures rendered are geometrically accurate and actual sizes of the structures can be measured using tools available in most of the software readers. Therefore, the image is viewed in slices (one layer or sheet of voxels), overlapping of structures does not occur and a true representation of the tissues can be seen, enhancing diagnostic yield. The volume data is required to be provided in the recognized DICOM format so that the volumes can usually be shared and viewed by clinicians using many different software readers, although some manufacturers of CBCTs have yet to make their volumes universally accessible.

Compared to 2-D radiography, the disadvantages of CBCT imaging are few. The resolution of the 3-D image is still not comparable to conventional radiographs. CBCT is prone to the creation of streaking (beam hardening) and volumetric distortion (cupping) artifacts in the presence of very radiodense materials such as dental restorations, surgically implanted metallic materials and root canal obturation materials (FIGURE 2). This limits the usefulness of the technology for assessment of restorative and postendodontic complications such as vertical root fractures or strip perforations.

Also, the incident radiation doses to the patient, while very small, are still higher than with 2-D radiography. Finally, the cost of purchasing and maintenance of CBCT equipment is generally much higher than that for 2-D radiography. The convenience of having a CBCT in the office is high and most medium FOV units can also produce a digital panoramic radiograph thus replacing the traditional panoramic machine. The proliferation of stand-alone imaging centers in dentistry provides an alternative to the purchase and maintenance of CBCT equipment. These centers can usually provide services with various CBCT units with multiple FOVs, frequently at a lower cost to the patient. Because they produce more volumes, imaging centers can negotiate better fees from radiologists for reading the volumes while making access to professional interpretation much easier. Manufacturers are now producing CBCT units with FOVs, higher resolution and artifact reduction software making the decision to purchase a unit or use an imaging center difficult.

FIGURE 2A. 2-D periapical radiograph of tooth No. 9 with a silver point endodontic filling (2A).
3-D CBCT slice from the axial plane showing beam hardening as streaks on the image (2B).
3-D CBCT slice from the sagittal plane showing the beam-hardening artifact as a thick black area lingual to the full length of the silver point (2C).
2-D periapical radiograph of tooth No. 20 (2D).
3-D CBCT slice from the sagittal plane showing apparent enlargement of the post (volumetric or “cupping” artifact) (2E).
AAE/AAOMR Joint Position Statement

Recently, the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) updated their joint position statement on the use of CBCT in endodontics. The updated statement provides guidance on the use of CBCT in various clinical situations where it is applicable. It is not intended to substitute for a clinician’s independent judgment regarding the needs of a patient, but the usefulness of this statement is valuable to clinicians performing endodontic diagnosis and treatment. It states that CBCT should only be used when the needs of imaging cannot be met with lower-dose conventional 2-D radiography, so it is not recommended for routine use on all patients. After a thorough evaluation of the patient including the patient’s medical and dental history and a thorough clinical examination, the clinician will then decide whether the unique situation of that patient requires the use of CBCT imaging to complete the diagnosis. The position paper also states that, for most endodontic applications, small or limited FOV CBCT is preferred although for large or multifocal lesions with possible systemic origin larger FOV imaging can be selected.

The AAE/AAOMR joint position statement further recommends that ALARA principles be followed when selecting an imaging modality. ALARA means choosing an imaging technology that achieves the diagnostic goals while using a radiation dose that is “as low as reasonably achievable.” Selected radiation dosages for some commonly used radiography modalities are provided in the table and show the relative incipient radiation and tissue susceptibilities in units called microsieverts (μSv). Limited FOV CBCT exposes the patient to reduced dosages compared to larger FOVs and so, where practical, compliance with the ALARA principle is best achieved using small FOV. It is particularly important in children (up to and including the age of 18) to reduce any exposure to radiation when the opportunity to use lower-dose imaging modalities is possible.

Finally, the AAE/AAOMR statement recommends that if a clinician has a question regarding image interpretation, an oral and maxillofacial radiologist should read the volume. With small or limited FOV CBCT, the imaged area usually contains tissues with which dentists are familiar, but even in these familiar areas, unusual or unexpected findings should trigger consultation with a radiologist. In a recent study, an oral radiologist detected more incidental findings in more than 200 limited FOV scans than endodontic graduate students could, suggesting that even small FOV scans should be routinely read by a radiologist. With medium or large FOV volumes and image regions that are outside the usual areas of expertise for dentists (such as the base of the skull or anterior spine), prudence suggests that those scans should be read by a radiologist.

Indications

The AAE/AAOMR joint position statement lists recommendations regarding the clinical use of CBCT in endodontics. These recommendations are a list of the possible clinical indications for use of CBCT. While not all of these situations would routinely require use of CBCT, there are situations where the use of 3-D imaging is especially helpful in the diagnosis and treatment planning of endodontically involved teeth. Preoperative 2-D radiographs are an integral part of the initial diagnosis of patients and should be used in all cases, and 3-D CBCT should only be used in those cases where more information is needed to answer any unanswered diagnostic questions.

Difficult Diagnosis

Endodontic disease can present in a variety of ways and it can be difficult to interpret conflicting diagnostic information pointing to a variety of pathological conditions. It may be challenging to determine with conventional diagnostic techniques whether a patient is suffering from endodontic pain, pain of musculoskeletal origin, pain from sinusitis or even neurogenic or atypical facial pain. Even

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Source: Adapted from references 3, 9 and 10
when all non-endodontic etiologies for a patient’s symptoms have been ruled out, it may still be difficult to identify the tooth that may be the origin of the patient’s chief complaint. This is related to the limitations in current clinical testing and intraoral 2-D radiography.

In many of such difficult situations, CBCT can provide information that can lead to a correct diagnosis. The recommendation of the AAE/AAOMR position statement is that limited FOV CBCT should be considered the imaging modality of choice for diagnosis in patients who present with contradictory or nonspecific clinical signs and symptoms associated with untreated or previously endodontically treated teeth. The superior ability of CBCT to provide information that can help identify endodontic disease has been demonstrated in several ex vivo and clinical studies. An example of where CBCT was essential in diagnosing a difficult case is shown in FIGURES 3.

Anatomic Variations

The success of root canal therapy depends on identifying, cleaning and sealing all of the root canal system. Because of the anatomic variations and complexities of the root canal system, 2-D radiography frequently is inadequate in revealing such things as the number and the shapes of canals and roots. The results of leaving untreated spaces in the canal system or not detecting severe curvatures in canals can lead to separated instruments, canal transportation and retention of necrotic tissue/bacteria in the canals. Lack of healing or posttreatment endodontic disease may be the eventual outcome. Use of CBCT can provide a much more accurate and detailed image than 2-D radiography and help avoid these undesirable outcomes (FIGURES 4). Studies have shown a strong correlation between anatomic information obtained from CBCT volumes and anatomic studies using sectioning or histologic methods in anatomic studies of teeth. Improvement in detection of second mesiobuccal canals in maxillary molars has also been shown.
Intraoperative Use

While not as routine, CBCT may occasionally be used intraoperatively. If during endodontic therapy it becomes apparent that not all of the canals have been found and no pretreatment CBCT images are available, the access can be sealed and a CBCT scan exposed to reveal untreated canal spaces. This is especially useful when treating teeth with extensively calcified canals, thus reducing the risk of root perforation.

Absent any questions about treatment outcomes, the posttreatment radiographic image need only be 2-D.5

Tooth Fracture

Cracks in teeth can be difficult to diagnose. Detection of tooth fractures, while complicated, is important because these fractures often affect the tooth’s prognosis. Undiscovered fractures can lead to treatment efforts that are in vain. Two-dimensional radiography rarely will detect a fracture in a tooth because the X-ray beam must be perfectly aligned with the fracture plane to allow it to be seen on the radiograph. CBCT imaging can help in visualizing fractures, but whether the fracture itself can be seen depends on the length and the width of the fracture, the spatial resolution of the volume and the presence of artifacts due to adjacent radiopaque restorative and endodontic materials. Two recent systematic reviews have indicated that direct detection of fracture in endodontically treated teeth is unreliable due to these factors.8,22 CBCT imaging can, however, be helpful in detecting the patterns of bone loss and alterations in the periodontal ligament space that usually accompany a tooth fracture. These changes in the appearance of the periodontium surrounding a cracked root are frequently not visible on a 2-D radiograph but can be more easily detected in the CBCT volume (FIGURES 5). Both laboratory and clinical studies indicate that CBCT imaging can show the presence of root fractures, even if the fracture itself remains difficult to visualize.23–26

Posttreatment Endodontic Disease

Millions of endodontically diseased teeth are treated every year through nonsurgical endodontic therapy. While this treatment modality enjoys a very high rate of clinical success,27,28 there are some cases that will exhibit endodontic posttreatment disease. The AAE/AOMR position paper1 points out that limited FOV CBCT may be the imaging modality of choice when evaluating cases of nonhealing that may need either surgical or nonsurgical re-treatment. The CBCT allows for very detailed analysis of factors that may have led to the posttreatment disease, such as untreated canals, (FIGURES 4) the adequacy of previous instrumentation and obturation, root perforations, periodontal disease, furcation involvements, vertical root fractures and the patterns of bone loss and locations of periapical lesions. By detecting otherwise hidden factors affecting prognosis, better treatment planning choices can be made.

In some instances, CBCT images can identify factors that would indicate that re-treatment (either surgical or nonsurgical) would have a poor prognosis. Lacking such information could lead to re-treatment procedures with high likelihood of failure. This may be avoided by using CBCT to evaluate teeth with posttreatment disease.

When planning for surgical re-treatment, the use of CBCT has many benefits. One will be able to see the spatial relationships between the affected tooth and adjacent anatomical structures such as the maxillary sinus29,30 (FIGURES 6), adjacent tooth root proximity, buccal bone thickness31 and the path of the inferior alveolar nerve32,33 and blood vessels. By accurately locating these structures, surgical complications such as sinus perforation, damage to adjacent teeth, paresthesia/dysesthesia and severe hemorrhage can generally be avoided.
Dental Trauma

The AAE/AAOMR joint position statement recommends that CBCT be the imaging modality of choice in the diagnosis and management of limited dentoalveolar trauma. The 3-D view will aid in the diagnosis of horizontal root fractures, alveolar fractures and luxation injuries. More extensive trauma may also require other imaging modalities.

The clinical value of using CBCT must be weighed against the increased radiation dosage especially in young patients. But in general, the benefits of using CBCT outweigh the risks such as missed fractures both in teeth and bone. Often the need for multiple 2-D images may result in more radiation than that from taking a CBCT image. Adjusting the exposure parameters of the CBCT can also reduce the radiation exposure while not impacting the diagnostic accuracy.

Resorption

Root resorption presents significant challenges in attempts to retain such teeth. The extent of the resorption and its possible effect on the structural integrity of the tooth posttreatment requires careful consideration. CBCT imaging has been found to be more accurate than 2-D radiography in detecting and
FIGURES 7. 2-D periapical and bitewing radiographs showing a small area of resorption on tooth No. 3 (7A). 2-D periapical radiograph from a distal angulation is not very helpful in assessing the prognosis (7B). 3-D CBCT slice from the axial plane showing the extent of the resorption and that it has opened a communication between the pulp space and the periodontium. The prognosis was unfavorable and the patient elected to extract the tooth (7C).

FIGURES 8. 2-D periapical radiograph of tooth No. 6 indicates a radiolucency consistent with external root resorption (arrow) (8A). 2-D periapical radiograph from a distal angulation indicates that it is on the palatal side (since the canal moved most to the mesial) (8B). There was no discontinuity in the structure of the tooth in any view on the CBCT. This axial plane view shows a suspicious notch (arrow) in the bone palatal to the tooth (8C). 3-D CBCT slice from near the sagittal plane indicates that the “lesion” is simply an anatomic variation. It is called the canalis sinuosus (Dr. Bruno Azevedo – OMR, personal communication) and contains the anterior superior alveolar nerve and blood vessels (8D). 3-D rendering showing the palatal view of this variant (arrows). If the CBCT had not been made, this patient would have possibly undergone unnecessary, potentially invasive treatment for a disease that did not exist (8E).
determining the extent of a resorptive lesion in a tooth35-37 (FIGURES 7). Prior to the availability of CBCT, invasive exploratory procedures to determine the extent of lesions were often necessary. Such exploratory procedures — whether surgical or nonsurgical — combined with treatment efforts would sometimes result in a poor prognosis for long-term retention. With the possibility of obtaining detailed preoperative information using CBCT imaging, managing cases of teeth with root resorption has improved.

Another advantage of using CBCT for assessment of suspected resorption is that occasionally the imaging will reveal that what appeared to be resorption is that occasionally the imaging will reveal that what appeared to be resorption is something else (FIGURES 8). In such cases, patients are spared unnecessary treatment and cost.

Treatment Outcomes and Healing Assessment

Treatment outcomes are evaluated following completion of endodontic therapy. This may be to determine improvements or recurrence in patients’ subjective symptoms, clinical findings and radiographic appearances or upon patients’ requests. The radiographic findings that are indicative of healing or nonhealing of endodontic disease have been influenced by two scientifically validated systems to assess two-dimensional radiographs: the Strindberg criteria38 and the periapical index (PAI).39

In light of the superior ability to detect periapical low-density areas and other changes that may indicate endodontic posttreatment disease using CBCT,15 concerns have arisen regarding the validity of previous endodontic outcomes studies.40 Complicating that concern is the lack of a universally accepted system for endodontic outcomes assessment using CBCT.41 While some research has been published addressing this recently,42,43 there is still no consensus. For example, it is common to find that an asymptomatic, endodontically treated tooth may exhibit a low-density periapical area as an incidental finding on a CBCT volume. If this is not visible on a 2-D radiograph and there are no subjective symptoms or clinical findings, it is difficult to tell if such a “lesion” represents disease or simply delayed healing. The ability to find suspected pathosis by using CBCT has exceeded the ability to determine accurately what is occurring in such instances.

The AAE/AAOMR joint position statement2 recommends that absent signs or symptoms, 2-D periapical radiographs are the imaging modality of choice for outcome evaluation following endodontic therapy. If, however, CBCT imaging was used preoperatively, the statement does make the allowance that the same modality may be used postoperatively to assess the outcome. If there are signs and symptoms of posttreatment disease, it refers back to the recommendation to use CBCT for assessment of this. The ambiguity of these recommendations reflects a lack of consensus that may be gained in the future. One can expect research to improve the ability to interpret endodontic outcomes using CBCT technology; for now practitioners with minimal experience should be encouraged to seek advice from oral and maxillofacial radiologists or other specialists with experience in the area.

Effect on Treatment Planning

The most compelling evidence of the importance of CBCT in endodontic diagnosis and treatment planning is found in three recent studies44-46 where clinicians were presented with complete diagnostic information including 2-D radiographs but not CBCT volumes. These subjects completed endodontic treatment plans for the teeth in question and were then presented with the CBCT volumes and asked if this information would change their treatment plans. The plans were changed in 35 to 62 percent of the cases illustrating the influence that CBCT information can have on endodontic treatment planning.

Conclusion

As more research is completed regarding CBCT imaging, specific guidelines and clinical best practices will evolve. In the future, one can expect improvements in 3-D imaging technology to enhance resolution akin to the micro-CT. Regardless of what the future brings in this rapidly growing field, the question now is: Can use of CBCT have an effect on endodontic treatment? The answer to this question, as posed in the title of this article, appears to be an emphatic yes.

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Can We Regrow Pulps?

Paul V. Abbott, BDS, MDS

ABSTRACT  Interest in regrowing pulps is increasing. Case reports and studies have been published but predictable protocols have not been developed. While periapical healing is predictable because of canal disinfection, clinical findings are variable especially regarding root maturation. Histological studies demonstrate connective tissue and blood vessels rather than pulp and dentin-like or cementum-like tissue but not dentin or cementum. Repair procedures can help retain teeth but currently have no advantages over apexification and apical barrier techniques.

In recent years, dentists have become excited by the prospect of regrowing pulps after they have become necrotic and infected. This possible new treatment modality became popular following two case reports in the early 2000s that described management of immature mandibular second premolars with infected root canal systems and chronic apical abscesses where a dens evaginatus fractured and exposed the pulp.1,2 Both cases were managed by disinfecting the root canal system prior to placing a material in the coronal part of the canal without a root canal filling to allow tissue to grow into the remaining canal space. Radiographs showed periapical healing and hard tissue within the canals. In one case,3 root formation appeared to progress normally with a narrow apical foramen after 30 months while the other case2 had considerable narrowing of the canal but not complete narrowing of the apical foramen after 24 months. The premise was that some viable pulp remained in the apical part of the canal and this recovered4 or new tissue grew in from the periapical region with the aid of a blood clot scaffold inside the canal.2

This concept was not new when these cases were treated. The earliest reports of attempts to regrow the pulp date back to 1961 when Nygaard-Östby histologically analyzed cases and reported that pulps and dentin were not reliably induced.3 Later, Hørsted and Nygaard-Östby reported that when canals were intentionally filled 2-4 mm short of the apical foramen, slightly inflamed connective tissue formed within two months. After six and 10 months, there was a cell-rich fibrous tissue with a few lymphocytes, but it was not pulp.4

With the progress of stem cell research in the last two decades, the desire to regrow pulps has resurfaced. The purpose of this paper is to summarize the literature and provide a balanced view of the possible treatment modalities for infected immature teeth.
Definitions

Before reviewing the literature, the terminology needs to be defined. Unfortunately, the profession has adopted terms that are ill defined and hence are not always used appropriately. It is essential that new terms or new procedures be clearly defined so all practitioners and authors understand them. The use of inappropriate terminology leads to misunderstanding and potentially inappropriate clinical procedures. It also leads to unrealistic expectations among practitioners and/or patients.

Regeneration — This term has become popular to the extent that it is almost used exclusively (although in varying forms — such as regeneration, regenerative endodontic procedures, etc.) when discussing procedures that attempt to regrow pulps. However, it has not been adequately defined. “Regeneration” when used in a biological sense means “restoration or new growth by an organism of organs, tissues, etc., that have been lost, removed or injured.” This implies that new tissue in the canal must be pulp and not other tissues. As outlined below, this does not predictably occur in animal studies or in the few human cases where histological analysis has been performed. Hence, use of this term should be abandoned until it can be proven that pulp is actually, and reliably, formed. Interestingly, the term “regeneration” was not used in the titles of the early papers; instead “revascularization” was used.\textsuperscript{1,2}

FIGURES 1. Maxillary left lateral incisor in a 9-year-old girl where revascularization occurred after avulsion. It was placed in milk, then replanted and splinted 45 minutes later. After replantation (1A). Three-month review (1B). It responded to electric pulp testing but not a cold test. Seven-month review — further root development and pulp canal calcification are evident. It still responded to electric pulp testing (1C). Fourteen-month review showing further pulp canal calcification (1D–1E). The tooth continued to respond to electric testing.

FIGURE 2. Diagrammatic representation of typical findings following repair procedures to treat infected immature teeth. These involve inducing a scaffold within the canal to encourage tissue ingrowth from the periapical region. The reparative tissue may be various types of soft or hard tissues or the canal may remain empty.
Revascularization — means “re-establishment of blood supply to a part or organ.” The American Association of Endodontists (AAE) defines it as “the restoration of blood supply.” This is known to occur after trauma where the pulp’s neurovascular supply is severed by luxation or avulsion. In immature teeth where the apical foramen is “open” — especially more than 1.1 mm — blood vessels can anastomose and re-establish blood supply to the pulp. Provided there is no bacterial contamination, pulps can recover and function normally. Pulp canal calcification typically occurs (FIGURE 1) but this is a normal physiological response demonstrating pulp survival and normal function.

Revitalization — means “to give new life to or to give new vitality or vigor to.” It is not defined in the AAE Glossary of Endodontic Terms. In dentistry, vitality refers to presence of pulp blood supply. It is a poorly understood and misused term. In clinical practice, it is impossible to determine whether pulps have viable blood supply because thermal and electric pulp tests are sensibility tests and not vitality tests — that is, they indicate the ability of the pulp to respond to a stimulus. Specific tests for blood supply (laser Doppler flowmetry or pulse oximetry) are required if claims about vitality are to be made, but these tests are not typically used in practice due to cost, time, lack of reliability and little research.

FIGURES 3. Traumatized immature tooth with a pulpless, infected root canal system and a chronic apical abscess treated with a repair procedure. Triple antibiotic paste was used followed by Ca(OH)_2 and induction of a blood clot. Preoperative (3A–B). Postoperative with an MTA cervical barrier (3C). Eighteen months (3D–E). Six years (3F). (Courtesy Dr. Eugene Chen)
**Repair** — this term can have several meanings, including “to restore to a good or sound condition after decay or damage, to restore or renew by any process of making good, strengthening, etc., to remedy and to make good.” This definition is appropriate for procedures where clinicians treat root canal infections and attempt to encourage pulp regrowth. By using this term, the profession recognizes that a reliable pulp regenerative procedure has yet to be developed (and proven) and that healing with other tissue may occur (FIGURES 2 and 3). Hence, this term will be used in this review.

**Apexification** — the AAE defines this term as “a method to induce a calcified barrier in a root with an open apex.” This usually involves placing intracanal medicaments such as calcium hydroxide to induce closure of the open apical foramen with a natural hard tissue barrier (FIGURES 4 and 5). This procedure has been used in dentistry for many years with great success and high predictability.

**Apical barrier technique** — the AAE defines this as “blockage of the apical foramen; may be an induced hard tissue or artificial materials.” Placing hard-setting materials such as mineral trioxide aggregate (MTA) or other bioceramic materials prior to filling the remaining canal is an example of an apical barrier technique (FIGURES 6 and 7). The barrier formed is artificial although a natural hard tissue barrier may form later — however this cannot usually be assessed radiographically because of the radiopacity of the barrier material.

**Literature Overview**

Nygaard-Ostby was the first to investigate whether pulp could regrow after infection of the root canal system but he was unable to predictably induce pulp regrowth. Subsequently numerous case reports and research papers have discussed this concept using modern approaches, especially with a focus on stem cells that may be in the periapical tissues.

Iwaya et al. assumed that some viable tissue remained in the apical part of the root canal. This assumption was based on the patient having pain when instruments were used in the canal. The authors stated that visual inspection confirmed the presence of pulp tissue approximately 5 mm apical to the canal orifice. They therefore avoided further instrumentation to preserve this tissue, and they postulated that it recovered, regrew and continued to function by producing dentin to complete the root development.

Banchs and Trope took a different approach. Following canal disinfection, periapical bleeding was induced to form a blood clot in the canal to act as a “scaffold” for ingrowth of new tissue. They hypothesized that this was “similar to necrotic pulp after a traumatic injury” in immature teeth where revascularization occurs. A triple antibiotic paste was used as the main disinfecting agent. This paste was based on an in vitro study that reported it to be highly effective for infected root dentin.

Many case reports and studies have now been published. On reviewing the course reports, it is apparent that there is no standard protocol and the types of cases vary considerably. There is no consensus regarding the materials used for canal disinfection, the timing and number of appointments, the use of adjunctive agents (such as blood products) and other variables to treat a range of presenting conditions. Reports have concerned dens evaginatus in mandibular premolars or traumatized maxillary incisors. Some cases have had draining sinus tracts indicating chronic apical abscesses, while others have had chronic apical periodontitis, acute apical abscesses or acute apical periodontitis. Each of these is a distinctly different condition (albeit with a similar cause) so they may have different responses to treatment. The stage of root development (apical foramen width, canal width, root length) varies considerably as do the methods and criteria used to assess outcomes. As a result of these variables and the lack of standardization/consensus, the findings are quite variable, which leaves the profession without true indications for when repair procedures are indicated and how to predictably perform them.

A systematic review found 214 studies regarding repair procedures but only six satisfied the inclusion criteria — English, performed in humans with five or more teeth, immature infected permanent teeth. Various outcome measures were used in these six studies, including tooth survival and function, resolution of signs of disease and success/failure. Two of the six studies were excluded from parts of the analysis due to discrepancies in their initial assessments. Hence, only four studies could be assessed for all criteria, which demonstrates the limited evidence available and highlights the wide variation between studies. The four studies included only 75 teeth treated with repair procedures and 53 treated by apexification or apical barrier techniques.
Unfortunately, the data for these latter two procedures were combined, which is inappropriate because they are different clinical procedures. Each procedure cannot be assessed individually as the results of one may (positively or negatively) influence results of the other procedure. Tooth survival was 98.6 percent for repair procedures and 88.6 percent for combined apexification/barrier techniques. The combined clinical success from two studies was 89.7 percent for repair and 100 percent for apexification/barrier techniques. Periapical healing based on radiographs from three studies was 89.7 percent for repair and 100 percent for apexification/barrier techniques. One study assessed bone density and found no difference among these procedures. Jeeruphan et al. reported average increases of 14.9 percent and 28.2 percent in length and thickness, respectively.17 These were compared with changes following apexification and barrier techniques but only the length changes should be compared because dentin thickness cannot possibly change with apexification and apical barrier techniques. After apexification, average root length increased by 6.1 percent.17 Another study found average changes following repair procedures were 5 percent for root length and 21 percent for dentin thickness.18 These changes were only detectable and quantified by computer software and could not be detected by visual examination of radiographs.18

Alobaid et al. reported no statistical differences for changes in root length and dentin thickness following repair and apexification/apical barrier procedures.19 They used 20 percent as a clinically meaningful change for each category but only four repair cases and one apexification/apical barrier case met this threshold. Hence, the clinical relevance of these changes is doubtful. The authors concluded that repair and apexification/apical barrier techniques were equivalent with insufficient evidence to claim superiority of any technique.

In another systematic review of repair procedures,20 the authors reported that the tooth survival rates and resolution of periradicular radioluencies were excellent. However, they also reported that apical closure and continued root development were inconsistent in the reviewed studies. Furthermore, they commented that there are few well-reported randomized prospective clinical studies, plus evidence regarding long-term outcomes and late effects was sparse. No study evaluated health economic outcomes and whether there were any improvements to quality of life for the patients. Their conclusions stated that there are many gaps in the profession’s knowledge regarding repair procedures and the published evidence.
does not provide definitive conclusions regarding the predictability of treatment outcomes following repair procedures.

Alobaid et al. compared outcomes and “adverse events” following repair and apexification/apical barrier procedures. Follow-up periods were short and the number of teeth was small — 19 teeth for 15 months average in the repair group and 12 teeth for 22 months average in the apexification/apical barrier group. One tooth from the repair group did not survive (further trauma) and four teeth had unfavorable outcomes (78 percent clinical success). In the other group, all teeth survived with favorable outcomes (100 percent clinical success). There were more adverse events in the repair group (eight teeth, 42 percent) than the other group (one tooth, 8 percent). The adverse event in the latter group was further trauma whereas the repair group had a variety of adverse events, including reinfection (three teeth), staining (two), fracture (one), pain (one) and further trauma (one). Some adverse events are unavoidable and/or unrelated to the procedure (e.g., further trauma, fracture) so they are not “negative” issues or contraindications. However, other adverse events (e.g., continued infection, pain, no healing) may be related to the procedure and must be considered whenever contemplating such procedures. Patients (and parents) must be informed of these possible problems.

When assessing new techniques, case reports and clinical studies have severe limitations because of the variations in techniques and conditions being treated. Hence, animal studies are extremely valuable because histology and scanning electron microscopy can be used to assess healing responses, the type/nature of reparative tissue (if any) and treatment outcomes. Animal studies can show progress of healing over time by examining animals at appropriate time intervals. They show tissue responses within both the canals and the periradicular tissues. Histological studies can rarely be performed on human teeth. If they can, it is usually due to an adverse event that led to tooth extraction so the findings may not be applicable to all cases. In addition, histological examination of extracted teeth does not usually include the periradicular tissues and it is an examination at a single time point without showing healing over time. Hence, histological animal studies are essential to provide evidence to support (or not support) new techniques.

A systematic review of repair procedures in animals where histology was used to assess tissue responses initially identified 123 studies but only 13 met the inclusion criteria. None of these studies identified pulp tissue in the canals — instead, there were varying degrees of connective tissue, fibroblast-like cells and blood vessels. Various types of hard tissue were found in the canals and none of the studies reported them as being dentin, bone, periodontal ligament or cementum — instead, they were “like” tissues suggesting similarity but not replication of these tissues. Dentin-like tissue was reported on canal walls in 4 percent of teeth after blood-clot scaffold procedures and 2 percent of teeth where blood clots plus additional materials were used. Periodontal ligament-like tissue was reported in 46 percent of teeth. Cementum-like tissue was in 64 percent of teeth with blood-clot scaffolds, 80 percent with blood clots and additional materials, 50 percent with alternative scaffold materials and only 5 percent when canals were left empty. Bone-like hard tissue was reported in 10 percent of cases with blood-clot scaffolds, 2 percent with blood clots and additional materials and 4 percent with alternative scaffold materials. The overall conclusion of this review was: “None of the regenerative protocols resulted in predictable formation of a true pulp-dentin complex.” This is a very important finding that contradicts claims in many reports of pulp regeneration, revascularization or revitalization. Furthermore, claims of root strengthening need reconsideration in light of this review because a “like tissue” is unlikely to have the same physical properties as the tissue it is replacing. It will not necessarily provide the same structural strength as the original tissue. In addition, different types of “like tissues” that would not normally be present in the canal (e.g., bone-like, cementum-like) are less likely to provide strength because strength relies on having sufficient dentin.

Some further observations from the literature, especially case reports, are:

- Infected immature mandibular premolars with dens evaginatus generally respond well to repair procedures. Radiographs suggest resumption of normal root development, indicating that pulps may have regrown. Radiographs usually show good periradicular repair, formation of normal periodontal ligament space, root canal narrowing and closure of

![Diagrammatic representation of typical findings following apical barrier techniques to treat infected immature teeth. A cement is placed to close the apical foramen prior to root canal filling.](image-url)
open apical foramina. However, caution is necessary as radiographs do not allow differentiation between dentin and other hard tissue and the tissue within the canal cannot be seen to determine its composition.

- Maxillary incisors that become infected following trauma do not respond as predictably as mandibular premolars discussed above. Damage to the periapical stem cell base during trauma is the likely explanation. The type of trauma is probably critical because some injuries damage periapical tissues more than others — for example, crown fractured teeth may have no damage while luxated and avulsed teeth have considerable damage.

- Controlled placement of the cervical barrier is difficult and radiographs often show the material placed well into the root canal rather than just in the cervical region (FIGURE 8). In some cases, material has been placed almost to the apical foramen, which leaves little space for repair and hard tissue formation — this is more akin to apexogenesis or an apical barrier technique.

- Follow-up radiographs usually show periapical tissue repair. This should be an expected outcome if the root canal system is adequately disinfected. It is well-known that periapical radiolucencies can heal without canals being filled.24,25 However, many authors use this as the sole criterion to claim pulp has “regenerated,” even without canal and apical foramen narrowing. These findings indicate periapical healing but not pulp repair/regeneration.

- Some cases have used radiographs to assess outcomes while others have used cone beam computed tomography (CBCT). Neither of these can determine the nature of new soft tissue (if any) that may form within the canal. These images only show hard tissue changes and not presence (or absence) of soft tissue. They cannot be used to distinguish between pulp, connective tissue, fibrous tissue or other soft tissue.

- Radiographs and CBCT cannot be used to determine the nature of new soft tissue.
hard tissue. This may be dentin, cementum, bone or a mixture of these. Animal studies have shown the new hard tissues are “like” these original tissues but they are not the same when examined histologically. Radiographs and CBCT images are not discriminating enough to distinguish between these different hard tissues.

Many clinicians report difficulty in inducing bleeding into the canal to create a scaffold. In such cases, hard tissue does not appear to form within the canal although periradicular healing still occurs because the canal has been disinfected.

Discussion

The literature suggests many teeth can be retained with repair procedures. However, histological studies do not support the concept of pulp and dentin regeneration. Hence, the profession needs to reconsider what it is trying to achieve with these procedures. If the intent is to retain teeth, then repair procedures can be performed but the evidence does not show any advantages over apexification and its derivative, the apical barrier technique. There are further aspects that need consideration other than just periapical healing and whether pulp and/or hard tissue form in the canal.

Periapical healing following treatment of infected root canal systems is predictable provided adequate disinfection protocols are followed.\textsuperscript{24,25} These include using a rubber dam, thorough instrumentation, antibacterial irrigants and medicaments, plus adequate tooth restoration during and after root canal treatment. Studies have shown that it is not necessary to fill canals with materials such as gutta percha and cement to achieve periapical healing.\textsuperscript{24,25} In these two studies, one group of infected teeth had root canal fillings placed while canals in another group were left empty. Periapical healing rates were identical for both groups in both studies. This clearly indicated that disinfection is the most important contributor to periapical healing. This approach should be identical for immature teeth, although instrumentation of canal walls is minimized to preserve dentin. Advocates for repair procedures employ disinfection methods although protocols vary between studies and cases. Typically, antibiotics (triple, double or single antibiotic pastes), calcium hydroxide or other antiseptics are used. These, along with canal irrigation (typically with sodium hypochlorite and ethylenediamine tetra-acetic acid), are very predictable in achieving bacteria-free root canal systems and therefore periapical healing should be expected. Hence, periapical healing following repair procedures is neither surprising nor remarkable.

Further consideration is needed regarding the aims of repair procedures. One aim is to strengthen tooth roots by regrowing pulp that can then produce dentin. This is based on Cvek’s findings of cervical root fractures in some teeth after calcium hydroxide apexification.\textsuperscript{26} The fractures usually occurred after further trauma (FIGURE 9) although some may result from normal functional loading (especially in very immature teeth). The proportion of fractures was highest (77 percent) in the most immature teeth — i.e., Stage 1 development — and lowest in mature teeth (28 percent). The frequency of fractures was also highly statistically significantly related to external inflammatory resorption defects where tooth structure had been lost.\textsuperscript{26} Unfortunately, Cvek’s data has been misrepresented by proponents of repair procedures who claim fractures are very likely after apexification because some publications suggest calcium hydroxide weakens dentin.\textsuperscript{27,28} However, the methods used do not replicate the clinical scenario of trauma as they typically use dentin samples rather than intact human teeth. In addition, the medicament is not just applied within the root canal and continuous loading is used rather than impact forces. Other studies have contradicted these findings, suggesting that calcium hydroxide may not be the cause of dentin changes.\textsuperscript{29,30} In a systematic review regarding nonsetting calcium hydroxide, no clinical studies directly supporting a correlation between calcium hydroxide intracanal dressings and root fracture could be found in the literature. This was despite most of the in vitro studies showing some reduction in the mechanical properties of dentin
after exposure to calcium hydroxide for five weeks or longer. However, conversely, there was no conclusive data concerning calcium hydroxide used for one month or less had a negative effect on the properties of dentin. Careful analysis of Cvek’s paper indicates that fractures were directly related to the amount of tooth structure rather than the effect of calcium hydroxide since all cases had long-term application of this medicament and the only significant variables were the stage of root development and the resorptive defects.

Increases in root length and dentin thickness are of interest because it has been assumed that they provide greater strength to teeth over time. However, this is purely an assumption and no studies have investigated this. Increases are usually reported as average percentages but if quantified as tooth structure, it is doubtful that they will strengthen teeth. As an example, extrapolating data from Saoud et al. suggests the change in root length averaged only approximately 1.0 mm while dentin thickness changed by only about 0.54 mm. Production of such a small amount of hard tissue at the root apex seems unlikely to increase resistance to fracture at the cervical level where fractures occur. Likewise, a small increase in dentin thickness in the apical two-thirds of the root is also unlikely to increase resistance to cervical fracture. If any procedure could increase resistance to fracture, it would need to produce a significant amount of dentin at the critical point where the fractures occur — that is, the cervical level. Unfortunately, current repair protocols cannot achieve this as barrier materials (MTA or a bioceramic material) are placed in the cervical part of...
the root, thus preventing dentin formation there. The material must be placed there to facilitate access cavity restoration and to avoid staining. Hence, it is impossible to overcome this fundamental problem of immature teeth being susceptible to cervical fracture using current techniques for managing immature teeth whether they be repair, apexification or apical barrier techniques. Furthermore, a study similar to Cvek’s needs to be conducted so the incidence of root fractures following repair and apical barrier procedures can be determined and compared with Cvek’s results for apexification.

Proponents of repair and apical barrier techniques often discuss the number of appointments and patient compliance as advantages over apexification. However, there is little difference apart from overall time to treat the tooth. Apexification studies have reported hard tissue barriers within 5.1 months (average 2.4 visits), 7.8 months (three Ca(OH)2 dressings) and 9.0 months. The time for apical closure was significantly related to size of the apical foramen — average 6.2 months when the opening was less than 2.0 mm and 11.0 months when more than 2.0 mm. Protocols for apical barrier and repair procedures vary between practitioners but both procedures require three to four appointments over one to three months. Hence, there is little difference in the number of appointments. Therefore, arguments regarding time and compliance are irrelevant and patients should be offered the most predictable treatment with a full discussion of the time and appointment scheduling. Well-informed patients are likely to comply in the interest of predictable outcomes.

Interestingly, although apexification has lost favor among some clinicians, it remains the “fall-back” procedure for repair cases that have not healed or have become infected again, as demonstrated by one case presented by Bukhari et al. Sometimes, apical barrier techniques are used. It is somewhat ironic that these procedures are only used as a “backup” rather than as the first choice of management when they are associated with fewer complications and are generally more predictable.

The potential need for endodontic re-treatment if and when the root canal system becomes infected again should always be considered when planning treatment. This is a possibility because all teeth require a restoration after root canal treatment. Over time, restorations break down, leading to reinfection, because all restorations have a finite life span. Hence, clinicians and patients should be prepared for possible endodontic re-treatment. The concept of “what goes in, must come out” should be followed — that is, materials must be capable of being removed without risking damage to the tooth, particularly in immature teeth as they already lack tooth structure. Use of hard cements as apical or cervical barriers may be problematic.

No reports have been published regarding barrier removal but it is likely to be difficult and even impossible in some cases. During removal, apical barrier materials may be extruded into the periapical tissues leading to inflammation or foreign body reactions. If the material cannot be removed, the apical part of the canal may not be able to be disinfected, which may lead to treatment failure or the need for periapical surgery. Cervical barriers used for repair procedures may be more accessible but still difficult to remove without damaging the canal walls. In contrast, following apexification to create natural hard tissue barriers it is relatively simple to re-treat as the gutta percha can be removed in the usual manner with solvents and files. The apical hard tissue barrier is usually still intact and the new root filling can be easily placed after canal disinfection (FIGURE 10).

Conclusions

Having treatment procedures that predictably lead to pulp regrowth is desirable but currently there is insufficient evidence to support this concept as a modality for managing infected immature teeth. The best that can be achieved with current repair procedures is periapical healing, but root maturation is unpredictable. In some cases, various types of soft and hard tissues may form in the canal. Current repair procedures show no advantage over apexification and apical barrier techniques. The latter two procedures tend to be more predictable, and they provide more possibilities for longer-term retention of immature infected teeth.

REFERENCES


FIGURE 10


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Implant Dentistry and Endodontics: Can There Be a Mutually Beneficial Relationship?

Tory Silvestrin, DDS, MSD, and Charles J. Goodacre, DDS, MSD

ABSTRACT Endodontics focuses on preservation of teeth with pulpal and periapical disease. Implant dentistry provides replacement of missing or nonsalvageable teeth with implant-supported restorations. Arguments have been made that teeth are sometimes treated endodontically but instead should be replaced with implants. Opposing arguments suggest that teeth have been needlessly replaced with implants. Data show that endodontics and implant dentistry play important roles in patient-centered dentistry.

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Endodontics as a specialty has promoted the preservation of teeth that can be properly restored and function satisfactorily after treatment of pulpal and periapical disease. Preserving the natural dentition has been the goal of endodontics since its initiation more than 100 years ago. Where teeth are not salvageable or missing, the introduction of implant dentistry has been a very welcome addition to dental care. In patient-centered practices, treatment options should be presented objectively for the patient’s benefit. When the popularity of dental implants was rising several decades ago, most endodontists resisted joining the move to incorporate the new treatment modality. Many were of the opinion that implants were a competitive challenge. While that notion still exists, endodontists have in recent years become increasingly interested in incorporating implant dentistry in their practices. They have begun to recognize the value of adding this treatment modality in cases where teeth cannot be treated endodontically or have a questionable prognosis. Implants provide the benefit that adjacent teeth do not need to be involved in replacing a nonsalvageable tooth such as in fixed prosthodontics.1

After a period of time of confrontations between endodontists and dentists promoting dental implants, it seems that the time has come for coexistence of the two treatment entities in the interest of best patient care. In light of this, there are times when retention of a compromised tooth through endodontic and restorative intervention is the most appropriate choice in a region that would otherwise be aesthetically marginalized if a dental implant were considered.2 At other times, the retention of some teeth with root canal
treatment could result in a compromised prognosis due to the extensive loss of tooth structure or an aesthetic compromise when adjunctive treatments such as crown lengthening or orthodontic extrusions are required to restore the tooth.

History of Implant Dentistry

Dental implants have a history that precedes Brånemark’s introduction of osseointegration. There is evidence of prehistoric people attempting to adapt and use foreign materials to replace missing dentition. These early attempts included replacement of teeth with wood, bone, ivory, gold and other materials. Early Egyptian and South American cultures used cobalt alloy, tantalum, stainless steel and iridium. In the 1970s, physician Per-Ingvar Brånemark introduced the concept of osseointegration (the physical contact of bone to titanium) of dental implants. Brånemark had previously discovered — serendipitously in another experiment — favorable soft and bony tissue reactions to titanium. The Brånemark protocol involved placing implants into the alveolar process and then covering it with the soft tissue flap raised to expose the bone. Then, following three to six months of healing, the implants would be uncovered and used for support and retention of a prosthesis.

Before the Brånemark root-formed implants were introduced, another form of implant had gained some popularity: endodontic implants. These were implants developed for the purpose of retaining poorly supported teeth. These implants were rigid (usually composed of titanium) and extended through the root apex into the apical bone to stabilize teeth with weakened periodontal support. Other applications for endodontic implants were stabilization of overdenture abutment teeth and teeth with root fractures and replanted avulsed and autotransplanted teeth. The use of endodontic implants for root fractures where the apical segment of the tooth is removed is no longer recommended.

The placement of endodontic implants gained some popularity from the mid-1960s to early 1970s. The popularity faded when the outcomes became unpredictable and apical lesions were often associated with the implants.

Despite the problems with apical lesions, these implants did solve the excess mobility of teeth that would otherwise need to be extracted. An advantage in using endodontic implants was that placement was a part of the specialty scope, it was considered to be within the practice scope of endodontists to also place endosseous implants. The Commission on Dental Education (CODA) modified the Standards for Advanced Specialty Education Programs in Endodontics in the early 1990s to include endosseous implants, thus including this new surgical procedure in the endodontists’ scope of practice. Prior to the introduction of this standard, the CODA Standards in 1985 stated that graduate students should provide service and demonstrate experience with endodontic implants. Currently, dental implants are included to varying degrees in all advanced endodontic education programs and thus endodontists may include them in their practices.

The American Association of Endodontists (AAE) has recognized the role implants play in the specialty of endodontics and have incorporated curricula in its annual sessions to educate endodontists about treatment planning, problem solving and surgical aspects of the placement of dental implants in practice.

Loma Linda University was a pioneer in the integration of endodontics and dental implants with the establishment of a program track in the advanced endodontic program that would include an additional year of surgical implant training. An advantage to including implant dentistry in the endodontic program is the opportunity for a patient with a nonsalvageable tooth to have it replaced with an implant without the need to be referred to another clinic. The patient may have been referred to the endodontic clinic for evaluation along with information about treatment options that could include a dental implant. With the approval of the referring dentist, the fractured tooth could
be replaced with an implant and returned to the referring dentist for the prosthesis.

Endodontists who offer dental implants as a treatment option to their patients are in a good position to present patients with clinical information about advantages and disadvantages of competing options as may occur in certain circumstances. A maxillary molar with a compromised buccal root but with minimal bone support may be better treated with a root amputation rather than replacement with an implant; conversely, a mandibular molar with a vertical fracture of one root may not be as suitable for root amputation.

Endodontists Placing Implants and Its Acceptance by Referring Dentists

Endodontists interested in including implant dentistry in their practices must show their referring colleagues that there is patient-centered value in the practice of implant dentistry by endodontists. Expertise in surgical placement of implants allows endodontists to offer patients that service if indicated. This can save patients time in reducing the number of visits to various dental providers. It may also reduce the number of surgical procedures. If surgical exposure of a root is needed to determine presence of a fracture, the extraction of a tooth with fracture could be accomplished at the same time. In addition to more efficient patient management avoiding a second surgical procedure to remove the tooth, it may also help preserve the bony housing. And there is evidence that placement of an immediate implant following extraction helps to minimize bone loss. Bone loss cannot be completely eliminated and bone remodeling and soft tissue changes will usually occur.

Beneficence — a core ethical pillar in dentistry — is demonstrated fully when an unbiased provider can clearly and knowledgeably discuss and offer both endodontic and dental implant information and treatments if accepted by the patient. Endodontics and implant dentistry can not only coexist, but also must coexist for the benefit of patients. Endodontic treatment and implant placement are uniquely positioned to challenge each other, contradict each other and ultimately perfectly complement each other.

In a recent survey, the majority of general dentists polled reported unfavorable attitudes regarding endodontists placing dental implants. Sixty-six percent of respondents opposed endodontists placing implants, and 73 percent indicated they would not refer patients to an endodontist for implant placement. It is no surprise that these responses are in opposition to a survey of endodontists regarding their thoughts on implant placement. In the latter survey, 57 percent of respondents supported endodontists placing implants with 5.7 percent of responding endodontists reporting they currently place implants.

In an ongoing survey by the authors of California endodontists, 18 percent of respondents report currently placing dental implants versus 82 percent who do not. Approximately 25 percent of the state endodontists have responded so far. Of those, 64 percent indicated that they believe implant dentistry should continue to be a part of the scope of endodontics versus 36 percent opposing. Sixty-seven percent of respondents reported feeling endodontics has been negatively affected by the growth of implant dentistry; 33 percent did not feel that way. Implant dentistry has become a part of many endodontic practices in California; however, the opinions on the value of including implant dentistry in practices is split and many endodontists still feel that they have to compete with dentists who place implants in patients who could benefit from endodontic treatment.

In addition to the above considerations, some referring dentists may feel that endodontists lack training in prosthetic reconstruction and soft tissue management — skills that are necessary to properly diagnose and place dental implants. Thus they may hesitate to refer their patients to endodontists for such a service. From the endodontists’ point of view, their experience in microsurgical procedures involving root-end isthmuses, manipulating neurovascular bundles and managing the maxillary sinuses equip them with both knowledge of anatomy and surgical skills. Such skills and knowledge can be employed by endodontists to precisely place dental implants in restoratively driven anatomic positions.

Implant Dentistry and Endodontics Compared: Patient-Centric Factors

Endodontics has long been perceived by patients as being associated with pain and fear, but the evidence from the literature shows that pain is not often associated with endodontic treatment and root canal treatment actually substantially reduces pain (50 to 75 percent) compared to preoperative levels. It is often the preoperative pain that the patients retrospectively associate with perceived postoperative pain, and it has been shown that postoperative discomfort...
related to root canal treatment and surgical implant placement is equal.\textsuperscript{29–31}

Financial concerns about dental treatment are important to patients. Nonsurgical root canal treatment and a prosthetic crown compare favorably to a comparable implant/crown treatment.\textsuperscript{29,32,33} Other options such as fixed partial dentures are also available at comparable cost.\textsuperscript{34}

A concern that patients often have is treatment time. When comparing endodontic treatment versus treatment involving dental implants, the latter requires significantly more time than the former.\textsuperscript{35} Patients experience more inconvenience due to the increased treatment time of a two-stage implant versus having a root canal-treated tooth back in function much more quickly. Even immediate placement with provisionalization requires a second appointment after healing to provide the definitive crown.

Postoperative complications occur more commonly with dental implants (screw loosening being the most common complication) than with endodontic treatment and this both adds to increased patient inconvenience and patient cost.\textsuperscript{36} The incidence of postoperative complications rises to approximately 20 percent and can range from the need to retighten the abutment screw to refabricating the crown.\textsuperscript{35} Others have found that the three-year complication rate with implants rises to 72 percent, but the implant-supported crowns in this particular study were acrylic resin fused-to-metal crowns, which are not widely used due to the higher complication rate.\textsuperscript{37} Despite the range reported in the literature, there is consensus that implant-supported crowns have a higher incidence of complications than root canal-treated teeth.\textsuperscript{38}

In terms of biomechanical considerations, implants have been found to provide a significantly lower maximum biting force, reduced chewing efficiency and smaller occlusal contacts compared to root canal-treated teeth.\textsuperscript{39}

Implant placement has been shown to increase patient quality of life measures, but this is more significantly pronounced when implants are used to anchor a removable partial denture (thus replacing multiple missing teeth) than when an implant is used for single tooth replacement. The majority of patients report some satisfaction or high satisfaction with both endodontic treatment and single tooth implants. In addition, endodontic treatment has been determined to significantly improve the quality of life for patients.\textsuperscript{26,40}

Prior to including aesthetics in the success criteria, poor aesthetics, implant malposition, soft tissue recession, bone maintenance and unfavorable soft tissue configuration were not considered when evaluating implant success.\textsuperscript{41} It is important to consider aesthetics when judging implants to be a success or failure, as aesthetic problems outnumber mechanical failures in the anterior dentition.\textsuperscript{38} Loss of dental papilla is the most common complication after implant placement and can result in black appearing triangles interproximally.\textsuperscript{42,43}

Contracture of the papillae occurs in 5 to 20 percent of patients after implant placement compared to the contralateral natural teeth; retaining natural teeth with root canal treatment has been recommended to help maintain the papilla in the anterior aesthetic zone.\textsuperscript{44} Treatment planning is crucial when considering implant placement, as thin gingival biotypes are more prone to recession than are thick biotypes and some authors have advocated preservation of natural teeth in aesthetic zones when a thin periodontal biotype is present.\textsuperscript{2,33,45} Aesthetic concerns clearly favor retention of natural teeth when possible in the maxillary anterior segment.

Cost, success, treatment time, postoperative interventions, postoperative pain, biomechanical factors, patient satisfaction with treatment and aesthetics all play an intertwined role in the patient’s decision whether to elect tooth preservation or replacement with a dental implant. Clearly both treatment options offer myriad benefits, but they also have drawbacks that need to be fully explained to the patient.

Both treatment options offer myriad benefits, but they also have drawbacks that need to be fully explained to the patient.

Outcomes of Dental Implants and Endodontic Treatment

Expected outcomes of treatment options need to be presented to patients. Comparing such outcomes is, however, difficult.\textsuperscript{46} Part of the problem comes from differences in defining outcomes since both success and survival concepts have been used.\textsuperscript{46} Nevertheless, there is information available to review.

Contributing to the difficulty in comparing outcomes between endodontic and implant treatments has been differences in success criteria, different lengths of historical data available and often less than rigorous research protocols.\textsuperscript{29} Success of root
canal treatment is defined in stages of healing versus implant healing which is binary success versus failure. This gives the appearance of less fully healed endodontic treatments than implants due to the structure of the success and failure criteria.47–52

Many publications have shown both implants and endodontic treatments to share high levels of success, with no significant difference in survival of single tooth implants or teeth with root canal treatment.29,36,53 Implant survival has been reported at very high levels, from 96 to 98.9 percent with at least a five-year follow-up period.54–58 Others have reported lower survival figures, ranging from 82 to 88.5 percent.59,60 Success of implants at the five-year period has been reported to range between 83 and 99 percent with the lower success specifically in the maxillary molar region.61–63

Initial and secondary (re-treatment) nonsurgical root canal treatment outcome studies have looked both at success and survival. In terms of

**FIGURES 1.** Treatment approaches for a mandibular first molar. Radiograph taken 10 years following root canal treatment due to pulp necrosis (1A). The tooth had developed a vertical root fracture in the mesial root and was extracted. In 1994, an implant was placed, but it was not centered in the edentulous space and there was a substantial mesial cantilever to the crown (1B). There were multiple episodes of screw loosening over the following years. In 1999, a new implant was placed due to the repeated mechanical complications with the initial implant (1C). However, it also was not ideally centered in the edentulous space and there was still an extension of the crown mesial to the implant. In 2006, the implant developed peri-implant mucositis, which was managed with improved home care (1D). Additional peri-implant bone loss was noted in 2010 (1E). Due to continued bone loss, bone grafting was performed (1F). In 2016, due to increasing bone loss, the implant was removed and bone graft material placed into the osteotomy (1G). Due to the regular recurrence of complications associated with the implants, the patient elected not to have another implant and instead have a fixed partial denture. After healing following extraction and bone grafting, a three-unit metal-ceramic fixed partial denture was placed (1H). Periapical radiograph of the completed fixed partial denture (1I).
survival, four-year retention has been shown to be 95 percent.64,65 Another systematic review indicated four- to five-year survival of 93 percent and 87 percent survival at eight to 10 years.66 Epidemiological studies containing greater than 1 million subjects have found 93 to 97 percent survival of root canal-treated teeth (both initial and re-treatment).67,68 Others have found success rates of endodontic re-treatment to range between 85 and 96 percent.67,69,70 Some have found lower success rates during re-treatment, with success of 85.5 percent using more strict radiographic criteria.71

Endodontic microsurgery has a much higher success rate than traditional root-end surgery (94 percent versus 59 percent).72,73 However, a systematic review found that endodontic microsurgery had a lower success rate than that of single implants (98 percent versus 90 percent at a two- to four-year follow-up, respectively). Additionally, at two to four years posttreatment, single implants had higher survival rates than teeth treated with endodontic microsurgery.74 This was one of the few studies that directly compared endodontic surgery and implant survival and success.

As dental implants are increasingly covered by dental insurance, the expansion of implant dentistry into the root canal treatment “market share” will likely continue to increase. Dentists also form opinions based on personal experience. A colleague of one of the authors (T.S.), who works in a remote town with no endodontists nearby, chooses to preferentially treatment plan and urge patients to consider dental implants rather than undergoing root canal treatment reasoning that “it’s faster for me to place an implant than to do a root canal … implants put more money into my wallet than do root canals.” This colleague’s opinion presents a challenge to both organized dentistry and dental education.

An alarming trend was highlighted in a recent editorial in the Journal of Dental Research. Dentists with less training who are less educated about surgical placement of dental implants (as well as prosthetic reconstruction of dental implants) more often recommended removal of teeth (as opposed to preservation of teeth via endodontic means).75 The editorial also mentions that there is a trend toward removal of teeth that are compromised but salvageable, such as teeth with periodontal disease, endodontic needs or prosthetic reconstructive needs. While dental implants may seem to be a solution to all problem teeth, the facts do not support that notion. Iqbal and Kim53 have stated that routinely choosing to place a single tooth implant for a compromised tooth that could otherwise be saved by endodontic treatment cannot be advocated in light of the sparse literature that directly compares single tooth implants and restored root canal-treated teeth. As advocated at a Consensus Conference regarding dental implants, the decision to treat a tooth with endodontics or replace with a single tooth implant should be based on criteria other than long-term outcome because the treatment modalities produce similar outcomes.76

**FIGURES 2.** Examples of failures due to poorly constructed prosthetic restorations of endodontically iterated teeth. The anterior fixed partial denture failed due to the presence of a post and core in the lateral incisor abutment that was both short and too large in diameter (2A). The maxillary canine root fractured due to the presence of a large diameter post (2B). Note that the lateral incisor has a short post that also has excess diameter.

**FIGURE 2A.**

**FIGURE 2B.**

An Evolving Change in Practice

Philosophy: Is This Change in Our Patients’ Best Interest?

The success and proliferation of dental implant therapy has caused many endodontists to notice a declining patient interest in preserving their natural dentition when faced with the prospect of saving a tooth through root canal treatment versus extracting the tooth and placing a dental implant. Despite literature showing similar survival rates for root canal treated-teeth and single tooth implants, some dentists seem to consider dental implants to be the gold standard and that root canal treatment is a temporary effort to keep a tooth with endodontic disease a few more years. To the contrary, one might say there is no better “implant” than a natural tooth. After all, with proper care, teeth have been lasting the entire lifetime of many patients. Additionally, implants and their restorations are not always successful due to systemic factors and other factors such as the surgical procedure used or the implant placement location that results in unfavorable biomechanics (FIGURE 1). Likewise, not all root canal treatments are successful either due to the inability to instrument the presence of unique anatomy or the subsequent restoration procedures (FIGURE 2).
Conclusion

Based on data from the literature, it is evident that both endodontic treatment and dental implants have a place in the dental care of patients. Patient-centered dental care must include providing patients with evidence-based information about treatment options suggested. Such an approach will allow both disciplines in dentistry to coexist for the patients’ benefit.

REFERENCES

LOS ANGELES COUNTY


ENCINO — GP w/ 4 eq ops in a prof. bldg. w/ views to the mountain. Fee for service. Net $144K. Gross. $488K in 2017. Property ID #5210.0

GLENDALE — Beautiful office w/ 3 eq ops in a 850 sq ft. LH & Equip Only! Great starter office. Near residential & commercial area. Property ID #5208.


MOTEBELLO — Grossed approx. $1M in 2017, located in a free standing bldg w/ 5 eq ops. Established in 2002. Property ID #5107.


KERN, VENTURA, & SAN LUIS OBISPO COUNTIES

COMING SOON IN FRESNO, GOLETA & OXNARD

ORANGE COUNTY

ANAHEIM — Established in 1960’s this practice is on a single story bldg w/ 3 eq ops. Grossed $735K in 2016. Net $308K. Property ID #5190.

BREA — Beautiful well established practice located on a corner location. Has 8 equipped ops and 3 chairs in open bay. Grossed $1.5M. On a busy major street of the city. Property ID #5190.


SANTA ANA — GP w/ 37 yrs of gdwl right off freeway in busy shopping center. Has 3 eq ops / 1 plumbed not eq. PPO/Cash/HMO. Projecting approx. $184K for 2017. Property ID #5161.

TUSTIN — Beautiful office w/ 4 eq ops w/ 3 eq ops. Grossing approx. $1.2M. Property ID #5182.

SAN DIEGO COUNTY

CARLSBAD—Well established GP w/ 3 eq ops and 2 plumbed not equiped residential are. Buyer’s net of $121K. Property ID #5191.

SAN DIEGO — Well established practice w/ 3 new eq ops in a 1,087 sq ft suite. Projecting approx. $300K. Net $127K. Property ID #5200.


RIVERSIDE & SAN BERNARDINO COUNTIES

BEAUMONT—GP + Real Estate: Modern GP w/ 6 eq ops in 2,400 sq ft of bldg. One two suites. Grossed $960K in 2016. Property ID #5182.

CHINO—Real Estate Only! This is a rare opportunity to purchase a condo located in a single story strip mall. Has been a dental practice for 40 years. Property ID #5076.


FONTANA — GP + Real Estate!! Premier office with 50 years of goodwill. In a 1,000 sq ft bldg w/ 8 eq ops. Has the latest technology. Grossed approx. $2.3M in 2016. Net of $968K. Property ID #5140.


TEMECULA—Modern dental practice w/ 3 eq ops. Projecting approx. $240K net of $444K. Property ID #5155.


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Spring is a prime time to deep clean your practice and tie up any loose ends from the previous year. It’s also a great opportunity to review your patient records and ensure all files are accurate and current.

Below are some things to consider when revisiting patient charts. If you find something is missing, review the chart with your patient at their next visit.

**Does the chart have a signed treatment plan?**
Before beginning any dental treatment, you should document the clinical exam findings, diagnoses of the patient and your treatment recommendations. A treatment plan should include a complete overview of the treatment to be performed, how it will help your patient, alternatives available and alternatives selected, in addition to any part of the treatment requiring referral to a specialist.

Note patient expectations regarding cost of treatment, overall aesthetics and longevity of treatment. Should finances affect the patient’s treatment decision, the risks and consequences of delaying treatment should also be discussed and noted in the chart.

**Does the chart have a signed financial agreement?**
For many patients, finances will play a significant role in the treatment plan. When discussing treatment options, be sure to include the patient’s estimated dental benefits portion of payment and predicted out-of-pocket expenses while making it clear that the patient is ultimately responsible for all fees regardless of what their dental benefits cover. If a patient has concerns about paying for treatment, consider offering payment arrangements that will fit their finances rather than altering the treatment plan.

Keep a signed copy of the financial agreement in the chart separate from the medical history. This will help avoid mixing the patient’s protected health information (PHI) with their financial information should there be a need to share financial data with a third party that should not have access to the PHI, such as a collection agency.

**Is the patient’s health history form current?**
Ideally, you should review a patient’s health history at every appointment. Go over the previous health history form and update as needed. Be sure to clarify any unanswered questions and inquire as to any recent visits to another health care provider.

Inquire about pregnancies, surgeries, radiation therapy, trips to the emergency room or other hospitalizations. Review their current medications and note if they have begun, discontinued or changed any

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prescribed or over-the-counter medications. Have the patient sign and date the health history form and all subsequent updates.

If you are concerned about treating a patient with underlying health issues, you can obtain medical consultation with their primary care physician before proceeding. Keep the physician’s response in the patient’s file and follow their recommendations to ensure patient safety.

Is the patient chart inactive?
While there are no statutory requirements, The Dentists Insurance Company (TDIC) recommends that you keep patient charts for a minimum of 10 years after the last date the patient is seen, if not indefinitely. For patients who are minors, you should retain their chart for 10 years from their last treatment or seven years past age 18. If you decide to dispose of inactive patient charts, it is imperative that you do so in a way that is consistent with HIPPA regulations.

In one case reported to TDIC’s Risk Management Advice Line, a dentist was seeking to shred outdated patient information. He canceled his prior contract with a licensed and bonded shredding company and hired a “friend of a friend” who promised to shred the confidential records at a reduced rate. The dentist paid the individual $200 to shred the files without having signed an associate agreement. The dentist became concerned when he did not receive a shredding confirmation. Ultimately, he realized that he might never hear from him. The dentist also understood the potential for a claim of unauthorized disclosure of PHI should these patient records be discovered intact. The Risk Management analyst suggested ways to avoid such problems in the future and recommended reporting the matter to the police for any assistance in locating the individual.

Having a complete, well-documented patient chart doesn’t just keep your practice neat and organized, it may help resolve potential patient disputes. Your treatment records are yet another tool to clearly communicate expectations with your patient and build a foundation of trust and transparency.

For more information on record keeping and to access patient forms and associate agreements, visit tdicinsurance.com/reference-guides.

TDIC’s Risk Management Advice Line at 800.733.0633 is staffed with trained analysts who can provide guidance on patient records and other questions related to a dental practice.

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Linda Brown
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4159 SANTA ROSA GP  Dedicated practitioner retiring from practice with emphasis on Restorative care. Located in a class “A” professional building in well-travelled area. 2,330 square foot office with 5 ops., reception area, business office, private office, consult room, staff lounge, lab area, sterilization area, and private bathroom. 4 doctor-days per week and approximately 1,000 active patients and average Gross Receipt of $733K+. Asking $557K.

4225 EUREKA GP & BUILDING Established since 1981 in charming Northern California port city. Retiring doctor is offering practice and building. Practice has approximately 1,200 active patients with new patients accepted on a selective basis. Average Gross Receipts of $769K+ with 61% average overhead. Free standing building at premier Henderson Center location in the heart of Humboldt county. Beautiful 1,400 square foot office with four (4) fully-equipped operatories. Asking price for practice $468K. Building available to purchase.

4216 SIERRA NEVADA FOOTHILLS 23 year practice located in the heart of the Sierra Nevada foothills in modern condiminumized building close to downtown area. 1,024 square foot office with 4 fully-equipped ops., upgraded major equipment and digital radiography. Seller is retiring and looking for a relaxed and personal practitioner for his loyal patient base. Average Gross Receipts $890K+ with 56% average overhead. Asking price for practice $634K. Seller is offering real estate for sale to the buyer of his practice.

4207 MID PENINSULA GP  Seller retiring 16 year practice with an emphasis on Restorative and Diagnostic care. Asking $386K.

4178 SONOMA COUNTY PERIO  Seller retiring from 21 year practice with trained, seasoned staff and great location. Exceptional 2,100 sq. ft. ample office with 6 fully equipped ops. Majority of equipment purchased in 2002. 4 doctor-days & 3 hygiene days per week. Average gross receipts $11M+. Asking $677K.

4198 NORTH BAY PERIO  Established Periodontic practice with loyal referral sources in 1,584 square foot office with 5 fully-equipped operatories conveniently located close to Petaluma Valley Hospital. Average Gross Receipts $480K. Seller is offering the condiminumized office for sale to the buyer of the practice. Asking price for practice $284K.

4191 SONOMA COUNTY ENDO  Seller retiring from 38 year endodontic practice located in attractive floor office (remodeled in 2011) with updated modern equipment and cabinetry. Close to several regular referral sources. Doctor sees an average of 7-8 patients per day. 5 year average Gross Receipts $700K+. Asking $447K.

4210 UNION CITY GP  Retiring GP offering 40+ years of goodwill. Excellent location in Professional Bldg on major thoroughfare. 5 ops in 1,100 sq. ft. 350 active patients, all fee-for-service. 2 yr average GR $177K. Seller willing to help for smooth transition. Asking $65K.

4202 SANTA CRUZ COUNTY GP  Retiring GP offering 40+ years of goodwill with emphasis on restorative. Asking $300K.

4161 CONTRA COSTA COUNTY ENDO  Seller retiring from well-established practice in desirable neighborhood. Located in professional center with several loyal referral sources. 1,445 square foot office with 3 operatories and current lease with two 5 year options to extend. 2016 gross receipts $388K+. Asking $248K.

4196 PACIFIC HEIGHTS SOLO GROUP  Enjoy the benefits of a well established successful group while maintaining your individual general practice in a modern fully-equipped office with well trained personnel. Approximately 1,400 active patients with an average of 10 new patients per month. Average gross receipts $689K+ with an equivalent of 3 doctor days per week. Asking $423K.

4172 NAPA GP  Amazing opportunity to own the practice of your dreams in one of the world’s premier wine destinations! Situated in a prime commercial and residential mix neighborhood close to shopping facilities and many amenities. Seller owned 1,200 square foot well laid-out office with 4 fully-equipped and updated operatories. Over 1,000 active patients. Average annual gross receipts over $700K based on the past 5 years. Asking price for practice $484K. Building available for purchase.

4219 SANTA CRUZ FACILITY  Great dental facility close to several amenities and minutes to HWY 1, and HWY 17. Plenty of parking and great street visibility. Turnkey dental office in 1,200 square foot facility with 3 fully-equipped ops. Asking $75K, sale.

4227 REDWOOD CITY GP  Profitable, established, general practice available, now, in rapidly growing Redwood City. Over 1,000 active patients & a 5 year average gross receipts of $850K net. Beautifully remodeled handicap accessible office with 4 fully-equipped ops. Asking $639K.

4230 SOUTH VALLEY GP  Well-established GP offering 30+ years of goodwill in very desirable suburb of Silicon Valley. 3 fully equipped ops in 1,000 sq. ft with room for 4th op. Beautifully appointed, pristine office in Professional Complex. Owner/doctor works 3 days/week. 350+ active patients. 2017 GR $278K w/adj net of $110K. Asking price $225K.

4229 SARATOGA GP  Absolutely beautiful turnkey office offering 30+ years of goodwill. All buyer has to do is move in! Fantastic location in well known Professional Building on well-traveled, major thoroughfare. 4 fully equipped ops in 1,500 sq. ft facility. 600 active patients (all fee-for-service). 1.25 days/hygiene week. Last 4 years average GR $285K. Seller willing to help for smooth transition. Asking $290K.

4215 SILCON VALLEY ENDO  Practice in prime Silicon Valley location with 40+ loyal referral sources. 900 square foot office in modern professional center with 2 operatories. Averaging 20 new patients per month. Long term staff. 2017 gross receipts $805K. Asking $399K.
A dentist is obligated to make reasonable arrangements for the emergency care of a patient whether or not the patient is a patient of record. A failure to make reasonable emergency care arrangements for patients of record may result in a charge of patient abandonment. It is unprofessional conduct for a dentist to abandon a patient without written notice that treatment will be discontinued and before the patient has had sufficient opportunity to secure the services of another dentist.

In addition, dental benefit plans require contracted providers to arrange for after-hours emergency care of their enrollees. Dentists should check a contracted plan’s provider manual or handbook for the requirements. One major plan requires that emergency care be available 24 hours a day, seven days a week and to have an active after-hours mechanism, such as an answering machine, answering service, cellphone or pager, available for 24/7 contact or instructions. The plan also requires that urgent care be provided within 72 hours when consistent with the patient’s individual needs and required by generally accepted standards for dentistry.

Professional ethics require that a dentist make a reasonable arrangement for emergency care of a patient who is not of record. Treating or consulting with a patient for the first time in an emergency does not make the individual a patient of record.

Examples of reasonable arrangements:

- Before leaving on an extended vacation or absence from the practice, arrange for emergency coverage with one or more colleagues. Notify patients in advance and provide contact information for the colleagues.

- For times when the dental practice is closed, leave an outgoing message on the telephone answering system that provides instructions on how a patient can contact the dentist or a colleague who is providing emergency coverage. If using an answering service, instruct the operator to collect information from the patient that includes full name, date seen by the dentist, complaint and a phone number (ensure...
a HIPAA business associate agreement has been signed with the service). The dentist should have a method for verifying patients of record as well as verifying patients of colleagues for whom the dentist is providing emergency coverage. After listening to a patient’s complaint, a dentist may choose to:

- Prescribe pain relief and other medication, as appropriate, with direction to the patient to present for an examination at the earliest possible time.
- Direct the patient to an emergency room or urgent care facility.
- Direct the patient to present at your dental office for an examination as soon as possible.
- A dentist who agrees to see a patient at a time when the office is typically closed should take appropriate precautions for personal safety. Dentists are not required to see an emergency patient in the middle of the night. If contacted by a patient in pain in the middle of the night, a dentist can refer the patient to a hospital emergency room or urgent care facility for pain relief and then direct the patient to present at the office at the earliest possible time.
- Be sure to keep records of these after-hours consultations.

Do not leave an outgoing message directing emergency patients to contact the local dental society, unless the dental society has agreed to and implemented a plan for handling such calls. A dentist may want to join or start a mutual aid group to formalize arrangements with colleagues for coverage. For more information, review “Practice Interruption and Mutual Aid Group Guidelines” on cda.org/practicesupport.

Reference

CDA Code of Ethics
Section 8: Emergency Service
A dentist has the obligation to make reasonable arrangements for the emergency care of his or her patients of record. A dentist has the obligation, when consulted in an emergency by a patient not of record, to make reasonable arrangements for emergency care of that patient.

Advisory Opinion:
8.A.1. Continuity of care: In the interest of preserving the patient’s continuity of care, a dentist who treats a patient not of record shall recommend to the patient to continue treatment with the original treating dentist unless the patient expressly reveals a different preference.

Regulatory Compliance appears monthly and features resources about laws that impact dental practices. Visit cda.org/practicesupport for more than 600 practice support resources, including practice management, employment practices, dental benefits plans and regulatory compliance.
6140 SAN RAFAEL  Dentist retiring after long career. Delta PPO provider. Has averaged $390,000 in annual collections on 3.5-day week. 900+ different patients seen in the last 18-months.

6139 SAN FRANCISCO BAY AREA PROSTHODONTIC PRACTICE  Very strong pedigree. Well positioned for the future. Excellent platform for younger Prosthodontist. Out-of-network! 2017 billed $1.2 Million and collected $1.19 Million. 4-days of Hygiene. Owner can work back to help assist with transition.

6138 SAN FRANCISCO BAY AREA'S SOUTH BAY  Phenomenal opportunity shall secure a rewarding career. 3-ops equipped (4th available), Panorex, and paperless.

6137 SOUTH SACRAMENTO AREA  Growing PPO practice topped $1.5 Million in collections in 2017. Profits exceeded $500,000 after paying Associates. 6-days of Hygiene. 6-ops. 3-D Pano and paperless. Over $400,000 invested here recently. Great location.

6136 SAN RAMON  Strong foundation here. Collections for 2017 totaled $575,000. And this was on a work schedule averaging 2.5-days a week. 3-ops. Seller can work back 1-day a week to assist in transition.

6135 SONOMA COUNTY’S Rohnert Park  2017 collected $1,050,000 reflecting nice growth over 2016 which collected $940,000. Profits exceeded $500,000 for the second year in a row. 6-days of Hygiene. There shall be no change in fees for the Successor. New homes being built nearby.

6133 SAN RAMON’S BISHOP RANCH  Beautiful 4-op, computerized and digital office. Located in the Bishop Ranch Medical Center. Bring Business Plan. Great addition to existing network. Full Price $150,000

6132 UNION CITY  $420,000+ invested here. Very high end for great patient experience. 3-ops. (4th available), Panorex, completely networked and digital. $600,000+ in revenues.

6129 FOSTER CITY / SAN MATEO  Wish to infuse your practice with quality patients? Out-of-network practice collected $500,000+ in 2017 on part-time schedule. Seller and Hygienist shall relocate into Buyer’s practice to transition patients. Full Price $100,000.

6125 OAKLAND’S LAKESHORE VILLAGE  Collections average $735,000 per year. Highest zip code with well employed Millennials next door. 10+ new patients per month. Digital and paperless.

6122 SANTA CLARA - STARBUCKS "LIKE" LOCATION!  Best exposure in beautiful strip center. Office just remodeled. 5-ops. Currently trending $1+ Million in Collections on 4-days. Perfect platform to operate 6-days a week. Can do $1.5+ Million.

6121 NAPA VALLEY FAMILY PRACTICE  Highly respected community asset. Collections for 2 years have averaged $1.28 Million per year. Beautiful facility. Condo optional purchase.

ALTA LOMA  Shopping Center. Hi identity. Absentee Owner. Grossing $700,000. Hands-on successor can do $1 Million. 5-ops, 3 equipped.

BAKERSFIELD  Free-standing 3,000 sq.ft. building. 5-ops. Established 60-years. Can do $1 Million. FP $650,000 includes RE.

BAKERSFIELD AREA  Small City. Grosses $400,000/month on 2-day week. 1,800 sq.ft. 5-ops with small apt. Full Price $330,000.

BELLFLOWER  Female DDS doing $100,000. 3-ops. FP $65,000.

COLTON  Hispanic practice grossing $350,000. Absentee Owner. 5-ops. Rent $1,450. Hands-on Owner will do $500,000 first year.

DIAMOND BAR  Korean / Chinese Shopping Center. Very busy until 9 PM. Owner works 1-day week. Does $450,000. Hands-on successor will do over $1 Million.

GLENDALE / BURBANK  Absentee Owner grossing $840,000. Beautiful corner building. Newly renovated. 5-ops with room for more. RE includes small apt. HMO almost pays mortgage.

GLENDALE  $2 Million location. Gorgeous.

INLAND EMPIRE  3,000 sq.ft. building. 7-Adec ops, Cone Beam. Grossing $1.3 Million. Full Price $2.5 Million includes real estate.

INLAND EMPIRE Dentical. Grosses near $300,000. 4-ops. Rent $1,350. Full Price $150,000.

INLAND EMPIRE Union Practice can do over $1 Million. 5-ops.

IRVINE  Female Owner grossing $1.2 Million. 5-ops.

LA MIRADA  Hi identity shopping center. HMO pays rent. Like new 3-ops with 2-more available. Grossing $450,000. Million Dollar location. New next-door tenant with 1,000 family members. Great upside.

LAKE FOREST  Adec equipped. Like new in appearance. Female DDS grossing $385,000. 30 new patients/month. Buyer shall do $500,000 first year. Option to purchase condo.

LOS ALAMITOS  Gorgeous. 5-ops. Grossing $1.4 Million. Special “All on 4” Program. Refers out OS, Endo, Pedo, Ortho. Absentee Owner.

ORANGE COUNTY BEACH  Professional building. 6-ops equipped. Dentrix, digital & computerized. Full Price $150,000.

ORANGE COUNTY BEACH CITY  Absentee Owner. Grossing $550,000. 4-ops with room for 5th. Hands-on Owner will do $1+ Million first year. Valuable RE possible.

ORANGE COUNTY’S FASHION ISLAND  Unique situation. Female grossing $400,000.

ORANGE COUNTY’S FASHION ISLAND  Grossing $650,000. Rare opportunity.

PEDO – CHINESE / HISPANIC  Grossing $450,000. Long established. Full Price $285,000.

REDLANDS  6-ops. Long established. Has done $1 Million. Lots of potential. Low rent. Grossing over $400,000. HMO pays rent.

RIALTO  210 Freeway. Professional building on 2.2 acres. HMO practice once did $1+ Million. Now only $325,000. Can be restored to $1+ Million.

SANTA CLARITA  70,000 autos pass daily. 8-ops. Absentee Owner. Full Price $250,000.

SANTA CLARITA  Hi identity shopping center. Owner wants to share office and remain 2-days in 2-ops. 5-ops available. Possible for long term employee DDS, with or without ownership. Upscale area.

WEST COVINA  Grossing $650,000. 2-days hygiene. Absentee Owner. Refers out OS, Endo, Pedo, Ortho.

SOUTH SANTA CLARA  Beautiful community asset. Collections have averaged $1.28 Million per year.

SOUTHERN CALIFORNIA  "LIKE" LOCATION!  Beautiful community asset. Collections have averaged $1.28 Million per year.
### Bay Area

<table>
<thead>
<tr>
<th>Facility</th>
<th>Description</th>
<th>Price</th>
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<tbody>
<tr>
<td>AC-624 SAN FRANCISCO</td>
<td>Wonderful patients, solid income in great stand-alone bldg</td>
<td>$475k</td>
</tr>
<tr>
<td>AC-649 SAN FRANCISCO</td>
<td>Richmond District, 3 ops+1 add'l, Equipment less than 5yrs old</td>
<td>$120k</td>
</tr>
<tr>
<td>AC-782 SAN FRANCISCO</td>
<td>Well maintained, multi-level Professional Medical Complex. 1450 sf w/ 5 ops</td>
<td>$250k</td>
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<tr>
<td>AN-752 SAN FRANCISCO</td>
<td>2 months Free Rent! Opportunities like this one are few and far between!</td>
<td>$1.4M</td>
</tr>
<tr>
<td>BC-741 DANVILLE</td>
<td>Move in Ready facility to build the practice of your dreams! ~ 1600sf w/ 3 fully equipped ops</td>
<td>$1.99M</td>
</tr>
<tr>
<td>BC-758 PLEASANT HILL</td>
<td>Gorgeous décor &amp; remarkable location! 768 sf w/ 2 ops</td>
<td>$35k</td>
</tr>
<tr>
<td>BC-789 OAKLAND</td>
<td>Perfect layout for Pedo or Ortho. 2800 sf w/ 6 fully equipped ops. Plumber for 2 add'l</td>
<td>$250k</td>
</tr>
<tr>
<td>BC-793 BERKELEY</td>
<td>2-story Prof Bldg. 1382 sf w/ 4 ops &amp; professionally designed for flow</td>
<td>$475k</td>
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<tr>
<td>BC-804 EMERYVILLE</td>
<td>Professional Complex (ADA-compliant). 1740 sf w/ 4 ops &amp; room for 2 add'l</td>
<td>$395k</td>
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<tr>
<td>BC-805 EAST BAY</td>
<td>Stellar, high Quality practice consistently generates ~ $3M annually. 3000 sf w/ 6 ops</td>
<td>$1.99M</td>
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<tr>
<td>BC-743 ANTIQUE</td>
<td>The perfect place to work, live and play! Located in desirable professional neighborhood. 1,323 sf w/ 4 ops</td>
<td>$315k</td>
</tr>
<tr>
<td>CC-798 PETHALUMA</td>
<td>Partially equipped dental office for lease. Only $2500/mo for 1400 sf! Call for Details!</td>
<td>-</td>
</tr>
<tr>
<td>CC-802 SANTA ROSA</td>
<td>Retail shopping center w/ 1200 sf and 4 fully equipped ops</td>
<td>$220k or $260k w/CT Scanner</td>
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<tr>
<td>CG-816 NAPA</td>
<td>State-of-the-art practice. Seller moving out of state!</td>
<td>$425k</td>
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<tr>
<td>CN-829 MILL VALLEY</td>
<td>This once-in-a-lifetime opportunity awaits your drive, talent &amp; skill! 1200sf w/3 ops + 1 add'l</td>
<td>$310k</td>
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<tr>
<td>DC-786 LIVERMORE</td>
<td>Move in ready &amp; recently updated! 2380 sf w/ 3 fully equipped ops. Plumberd for 3 add'l</td>
<td>$190k</td>
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<tr>
<td>DC-805 CASTRO VALLEY</td>
<td>Seasoned Staff and Loyal PT base! 1800 sf w/4 ops in 2-story prof bldg</td>
<td>$420k</td>
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### Bay Area Continued

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<th>Description</th>
<th>Price</th>
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<tbody>
<tr>
<td>DC-812 REDWOOD CITY</td>
<td>Reasonable rent and great landlord! 740 sf w/ 3 fully equipped ops</td>
<td>$100k</td>
</tr>
<tr>
<td>DG-635 CASTRO VALLEY</td>
<td>Excellent location &amp; stellar reputation! Solo Group Practice</td>
<td>$650k</td>
</tr>
<tr>
<td>DN-771 SOQUEL</td>
<td>The perfect place to sink down roots, raise a family &amp; build an empire!</td>
<td>$50k</td>
</tr>
<tr>
<td>DN-774 FREMONT</td>
<td>This opportunity has it all and awaits your talent and skill! 1,150sf w/3 ops + 1 add'l</td>
<td>$150k</td>
</tr>
<tr>
<td>DG-785 SANTA CRUZ</td>
<td>Known for its amusement park &amp; beach boardwalk, this community has much to offer! 1000sf w/4 ops. Now Only: $200k</td>
<td></td>
</tr>
<tr>
<td>DG-790 SAN JOSE</td>
<td>Two Practices being offer at one great price! Priced to sell at $1.4M. Call today for more details!</td>
<td>-</td>
</tr>
<tr>
<td>DN-796 SAN JOSE</td>
<td>This well-oiled general practice w/ emphasis on treating Pediatric patients! 3473sf w/10 ops + 2 add'l</td>
<td>$550k</td>
</tr>
<tr>
<td>DG-806 WATSONVILLE</td>
<td>This quality, family-oriented practice thrives 5 focuses on delivering quality care. 1,187sf w/4 OPS.</td>
<td>$550K/ Real Estate TBD</td>
</tr>
<tr>
<td>DN-809 PLEASANTON</td>
<td>Ranked as “one of the best cities to live in”, one can certainly understand why! 1100sf w/ 3 ops + 1 add'l</td>
<td>$480k</td>
</tr>
</tbody>
</table>

### Northern California

<table>
<thead>
<tr>
<th>Facility</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC-729 GREATER SACRAMENTO AREA</td>
<td>Seller retiring! FFS Practice and Real Estate Available!</td>
<td>-</td>
</tr>
<tr>
<td>EN-664 SACRAMENTO</td>
<td>Great corner location, excellent visibility &amp; easy access! 2300sf w/ 4 ops.</td>
<td>$140k</td>
</tr>
<tr>
<td>EN-702 SACRAMENTO</td>
<td>Long-established practice w/ emphasis on preventative dentistry! 1600sf w 4 ops + 1add'l. $450k Real Estate $325k</td>
<td>-</td>
</tr>
<tr>
<td>EN-747 CITRUS HEIGHTS</td>
<td>Be the only dental office in this attractive, popular Retail Shopping Center! 2200sf w/5 ops + 6 add'l. $75k</td>
<td>-</td>
</tr>
<tr>
<td>EN-754 FOLSOM</td>
<td>A perfect location, envied by all! Enjoy an amazing quality lifestyle in this thriving city. 1200sf w/ 4 ops.</td>
<td>$175k</td>
</tr>
<tr>
<td>EN-768 WEST SACRAMENTO</td>
<td>family-oriented practice, equipped with updated technology! 1612sf w/4 ops.</td>
<td>$275k</td>
</tr>
</tbody>
</table>

**800.641.4179 WPS@SUCCEED.NET**
NORTHERN CALIFORNIA CONTINUED

EN-791 SO. SACRAMENTO CO: Highly esteemed practice to an adoring & appreciative patient base! 1950sf w/ 5 ops $450k
EG-788 ROSEVILLE: Do not pass up on this remarkable opportunity! 2700sf w/ 6 ops, $300k
EN-800 SACRAMENTO: Awaiting your talent and skill to take it to the next level! 1200sf w/ 4 ops, $150k
EN-797 WOODLAND: Do not hesitate or this enviable opportunity will fulfill someone else’s dream! 2316sf w/ 6 ops. Practice $650k/ Real Estate TBD
EN-803 ROCKLIN: Continue the philosophy of serving your patients as if they are family! 150sf 3 ops + 1 add’l, $425k
EN-831 SACRAMENTO: Location & practice philosophy make this opportunity “a cut above” others! 1600sf w/ 4 ops. $775k
FC-650 FORT BRAGG: Family-oriented practice. 5 ops in 2000sf, 6 npts/ mo $350k for the Practice & $400k for the Real Estate
FN-754 SO. HUMBOLDT: If you love the lure of sea air, a relaxed lifestyle & charm of coastal living, then look no further! 1500sf w/ 3 ops + 1 add’l. Now $150k
GC-472 OROVILLE: Live & practice in charming small town community. 1000sf w/ 2 ops. Seller Retiring $160k
GN-717 YUBA CITY: Seller Retiring. All reasonable offers considered. Building available for purchase! 2400sf w/ 5 ops $475k
GN-746 YUBA CITY: State-of-the-Art Equipped! Includes the latest technology in CBCT Imaging. Real Estate also available! 1600sf w/ 3 ops + 1 add’l. Practice $480k/ Real Estate TBD.
GG-769 REDDING AREA: Offering a full spectrum of general dentistry and total care! 2700sf w/ 6 ops. Practice $390k. Real Estate $540k
GN-799 PARADISE: This remarkable opportunity is undeniably too good to be true! 1800sf w/ 4 ops. Practice $375k, Real Estate $325k
HG-732 GRASS VALLEY: Seller retiring. Well established practice. 1250sf w/ 3 ops. Real Estate also available. $215k
HG-815 SIERA CO: Perfect location for outdoor enthusiasts! 1000 sf w/ 3 ops $180k / Real Estate $437k
HN-280 NORTHEAST CA: Only Practice in Town! 900sf w/ 2 ops $60k
HN-618 SIERRA FOOTHILLS: Seller Retiring! Huge opportunity for growth by increasing office hours! 750sf w/ 2 ops $65k
HN-740 SHASTA CO: Beautiful mountain community, well-established practice, exceptional long-term practice. 2400+sf w/ 5 ops + 1 add’l. $475k/ Real Estate $350k
HN-773 SUTTER CREEK: Located in an area known for beautiful scenery, excellent wine and rich history! 1536sf w/ 4 ops + 1 add’l $195k
HN-816 CHESTER/ALMANOR AREA: The perfect place to work, live and play! Do not hesitate, or this practice will be gone! 1250 sf w/ 4 ops. Practice $140k/ Real Estate TBD

CENTRAL VALLEY

IC-468 SAN JOAQUIN VALLEY: High-end restorative practice! 6 ops in 2500+sf office. Call for Details! $425k

CENTRAL VALLEY CONTINUED

IG-687 TURLOCK: Established quality practice - remarkable opportunity! 2000sf w/ 5 ops $298k
IN-764 STOCKTON: Well-established, fully computerized, paperless, digitalized practice just waiting for your talent & skill! 5,000sf w/10 ops $267.5k
IN-776 STOCKTON: Step right in and you won’t miss a beat in this long-established, quality practice! 1046sf w/2 ops add’l. $25k
IN-830 LODI: Start living the life! Small town charm, stable patient base & low overhead! 1550 + 800sf w/ 4ops. $360k, Real Estate $300k
IC-811 FRESNO COUNTY: Amazing Opportunity! Considerable Goodwill in Community! 3,000 sf w/ 6 ops $350k
JG-778 FRESNO: What a steal. Consistent collections over $600k with cash flow over $300k!! 1452 sf w/ 4 ops $295k
JG-807 FRESNO: Reasonable Overhead, Stellar Reputation, Excellent Location! 1000 sf w/ 3 ops $156k
JH-770 MERced AREA: Stellar family-oriented practice with a loyal, stable patient base! 1250sf w/ 4 ops. $410k

SPECIALTY PRACTICES

AC-759 SAN FRANCISCO Endo: Union Square. 1190 sf w/3 ops (plumbed for 1 add’l) $495k
BC-784 CENTRAL CONTRA COSTA CO Perio: Seasoned Staff. Office runs like well-oiled machine! 3 ops $395k
BN-801 SAN RAMON Ortho: Don’t wait or you may miss out on this spectacular opportunity of a lifetime! 1865sf w/ 5 chairs/bays. $775k
EG-826 ROSEVILLE Perio: Create your success story with this warm and caring, patient-centered practice! 1000sf w/3 ops + 1add’l $150k
EN-821 GREATER SACRAMENTO AREA Perio: Live, practice & play here! It’ll be the BEST decision you’ll ever make! 1700sf w/ 4 ops + 1 add’l. $395k
EN-822 SACRAMENTO Perio: This practice is known throughout Sacramento for its stellar reputation! 2200sf w/ 5 ops + 1add’l $840k
IC-543 CENTRAL VALLEY Ortho: 1650sf w/ 5 chairs in open bay & plumbed for 2 add’l. Strong referrals and PT base $125k
HG-763 GRASS VALLEY Ortho: Avg 30+ pts per day. Newer retail Shopping Center $210k
IJG-757 VISALIA Perio: Keep implants in house and imagine the growth possibilities! 9 hygiene days per week! Rare Gem! 2,000 sf w/ 5 ops $395k

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Notability ($9.99, Ginger Labs)

Note-taking has an important place in human history. Whether it is on a piece of scratch paper, notebook, mobile device or tablet, the ability to jot down ideas and memorable thoughts is both invaluable and very personalized for each individual. Digital note-taking and its advances, such as the Apple Pencil for iPad Pro, have given consumers a worthwhile alternative to paper. Notability was created to give users the simple capability of writing notes with the flexibility and freedom that extends far beyond what paper can do.

Notability has myriad features that will satisfy any need. Pencil and highlighter sketch tools can be customized by stroke style, thickness and color. Text annotation can be modified by font, size, color, typography and paragraph style. Eraser, cut and picker tools allow for easy content modification. Voice annotations from the device microphone can also be attached to notes. Paper backgrounds can also be personalized by color and line or graph configurations. Imported photos and PDF files from other apps can be marked up and annotated. Multiple undo and redo functions give users the ability to correct any mistakes when sketching. Users have options to print, email and share with Dropbox, Google Drive, OneDrive, Box or WebDAV accounts. Notes can be organized into subjects and groups of subjects can be placed under dividers. Furthermore, notes can be backed up to any connected account and kept up to date across MacOS and iOS devices with an iCloud account. Users can purchase multiple themes to further personalize their note-taking space within the app.

Compared with the amount of supplies needed to take detailed notes conventionally, Notability gives users the capability to take powerful notes in a mobile or desktop app without the need for extra supplies. People can now simply put down their thoughts and ideas wherever they go.

– Hubert Chan, DDS

Vero (Free, subscription fee required, Vero Labs Inc.)

In the world of social media, platforms such as Facebook, Instagram and Snapchat are some of the recognizable powerhouses. A new app is gaining popularity, however. It is called Vero and it touts itself as a “true social” experience. The idea is that users can share videos, photos, links, etc. like on other platforms, without the things that are currently hampering the experience on other platforms. Vero claims there are no ads (there is a subscription cost to use it), no diving through user data, the posts show up in chronological order without constant algorithm changes, and it features security settings that allow users to build friend lists. According to reports, downloads of Vero for iOS and Android soared by a whopping 1,465 percent in one week in February. Time will tell if this app makes a true dent in the social media space.

– Blake Ellington, Tech Trends editor

70 Percent of Adults Over 50 Own Smartphones

A new study details the use of technology among adults over the age of 50. The study, conducted by AARP, found that 70 percent of adults in this age group own a smartphone and about the same amount have a presence on social media. In terms of staying connected, text messaging is the preferred method for those between the ages of 50 and 69. Adults who are in their 60s are more likely to use their device to manage medical needs than those who are in their 50s and 70s, according to the study. For the study, 1,520 adults over 50 were surveyed between Nov. 16–27, 2017. For more information, visit aarp.org.

– Blake Ellington, Tech Trends editor

Would you like to write about technology? Dentists interested in contributing to this section should contact Andrea LaMattina, CDE, at andrea.lamattina@cda.org.
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