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Journal of Cosmetic Dentistry

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The mission of the *Journal of Cosmetic Dentistry* is to educate AACD members, as well as other professionals in the field, on the art and science of cosmetic dentistry. We will endeavor to do this by publishing well-researched, peer-reviewed articles accompanied by high-quality, comprehensive clinical imagery. The objective is to enhance readers' knowledge and skills while showcasing the latest cosmetic techniques and procedures. The *Journal of Cosmetic Dentistry* will strive to help readers become better clinicians, so they can offer their patients the best—and most responsible—treatment possible.

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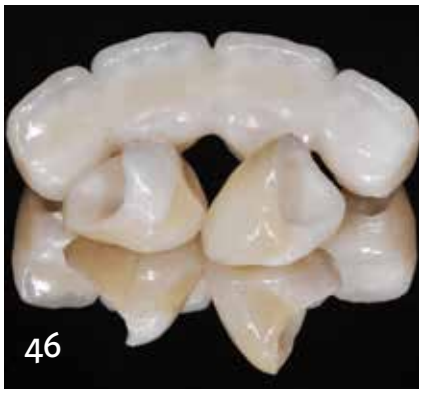

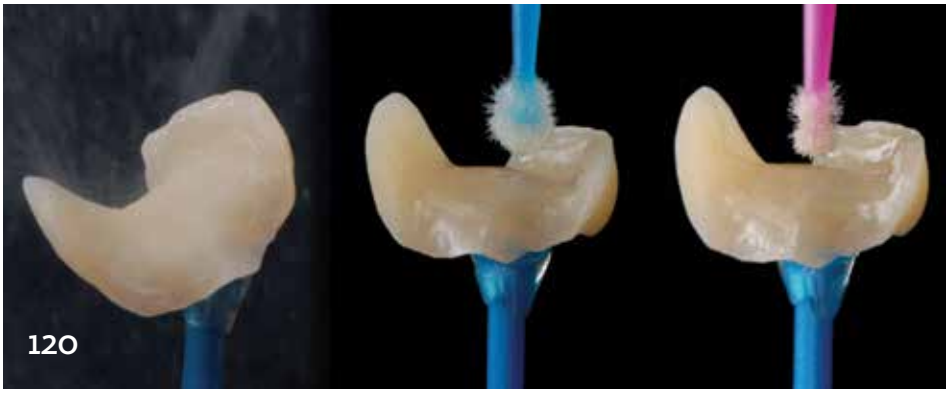

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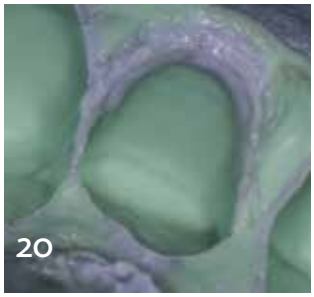

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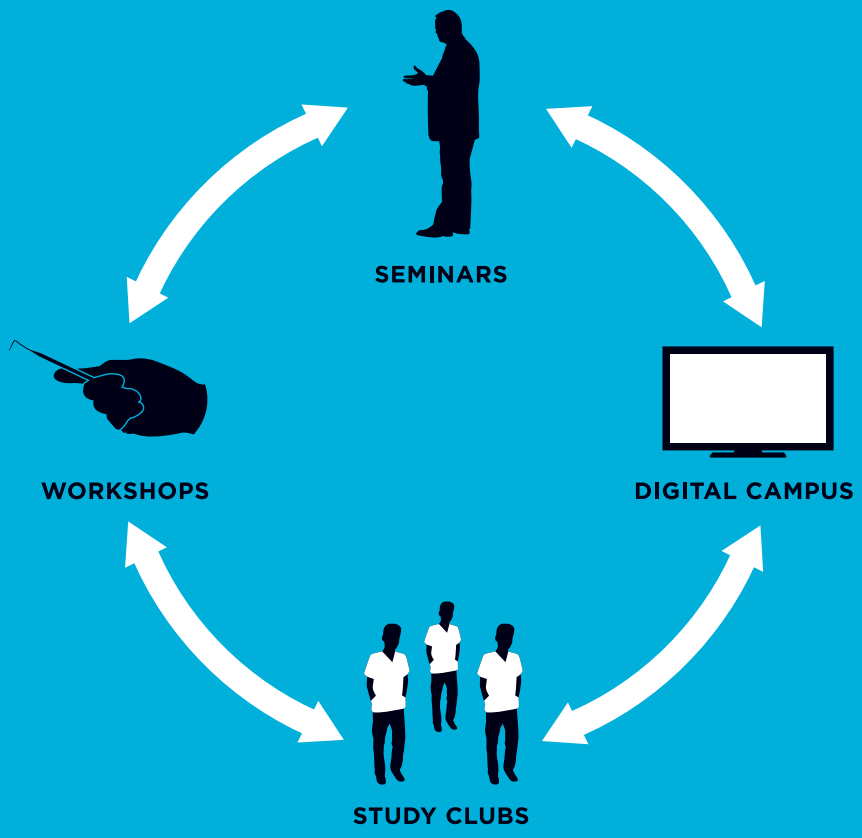

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Less Glitz, More Substance

Donald M. Brunette, PhD

Dr. Brunette is a professor in the Department of Oral Biological and Medical Sciences, Faculty of Dentistry, at the University of British Columbia.

Disclosure: Dr. Brunette is the author of the book mentioned in this article and he receives royalties from it.

Dentists are usually considered as the agents rather than the targets of persuasion. Certainly dentists must counsel their patients to choose the right treatment, but they need to be wary of the methods used in "selling" equipment/materials and clinical techniques.

While some innovations prove useful, dentists sometimes buy equipment and supplies they do not use. It is advantageous for dentists to be sophisticated consumers of clinical papers and continuing education courses, but these obviously are designed to convince the audience of the truth of the presenters' conclusions.

The tools of rhetoric classically employed, logic and emotion, are now supplemented with information obtained from modern psychological research. In particular, persuasion can be enhanced by such factors as the personality and perceived authority of the presenter, popularity of the method, simplicity and consistency of the message, and the use of vivid, concrete illustrations. But these attributes do not guarantee the truth of the message. Moreover, presenters may employ techniques such as overloading their audience with information, knowing that many of us tend to accept assertions at face value. Recognizing the employment of such approaches is a defense against their effectiveness.

Some general methods can be used to guard against being affected by rhetorical techniques. For example, one can employ the "assertability" question, developed by UK logician Robert Fisher, which asks: "What data would it take to convince me of the truth of the conclusion?"[1] In effect, this question takes away the presenter's advantage of controlling the agenda. Another useful approach is to examine every sample for its size, spread, and representativeness. The easily manipulable "before and after" images used as proof of effectiveness for diets or dental procedures can have considerable visual and persuasive appeal, but represent a sample of one that is highly unlikely to be representative of all patients treated.

Abelson's MAGIC criteria for persuasive force comprise assessing the following:

- magnitude of the effect
- articulation (the degree of comprehensible detail in the conclusion)
- generality (breadth of applicability)
- interestingness
- credibility (overall believability).[2]

Some general methods can be used to guard against being affected by rhetorical techniques.

The ability to assess these criteria accurately can entail some knowledge of statistics and research design, such as how various types of bias can lead to erroneous conclusions. Common sense will identify some problems, but others are subtle and require study to identify.

As presentations are often information-dense and delivered quickly, recognizing their deficiencies on the fly requires the target of persuasion to be able to use critical thinking and a systematic approach. The core skills in critical thinking, such as those presented in my book *Critical Thinking: Understanding and Evaluating Dental Research*,[3] have a wider application than just critical evaluation of professional presentations; they are useful in evaluating persuasive arguments in everyday life, including those of sales personnel, family, and friends.

Mastering such critical thinking skills will not guarantee you victory in every argument (emotion may raise its ugly head), but you will become a more discerning consumer who demands more substance and less glitz from the presentations you attend.

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WE DON'T HAVE A B TEAM.

Color in Esthetics: Dental Biomaterials—Friend or Foe?

Rade Paravina, DDS, MS, PhD

Dr. Paravina is a tenured associate professor at the University of Texas School of Dentistry at Houston and director of the Houston Center for Biomaterials and Biomimetics. He also is the Ralph C. Cooley Distinguished Professor in Biomaterials.

Disclosure: Dr. Paravina jointly developed VITA Linearguide 3D-Master and VITA Bleachedguide 3D-Master with Vita Zahnfabrik. The University of Texas Health Science Center at Houston has licensing agreements with Vita Zahnfabrik regarding commercialization of these two shade guides. Dr. Paravina is a paid consultant for Vita Zahnfabrik and the Society for Color and Appearance in Dentistry (SCAD).

Up Front *provides a forum for influential leaders to share their opinions. In this issue, we welcome dental color expert Dr. Rade Paravina. The views expressed in Up Front reflect the opinions of the author. They do not imply an opinion on the part of* jCD *or the AACD.*

We want materials that are color-compatible, color-stable, and exhibit good color interactions.

Dr. Ralph C. Cooley, the inventor of Copalite, was one of the first graduates of the Texas Dental College at Houston in 1908. He proved that there was much to be gained in patient care by the development of oral biomaterials, thus complementing the development of techniques, skills, and instruments. The passage of time has further validated Dr. Cooley's vision and beliefs, with the last decade probably being the most dynamic and exciting in the history of oral biomaterials.

Esthetics of dental restorations is related to many factors, including color, form, size, and position. Beauty is indeed largely in the eye of the beholder; patients' requirements range from "invisible" restorations to those that are perceptible yet harmonious with adjacent teeth, all the way to the "extreme makeover." Although individual expectations vary, they are frequently related to restoration type: fillings on individual teeth may elicit one expectation, whereas full-arch reconstruction would elicit another. Tooth whitening is not a restorative procedure in traditional understanding, but it can be seen as restoring and establishing (or reestablishing) their "lightest" color.

Optical properties of dental biomaterials and their interactions are very important predictors of esthetics in dentistry. They encompass color, translucency, gloss, photoluminescence (with fluorescence as its most relevant component), and iridescence. Color-related properties of dental materials are related to color compatibility, color stability, and color interactions.

There are three main categories of color compatibility in dentistry: compatibility between tooth and restoration, between different materials in the same mouth, and between different batches of the same material. Tooth-colored materials are typically keyed to dental shade guides and are supposed to match corresponding shade tabs.[1] Moderate-to-pronounced color mismatch among the same or different dental materials of the same shade designation can complicate dental restorative treatment.[2]

Shade guides are schematic representations of tooth color space and there is significant difference among shade guides in fulfilling two basic requirements: to have logical order and adequate color distribution. A parameter known as "coverage error" is very convenient for evaluation of shade guide quality. It represents the mean color difference between a set of natural teeth and their best matches in the given shade guide—the smaller the number, the better the shade guide. There have been numerous studies evaluating "coverage error" and they all reported that the best results were obtained for VITA 3D-Master shade guide (VITA Zahnfabrik, Bad Säckingen, Germany).[3] The most recent version of this product, Linearguide 3D-Master, offers additional simplicity and user friendliness, thereby maximizing the chances to select a good match.[4] The results of "coverage error" evaluations are not surprising given that 3D-Master is research-based, as opposed to the more widely used VITA Classical, which is based upon the empirical concept.

Color stability of dental biomaterials during fabrication (firing, glazing); at placement (polymerization, other types of setting);[5] and after placement (aging, staining),[6] can also be a friend or foe. Materials that exhibit good color stability are certainly welcome when it comes to immediate esthetic outcome and longevity of restoration. Tooth bleaching also includes color stability considerations. While color stability of dental restorations is highly desired and related

to materials, color stability upon bleaching is related to teeth, and their ability to change shade is welcome. Visual monitoring is frequently used for quantifying bleaching efficacy. A significant breakthrough in this area occurred with the inclusion of the 29-step VITA Bleachedguide instead of the so-called value scale of VITA Classical in the ADA guidelines for bleaching products.[7] This change will increase credibility of bleaching studies and enable inclusion and monitoring of all patients (even those with B1 tooth shade before bleaching), not only the patients with darker teeth as when Classical is used.[8]

The third group of color-related properties encompasses color interactions, specifically layering and blending. Overlapping multiple layers of different thicknesses is the very essence of dental anatomy and restorative dentistry. While layering has been thoroughly studied by clinicians, dental technicians, and researchers, and a plethora of information is available, blending effects are still on the "mysterious" side of color interactions. The number of dental materials that, according to manufacturers' descriptions, exhibit blending effect is inversely proportional to the number of references that back up these statements. The blending effect, frequently referred to as the "chameleon effect," consists of two major aspects:

- primarily perceptual phenomenon (optical illusion)—visible, but not measurable with any device
- translucency of dental materials and hard dental tissues as physical phenomenon—a component that can be measured.[9]

We want materials that are color-compatible, color-stable, and exhibit good color interactions. If we mismatch the shade or there is no good match in the shade guide, the material that blends well will compensate for this mismatch to a certain extent. In science, materials that have one or more properties that can be significantly and reversibly changed in a controlled fashion by external stimuli are called "smart" materials. Materials that change color in response to light are called "photochromic" materials, and this is exactly what we want to happen in the patient's mouth. Light-sensitive glasses and sunglasses that darken when exposed to bright sunlight are very common. Is something similar really impossible as a goal for esthetic dental materials?

In summary, why should we worry about color in dentistry? The answer is very simple: We are not as successful in our work with color as we tend to believe. The best cases of the most renowned dentists, shown at dental meetings and continuing education courses, are inspiring but they do not realistically represent day-to-day dentistry. The outdated sources of information with a dogmatic and mechanical approach to color problems in dentistry are certainly not helpful in overcoming some "weak links." On the bright side, improvements are possible and occur through collaboration, standardization, and research. At the individual clinician/laboratory technician level, several color education and training resources, with topics ranging from proper shade matching conditions and methods, all the way to advanced shade matching tools and dental materials, offer good background information and foundations.[10-14] Almost 40 years ago, Dr. Robert C. Sproull, a pioneer in color in dentistry, wrote: "The technology of color is not a simple matter that can be learned without study; neither is it a complicated matter beyond the comprehension of dentists."[15] Development of new materials and technologies continues to underline this statement. Buckle up—the best of color in dentistry is yet come!

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The Merit of Brilliance With the Finesse of Material

Excellence in cosmetic dentistry is what we all strive for, whether it is in delivering or receiving quality education or in enhancing our clinical skills. The *Journal of Cosmetic Dentistry* (*jCD*) is committed to educating readers about the art and science inherent in our dynamic field and we are proud to bring you some of the most magnificent talent ever seen.

This issue's cover depicts a molar buildup progression created by Dr. Newton Fahl, Jr. His pictorial essay about this buildup will be featured in the *jCD*'s Spring 2013 issue. It will present spectacular imagery with informative steps describing the creation of the molar buildup and will undeniably enlighten our readers.

For now, be sure to read Dr. Fahl's clinical article in this issue, beginning on page 60, regarding the application of direct composite for a Class IV anterior restoration.

Cover photography: Newton Fahl Jr., DDS, MS (Curitiba, Brazil). Cover images shot with a Canon EOS 5D Mark II (Lake Success, NY).

A Cosmetic Legend Shares His Secrets

An Interview with Dr. David Garber

Clinician and educator David Garber, DMD, lectures extensively throughout the U.S., Europe, South America, and Asia. He has co-authored numerous texts on topics including porcelain laminate veneers, porcelain and composite inlays and onlays, and complete dental bleaching. Dr. Garber and Dr. Maurice Salama will be speaking at the 29th Annual AACD Scientific Session in Seattle, Washington, on April 24, 2013. The title of his lecture is "*The Role of 'Team' in Reconstructive Esthetic Dentistry: A Defined Algorithm for Success.*" In this interview, Dr. Garber answers thought-provoking questions from the Editorial Review Board of the *Journal of Cosmetic Dentistry*.

Dr. Garber giving a small hands-on training course.

Q. Dr. Garber, many practices today are experiencing challenges with a tight economy and seeing patients who often want a better smile, but are unable to spend what it takes to achieve the "ideal" level. With that in mind, and considering your experience in both patient care and teaching, what are the three most important factors in improving a smile that give the greatest patient satisfaction?

A: It may seem contradictory, but I believe that the tight economy has, in fact, driven a particular group of patients into our offices specifically searching for cosmetic enhancements. This is not quite the same as during the cosmetic dentistry "boom" that coincided with the economic surge of the 1980s and early 2000s, when everyone wanted white teeth, veneers, etc. Rather, it is due to the fact that members of the "Baby Boom" generation are electing to remain in the work force far longer than what had been the norm. This, in turn, causes them to want a more youthful look, although inevitably on a much tighter budget. The AACD has long recognized that the predominant assets of a better smile for this age group (or any age group) are as follows:

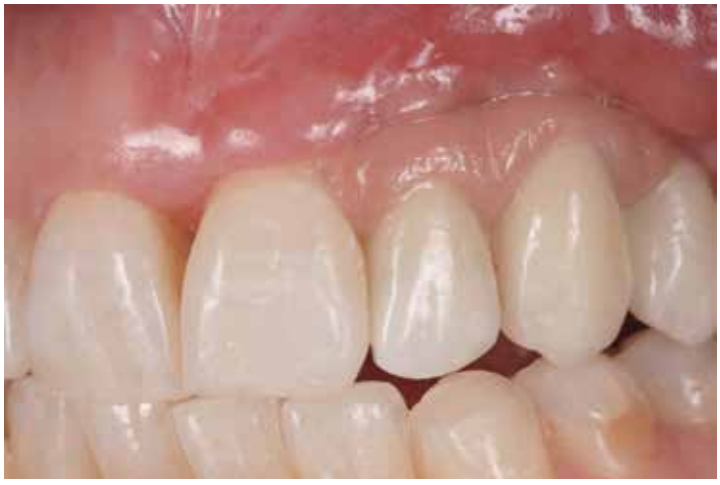
Web-based learning...has changed the very nature of dental education.

1. Color. Nothing signifies youth as effectively as lighter, brighter teeth. Fortunately, this can be achieved today with ever-evolving bleaching protocols.

2. Direct bonding. The new techniques of "matrix-derived" direct composite bonding provide a remarkably effective, yet economical, simple, and efficacious way of achieving beautiful immediate results. It does require, however, that we, as clinicians, learn to utilize this simpler, quicker, and better method of having a model waxed up to ideal tooth form and a hard silicone index made from it. This needs to be available chairside at the bonding appointment to make the process quick and financially viable within the context of our day-to-day practices. Few things indicate age as much as tooth wear and discoloration of exposed dentin. However, the simple combination of bleaching and pure, additive composite can make a truly significant yet economical change.

3. Tooth silhouette form and arch arrangement. We have long been aware that the individual tooth forms and their relative arrangement in each arch, as framed by the lips, need to be integrated with the physiognomy of the face.

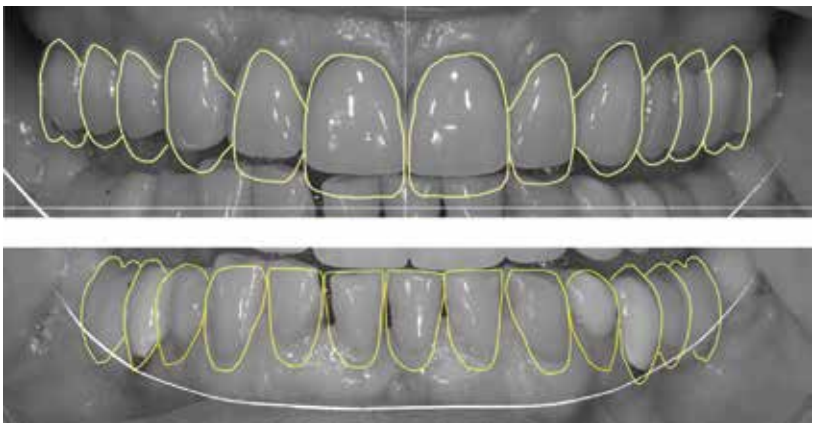
This concept of "smile design" and the relative positioning of teeth to one another, as well as the opposing arch and, most importantly, the lips, dates back in restorative dentistry to the 1970s and Dr. Leonard Abrams, and even before that in the realm of removable dentures. Dr. Earl Pound, at the 4th Annual AACD meeting, in 1988 (when we were still using slides with three projectors), presented "12 Steps to Smile Design." Dr. Jonathan Scharf tried to fix a jammed slide, and they all tipped out, making for a very disjointed smile design! We certainly have evolved since then. Today, we utilize computers, and the same type of presentation has been simplified into a "Digital Smile Design" by Drs. Christian Coachman, Gui Cabral and Ed McLaren (with nary a jammed slide). So it is effectively a repeat of the same past concepts, but with newer, simpler, faster, and more effective techniques and products. Soon, we should be using three-dimensional "dynamic" smile designs, incorporating motion into the treatment planning and clinical execution, with teeth developed by computer-assisted design/computer-aided manufacturing (CAD/CAM).



Compromised site restored with two implants and CAD/CAM-milled zirconium pink and white restoration.

So, from an economic perspective, simply lightening the remaining teeth, redeveloping the initial form with composite, and creating, if necessary, a more harmonious arch alignment will vastly enhance, if not completely optimize, the smile. A more complete but expensive makeover would require slightly more and invasive technologies such as porcelain laminate veneers; or newer all-ceramic, but less invasive, full-coverage restorations.

Q. After altering the dentition for a smile improvement, do you recommend a post-treatment bruxing guard for your patients? If so, what are your criteria for deciding which cases are appropriate, and can you elaborate on the design of the appliance?



Digital smile design using Keynote software.

A: The decision about whether to recommend a bruxing guard really depends upon clinical evidence of a "tooth-to-tooth" grinding habit. If so, I suggest the use of an upper, hard, full-coverage maxillary nightguard encompassing a soft liner material. This creates a more predictable fit and greater comfort for the patient. I ask that my patients bring the appliance with them at each hygiene appointment so that I can see the "track marks" created by the nocturnal grinding. I actually want to see it "grungy," with troughs so that we know it is being used. If the patient comes in and the guard does not appear to have been used, or if the patient is complaining that it is simply impossible to wear, I often move on to an anterior NTI-type appliance.

Q. Restorative dentistry has been revolutionized, and continues to be influenced, by CAD/CAM technologies. What current digital technologies do you incorporate in your daily practice, and what is your vision of the future periodontal/prosthodontic practice benefiting from these advancing technologies? Are you involved in any research and development of new technologies, and, if so, can you share with us what we may expect around the corner?

A: We have, at many different levels, been involved with CAD/CAM dentistry since its early days with Jean François Roulet, and we then evolved to our first-generation CEREC unit. Today, we also have the "three-shape" digital scanners and traditional Procera units. When we want to use CAD/CAM on multiple-unit restorative cases, we take a full-arch polyvinyl impression, pour the impression, then scan that model and send the digital information via the Internet to an off-site milling facility to develop the CAD/CAM dental restorations in lithium disilicate or full-contour zirconium on the molars and, perhaps, second premolars. Smaller cases are more effectivley done with an intra-scanner.

We have also worked with cone beam computed tomography (CBCT). The evolving three-dimensional software for CBCT is the key, making clinical information immediately available. I don't doubt that CAD/CAM and other digital technologies are the future of dentistry; in fact, I believe they are already the "present." The whole implant arena is testimony to this. This market is growing at an exponential rate because of the greater availability and lower cost of CBCT units, which are utilized for the initial diagnostics, then the treatment-planning phases and precise surgical placement. Use of these CT-developed surgical guides will become the standard of care and an invaluable tool in diagnostics.

Today, it is also possible to make digital impressions and have CAD/CAM customized, "virtually" developed abutments planned and sent back digitally for verification before being actually milled. Take a look at a video at www.DentalXP.com by Drs. Dean Vafiadis, Alessandro Agnini, and Andrea Mastrorosa Agnini, along with Luca Dondi, showing this process literally chairside; it is quick and easy. The temporary or final restorations can similarly be milled using an ever-expanding array of materials, including newer ceramic-filled composite or lithium disilicate and zirconia. The whole procedure is much safer and more versatile—thereby making it available to a much greater percentage of the population by an increasing number of providers.

The economics of the whole implant/restorative procedure, which was previously available only to wealthier patients, have been dramatically reduced by virtue of these digital technologies in so many different arenas. It is a fascinating, rapidly evolving, and exciting realm that we have fortunately been involved in both clinically and in a research and development capacity.

Q. Have various forms of social media (e.g., Facebook, Twitter) and the Internet had an effect on your practice? Are your patients more educated about the need for perio health when they arrive at your practice, and are they more willing to accept advanced treatment because of their greater awareness?

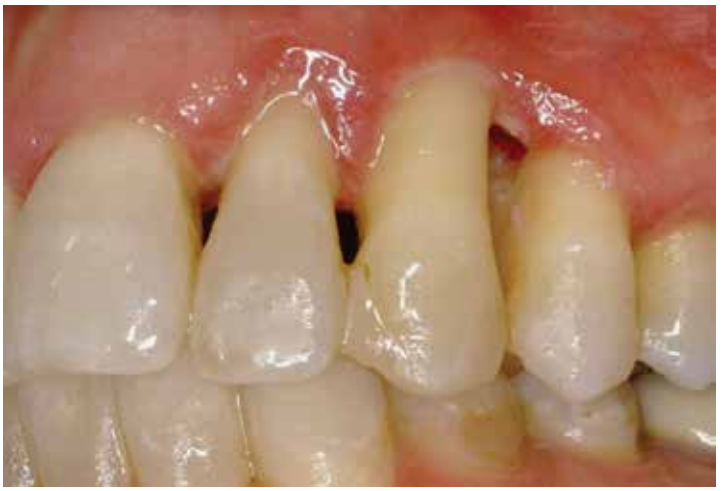
A: The Internet and social media have all had a major effect on our clinical practices and teaching methods. Patients can now participate, literally with a key stroke, in a "digital smile design" on a computer, tablet, or smart phone.

Learning and teaching are also more available to dentists by means of the Internet, and AACD members have access to www.DentalXP.com, where, at any time, they can watch videos of virtually any procedure, from 180 different experts with varying points of view and philosophies. Different techniques and materials are demonstrated, as the site is not aligned with any particular company, individual lecturer, or single product line. If, for example you are interested in the subject of composites, you can access experts such as Newton Fahl, Brian LeSage, Harry Alberts, Ronald Goldstein, Nassib Fares, Tom Trinkner, John Weston, Didier Dietschi, Jose Roberto Moura, Sergio Rubenstein, Nitzan Bichacho, Claudio Pinho, Glen van As, Wynn Okuda, Lou Graham, Corky Willhite, Jose Luiz Ruiz, Jeff Brucia, and Robert Lowe, among many others.

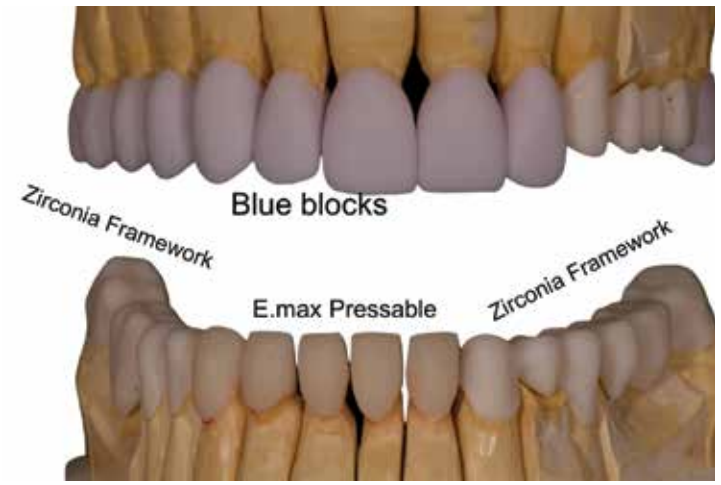
The DentalXP forum allows anyone to ask questions and easily post their own cases, images, and videos directly online. More than 10,000 other clinicians worldwide then have the opportunity to respond with a solution to that problem. In addition, it can be accessed on Facebook and with an always-accessible iPhone App or Android network. You can join this ever-expanding, socially aware group of dentists that constantly shares dental knowledge and experiences.

Q. Many of us have learned from amazing teachers across the globe. How can today's young dentists do this? The ability to travel to great teachers is sometimes unachievable financially.

A: Yes, many of us have been fortunate enough to travel great distances to learn from teachers in Europe, South America, and Asia. Today's economic climate, however, has made this more difficult and may preclude it entirely for many dentists. Web-based learning, however, has changed the very nature of dental education, as dentists can now access outstanding teachers online.



Preoperative view of three compromised teeth.



Full-mouth CAD/CAM-milled restorations.

The AACD had the vision to provide all its members with this access to online learning via www.DentalXP.com. This site has more than 2,000 pieces of content from 200 different experts in all aspects of clinical dentistry, including practice management, medical/legal considerations, and more.

Q: You have been a mentor to many over the years, and we greatly admire your commitment to being an active learner and maintaining a strong relationship with world-class ceramists, including Pinhas Adar, Christian Coachman, and Gui Cabral. What advice would you give to the younger dentist or someone seeking AACD Accreditation to help develop this relationship with a partner in clinical success?

A: Staying active and current is more difficult as a solitary process. My advice is to develop a team of disparate dentists and technicians who have a commonality of interest, and then make an active effort to get involved in a singular particular topic. Learn, argue, talk it out. Find a mentor for that topic or a lecture series, and delve into it as deeply as possible…but try to do it together within a prescribed time frame. This could then be extended on an as-needed basis (by communal consent). Everyone, however, should be encouraged to "learn together."

Q. Can you describe a dental experience that guided how you currently approach patient treatment for function and beauty and how your thought processes evolved?

A: I treated a very elderly (in her 90s) patient. I maintained her oral health, but did not do any cosmetic work. One week, during a hygiene visit, she saw my partner, who discussed some possible cosmetic enhancements for her that I didn't really think would interest her because of her age. Was I in for a surprise! On her return visit, she was angry with me for second-guessing her particular needs because of her age. In fact, she had the work done by my partner! So, never project your viewpoint on someone else, young or old, rich or poor, as we really cannot fully appreciate each patient's subjective needs. Listen to your patients, as everything they tell you can be important.

Q. What is the most exciting trend and biggest opportunity in cosmetic dentistry today?

A: The "Baby Boomers," who are not retiring, but remaining longer in the workplace and living far more active professional and social lives than traditionally expected. This requires their feeling and looking the part, and we know that the face—and, specifically, the mouth—remains a central focus.

Thank you, Dr. Garber, for sharing your thoughts and experiences with *jCD*'s readers. We look forward to hearing you speak at the 29th Annual AACD Scientific Session in Seattle in April.

Listen to your patients, as everything they tell you can be important.

Dr. Garber is a clinical professor in the Department of Periodontics at the Medical College of Georgia School of Dentistry, in Augusta. He is also a visiting professor in the Department of Prosthodontics at Louisiana State University in Baton Rouge. Dr. Garber is co-owner of a private practice in Atlanta, Georgia.

Disclosure: Dr. Garber's group practice has a financial interest in DentalXP.

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Using the Erbium Laser to Remove Porcelain Veneers in 60 Seconds

Minimally Invasive, Efficient, and Safe

Glenn A. van As, DMD

Dr. van As will be speaking at the 29th Annual AACD Scientific Session in Seattle, Washington, on April 26, 2013. The title of his lecture is "*You Light up My Life: Lasers in Contemporary Esthetic and Implant Dentistry*." In this article, Dr. van As discusses how erbium lasers have the ability to quickly and safely remove all porcelain restorations.

Abstract

For more than 30 years, porcelain veneers have provided clinicians with a method for changing a patient's smile almost instantaneously. At times, however, veneers require replacement due to caries, fractures, or leakage or simply because the patient is unhappy with the esthetic outcome. Erbium hard tissue lasers can be used to efficiently, safely, and predictably remove all porcelain restorations while also keeping them in one piece. In doing so, this new tool for removing porcelain restorations provides clinicians with an alternative to high-speed handpieces while preventing further iatrogenic damage to underlying tooth structure.

Key Words: veneer, erbium laser, removal, esthetics, porcelain

Although erbium lasers have been shown to safely remove orthodontic brackets without damaging increases in pulpal temperature, research should continue...

Introduction

Porcelain laminate veneers, originally developed in the early 1980s, are very thin porcelain or all-ceramic facings used to improve anterior esthetics.[1-3] These porcelain facings can be used to enhance the appearance of peg-shaped lateral incisors, enamel hypoplasia, fluorosis, or tetracycline discoloration when they are placed on top of the underlying tooth.[4]

Originally, the preparations for the laminate restorations were considered to be minimally invasive and typically limited to enamel. As little as 0.5 mm of axial and incisal tooth reduction has been stated as being required to allow for adequate space to fabricate a stacked porcelain veneer.[5-8] Longevity studies at 10 years have shown a remarkable success rate for porcelain veneer restorations, with failure rates that are often cited in single-digit percentages.[9-12] Beier,[13] however, estimated a much higher failure rate of approximately 22% at 20 years following placement.

With the population living longer and many people proceeding with veneers at a younger age, there is a requirement for removal or replacement of these porcelain laminates for a variety of reasons, such as fracture, discoloration due to luting cement, marginal failure, or esthetic concerns from a patient's perspective **(Table 1)**.

At present, the most common method for removing all-ceramic restorations is to use a high-speed handpiece with a diamond.[14] Due to the nature of the tremendous color-matching abilities of both resin bonding cements and the veneers themselves with underlying tooth structure, removing veneers without damaging the underlying natural tooth can be both difficult and time consuming, even with magnification. Friedman[15] has discussed how valuable enamel as a substrate is to the long-term success of porcelain veneers, and Ozurk[16] has shown a drop in bond strength if veneer preparations are overly aggressive with large amounts of dentin exposure. Therefore, it can be assumed that alternative methods that could safely, predictably, and quickly debond porcelain restorations without the risk of developing further iatrogenic damage to underlying tooth structure would be met with enthusiasm by many dentists who currently face a difficult task when the need to replace existing all-porcelain restorations arises.

Table 1: Clinical Reasons for Porcelain Veneer or Crown Removal.

	Diagnosis of Problem	Benefit of Laser Removal of Restoration
1	**Improper initial placement of new porcelain veneers or crowns.**	May remove restoration without fracture and rebond it properly without redoing it.
2	**Old fractured, chipped porcelain restorations.**	May remove restoration without further iatrogenic damage to underlying tooth.
3	**Caries around restorations.**	May remove restoration without further iatrogenic damage to underlying tooth.
4	**Irreversible pulpitis after bonding new porcelain restoration.**	May remove restoration to save tooth structure or prevent fracture of it during endodontic access.
5	**Patient unhappy with shade of new restorations.**	May remove restoration and have lab repair shape instead of redo veneers.
6	**Patient unhappy with shape of new restorations.**	May remove restoration and have lab repair shape instead of redo veneers.
7	**Patient decides that they do not like diastemas closed in minimal or no-prep veneer cases.**	May remove restoration without further iatrogenic damage to underlying tooth (can be a reversible procedure now).

Literature Review

Since the early 1990s, lasers have been used experimentally to remove ceramic orthodontic brackets. Each of the four major dental laser wavelengths (diode, CO2, Nd:YAG, and Er:YAG) have been utilized to try and help with debonding these brackets.[17-24] Oztoprak and colleagues[25] developed a new method to debond ceramic brackets using the Erbium YAG laser wavelength (2,940 nm). They found that short durations of three to nine seconds with moderately high energies of 4.2 W were effective and safe for this procedure. Enamel was not affected by the laser energy, and the pulpal temperature rise was measured to be below the 5.5°C threshold, at which point irreversible changes to the pulp can occur. Although erbium lasers have been shown to safely remove orthodontic brackets without damaging increases in pulpal temperature, research should continue, to ensure that the initial studies showing safety with laser removal of bonded veneers and crowns are also confirmed.

The erbium family of lasers exists between 2,780 nm (erbium, chromium:yttrium scandium-gallium-garnet [Er:CrYSGG]) and 2,940 nm (erbium:yttrium-aluminumgarnet [Er:YAG]). These wavelengths are well absorbed in water and hydroxyapatite **(Fig 1)**, and their absorption in these tissue compounds makes it possible to ablate both soft tissue and hard tissue compounds, which both consist partially of water. Enamel has 6% water, bone has 22% water, and soft tissue is composed of approximately 80% water. The mechanism of action of ablation with erbium lasers, as proposed by Fried,[26] is that the erbium laser wavelengths are absorbed in water molecules and cause a rapid expansion of these molecules. The rapid expansion causes micro-explosions, and this, in turn, creates an ablation crater of 30 to 50 µ in hard tissue **(Fig 2)**.

Lasers, of course, have been utilized extensively in the provision of esthetic dentistry for soft and hard tissue crown lengthening associated with porcelain-bonded restorations.[27-37] In addition, frenectomies, gingivectomies, and other soft tissue procedures can be completed in combination with esthetic dental procedures.

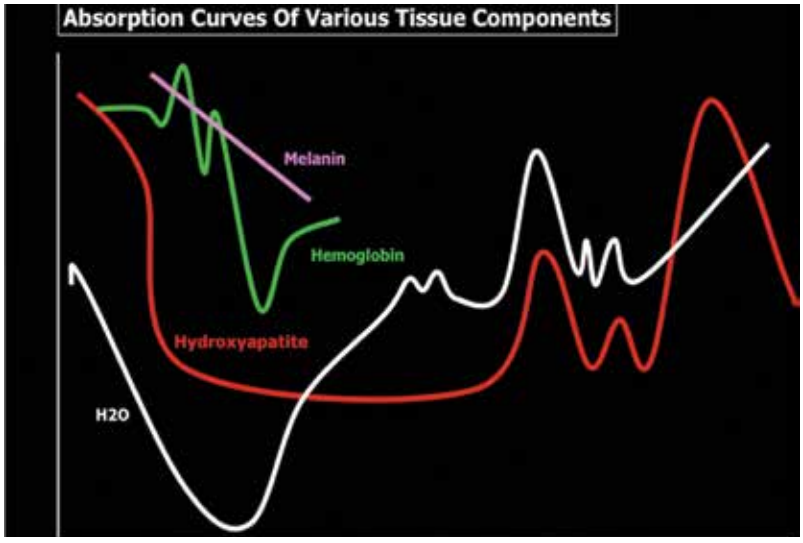

Figure 1: Absorption curve of various tissue components in the four major dental wavelengths. Erbium laser wavelengths are well absorbed in water and hydroxyapatite.

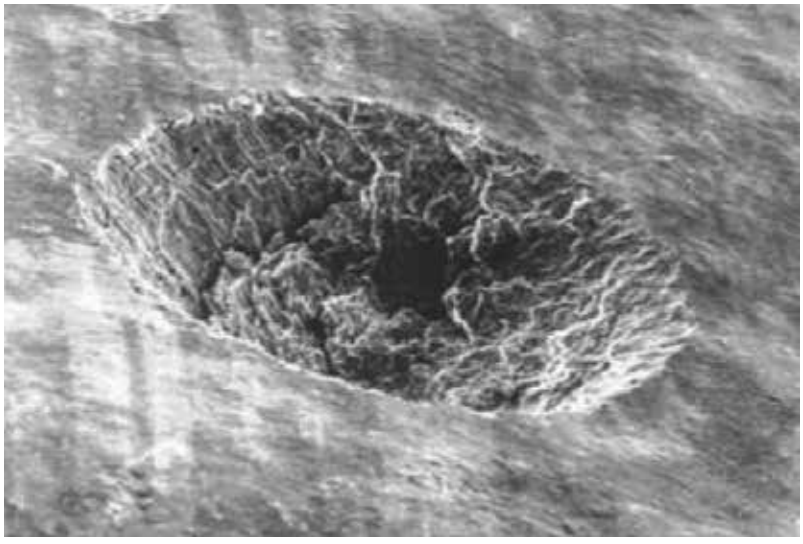

Figure 2: A 30- to 50-µ ablation crater made by a single pulse from an erbium laser.

Morford Study

Within the past five years, research has begun to look at the use of erbium lasers as an alternative to traditional veneer removal techniques utilizing burs.[38-41] Morford and colleagues[42] produced a study in 2011 that was "designed to systematically investigate the efficacy of an Er:YAG laser on veneer debonding, possibly without damage to the underlying tooth, and

Table 2: Comparison of Techniques for Er:YAG Laser Veneer Removal.

Study	Wavelength	Energy used to debond veneers	Tip-to-veneer distance	Thickness of veneer	Seconds to debond veneers
Morford et al.	2940 nm	10Hz, 133mj 1.33 watts energy	3-6 mm away	0.76-1.18 mm	31-290 seconds
Oztoprak et al.	2940 nm	50Hz, 100mj 5 watts energy	2 mm away	0.07 mm	3-9 seconds

preservation of the veneer integrity."[42] The researchers used an Er:YAG wavelength (2,940 nm) at a low repetition rate of 10 Hz and a low-energy setting of 133 millijoules (mj) (1.33 W) with a short pulse duration of 100 milliseconds on 24 porcelain (lithium disilicate and leucite-reinforced glass ceramic) veneers (13 e.max and 11 IPS Empress Esthetic [both Ivoclar Vivadent; Amherst, NY]). These veneers were bonded to preparations on freshly extracted incisors. They measured the energy and time necessary for debonding the veneers in seconds elapsed as well as the percentage of transmission of the erbium laser through the two different types of porcelain. The laser tip was held in a non-focused position that was 3 to 6 mm away from the veneer itself.

The results of their study found that the veneers transmitted between 11.5% to 43.7% of the incidental Er:YAG energy. Twice as much laser light was transmitted through e.max restorations versus IPS Empress Esthetic restorations at comparable thicknesses. All 24 veneers were completely removed with these low settings and the veneers "slid off" without mechanical dislodgment. The time for complete porcelain veneer removal with the laser was, on average, just under two minutes (113 ± 76 seconds). The author of this article contends that the longer times needed to remove the veneers are likely due to the very low energy settings used in this study. There were no signs of underlying tooth structure because the energies used for debonding were up to 20 times less than needed to ablate enamel and dentin.

The debonding mainly occurred at the cement/veneer interface, possibly by interacting with the hydroxyl molecule in the silane bond or by expanding the water molecules in the porcelain. None of the e.max lithium disilicate veneers fractured during debonding, whereas 36% of the Empress Esthetic veneers did fracture. The authors postulated that this was possibly due to the known higher flexural strength of e.max restorations, which might more easily resist the pressure buildup between the tooth and the veneer during the explosive ablation of the cement. The higher flexural strength of e.max (lithium disilicate) veneers might explain why these veneers do not fracture during the removal process. Morford and colleagues[42] concluded that other porcelain systems and other veneer cements, aside from RelyX (3M ESPE; St. Paul, MN) veneer cement, should also be tested in the future.

Oztoprak Study

In another recent study, Oztoprak and colleagues examined the effect of erbium lasers on debonding porcelain veneers.[43] The group had looked previously at using lasers to debond orthodontic brackets and used many of the materials and methods employed in their other studies for the removal of veneers. **Table 2** shows that many differences exist between the studies of Morford et al.[42] and Oztoprak et al. The latter group used much higher settings (50 Hz and 100 mj) directed closer to the veneers, which were thinner in dimensions. They also used mechanical dislodgment of the veneers after utilizing the laser for less than 10 seconds. Compared to the control group in their study, when using the laser at 5 W for nine seconds, the energy needed to pop the porcelain veneers off was only 12.8% versus the control group, which did not use a laser at all (27.5 ± 1.44 MPa for control group versus 3.54 ± 0.46 MPa for the laser group). The research paper explained the mechanism of action of debonding as a physical disruption of the composite luting agent; the authors found that failure occurred mainly within the luting agent, with no damage to the enamel itself during debonding. **Table 2** compares the different studies, but both studies show that laser veneer removal is not only possible but also is probable in very short periods of time, with no risk to the enamel or pulp.

Clinical Cases Using Er:Yag Laser Removal of Veneers

The author has used the Er:YAG laser to successfully remove both single and multiple veneers as well as single and multiple all-ceramic e.max and IPS Empress Esthetic restorations. Zirconium restorations and more traditional restorations such as porcelain fused to metal (PFM) are not able to be removed with the laser. Only erbium wavelengths (Er,Cr:YSGG at 2,780 nm and Er:YAG lasers at 2,940 nm) will work to safely remove

Table 3: Settings for the Removal of Porcelain Veneers.

Porcelain Veneer Type	Removal Possible	Settings
Lumineers or minimal prep	Yes—cracking possible	4-5 watts, H2O for 30 seconds facial and incisal
Pressed feldspathic	Yes—thicker veneers need mechanical removal after laser	4-6 watts, H2O for 30-45 seconds facial and incisal
e.max	Yes—less likely to crack	5-6 watts, H2O for 30-45 seconds

Table 4: Settings for the Removal of Porcelain Crowns.

Porcelain Crown Type	Removal Possible	Settings
All-porcelain, Empress, e.max	Yes—anterior easier than posterior	5-6 watts, H2O, 30-45 seconds facial, lingual, incisal
Porcelain fused to metal	No	NA
Zirconia, Procera, LAVA	No	NA

the porcelain restorations. Other wavelengths, such as diode, CO2, or Nd:YAG lasers, which are primarily soft tissue lasers, will not effectively or safely remove porcelain restorations. When using the erbium lasers, it is typical for veneer restorations to require less time and energy to remove than full-coverage all-porcelain restorations. The laser will not work on PFM, full metal, or any zirconia restorations that are cemented into place. In order for the laser to remove the porcelain veneers, etch and bonding of the restoration must be the cementation technique used. This allows the laser energy to interact with the resin bonding substrate so that the veneer or crown may be debonded. Traditional cementation of restorations with cements—such as regular or resin-modified glass ionomers, zinc phosphate, or temporary cements—will prevent laser removal of these restorations **(Tables 3 & 4)**.

This article's author has used higher settings (6 W with water spray) and lower settings (1.5 W without water) to successfully remove old restorations. Further research will be needed to see if one technique or another will provide for greater success in removing all porcelain restorations, but the following cases show how the laser might be used successfully and how it can be a "life saver" for many recently completed cases where the patient is in discomfort or unhappy with the final result.

If the restoration can be removed and reused and rebonded with minor alterations, it can be a huge time and cost saver for all parties involved.

If the restoration can be removed and reused and rebonded with minor alterations, it can be a huge time and cost saver for all parties involved.

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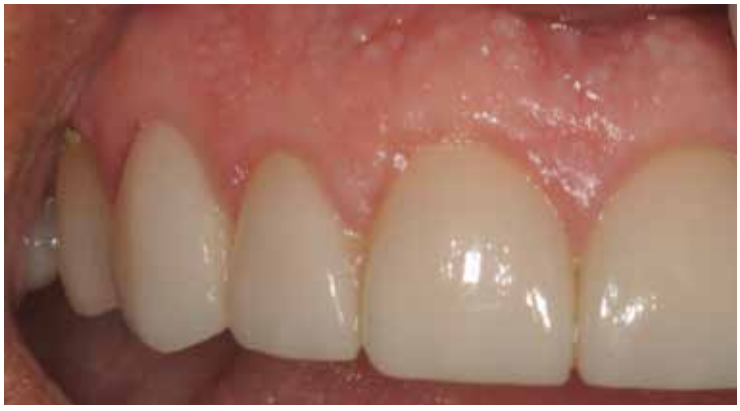

Figure 5: Preoperative view of e.max lithium disilicate veneers.

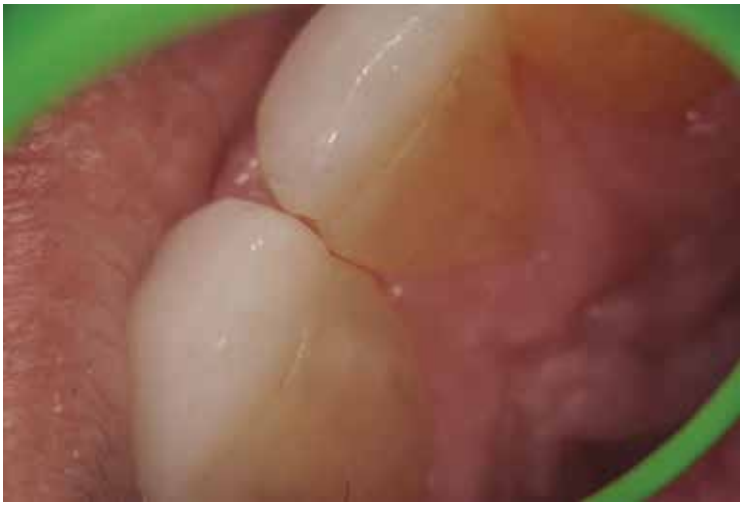

Figure 6: Incisal view of a slight interproximal fracture on the distal incisal embrasure of a lateral incisor.

Clinical Case 1: Er:Yag Removal of a Single E.Max Veneer

In this case, a 52-year-old male patient had fractured the distal incisal edge of an e.max porcelain lithium disilicate veneer on his maxillary right lateral incisor. The final restoration had been placed just three months earlier. Treatment options were discussed with the patient; the decision was made to remove and replace the veneer, as the patient was trapping food interproximally and he found the small chip was rough to his tongue and was shredding floss **(Figs 5 & 6)**. The Hoya ConBio (Fremont, CA) Er:YAG laser (2,940 nm) wavelength was used at a setting of 10 Hz and 100 mj (compare with Morford et al., who used 10 Hz but 133 mj)[42] with no water spray for 40 seconds on the facial surface and 10 seconds on the lingual surface. The veneer was removed with one downward pull using a crown and bridge remover. The veneer was intact **(Figs 7 & 8)**; afterwards, diode laser troughing was used for tissue management and a final polyvinylsiloxane (PVS) impression was taken **(Figs 9 &10)**. The new porcelain veneer was bonded into place 10 days later. **(Fig 11)**.

The role of the erbium laser in removing bonded porcelain restorations is promising, not only for the dentist but for the patient and laboratory as well.

Figure 7: Intaglio (lingual) view of a veneer removed with an Er:YAG laser. Note the intact nature of the veneer.

Figure 8: Facial view of the same veneer after removal using an erbium laser.

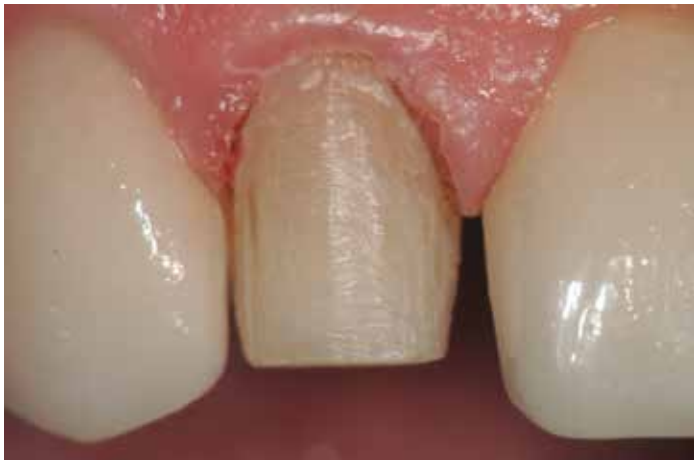

Figure 9: View after completion of diode laser troughing for tissue management.

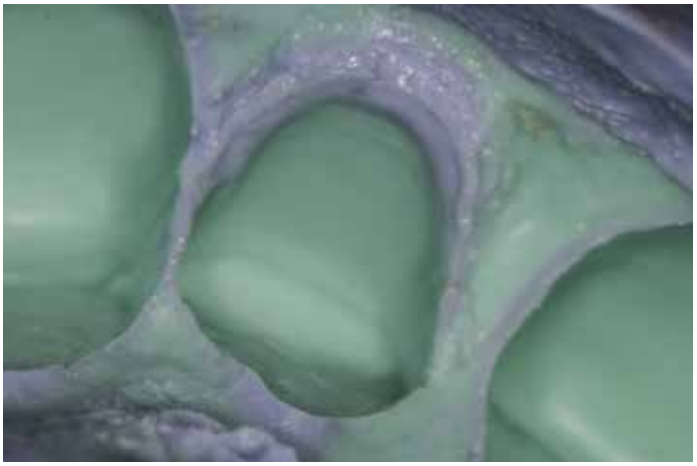

Figure 10: PVS impression of a veneer margin at high magnification.

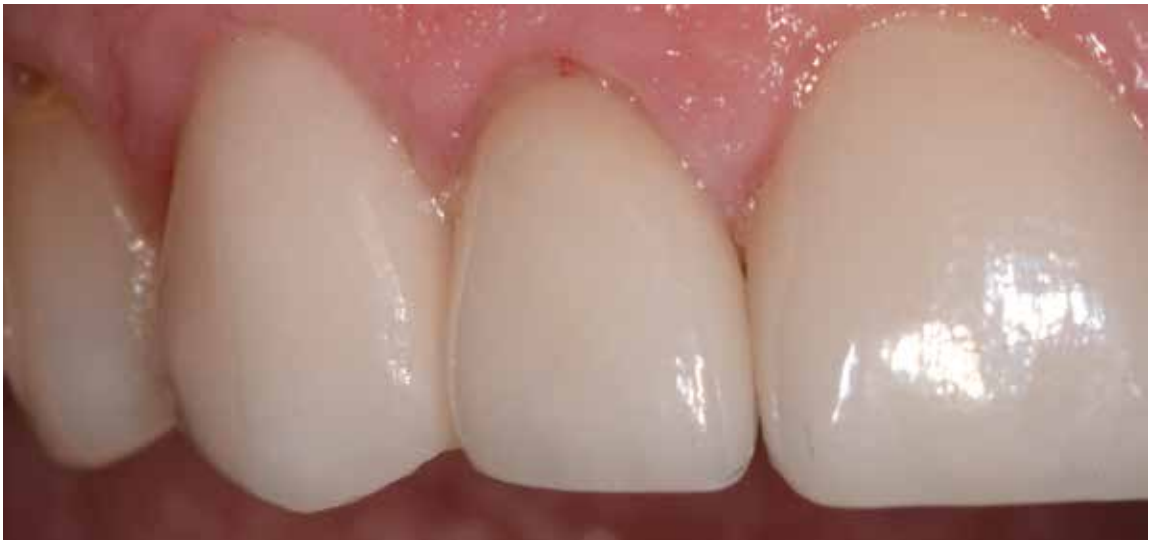

Figure 11: Facial view of a completed veneer immediately postoperative.

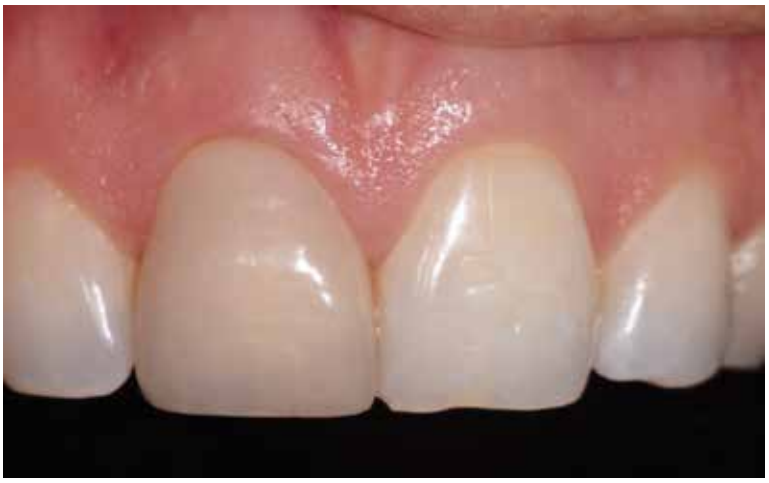

Figure 12: Preoperative appearance of an old porcelain veneer on the right central incisor that is discolored and does not match the adjacent incisor.

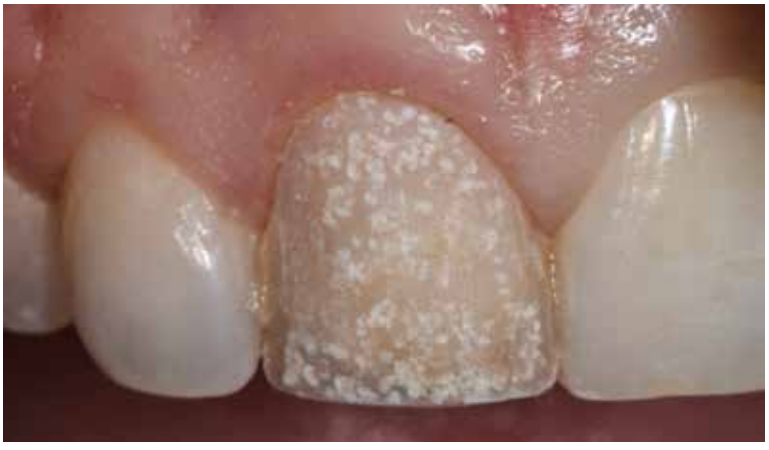

Figure 13: Immediate appearance after the veneer was removed with an Er:YAG laser.

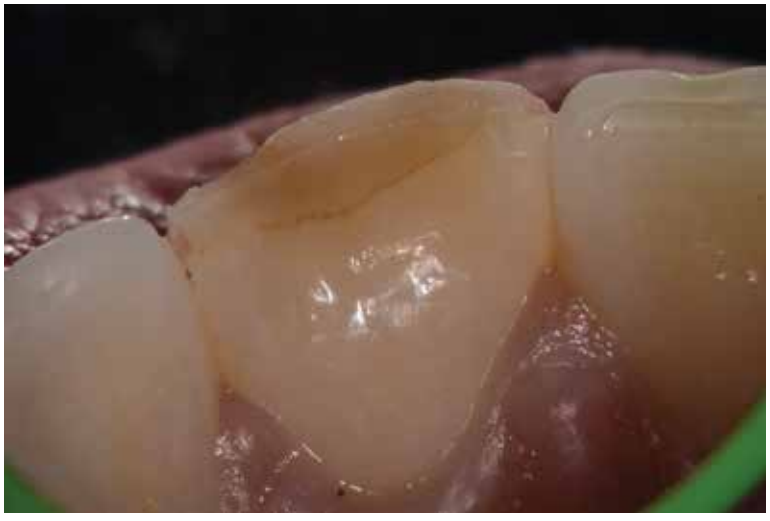

Figure 14: View of the lingual surface shows decay and old resin requiring full-coverage crown preparation instead of a veneer preparation.

Clinical Case 2: Er:Yag Removal of a Single E.Max Veneer

In this case, a 37-year old female patient wanted to have a discolored maxillary right central porcelain veneer replaced **(Fig 12)**. Treatment options were discussed with the patient; the decision was made to remove and replace the veneer and try to create a better color match to the left central incisor. The Hoya ConBio Er:YAG laser (2,940 nm) wavelength was used at a setting of 30 Hz and 200 mj (compare with the 50 Hz and 100 mj used by Oztoprak et al.) accompanied by a fine water spray for 30 seconds on the facial surface and 10 seconds on the lingual surface. The veneer was removed after several downward pulls with a crown and bridge remover. The clinician should extend care when using mechanical means of removing restorations after the laser is used. Ideally, a small overhang in one area will help provide a "catch," whereby the clinician may remove the loosened restoration via a controlled, downward pull. The retained resin cement was visualized on the preparation **(Fig 13)**. Due to the excessively aggressive previous preparation into dentin as well as the lingual decay **(Fig 14)**, the decision to fabricate a full e.max lithium disilicate crown was made **(Fig 15)**. The new porcelain restoration was bonded into place 10 days later **(Figs 16 &17)**.

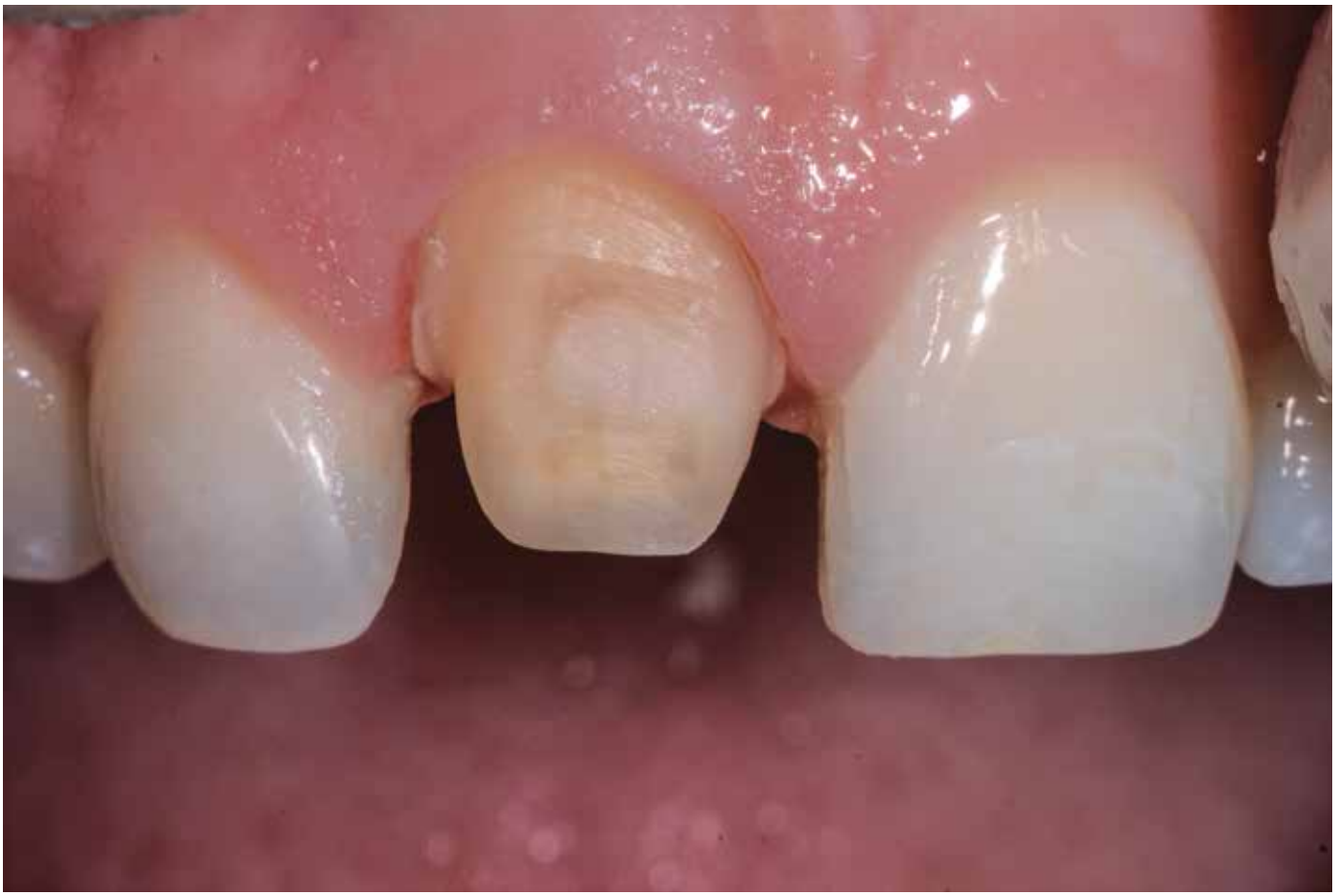

Figure 15: Full-coverage preparation for a right central incisor with an e.max lithium disilicate crown.

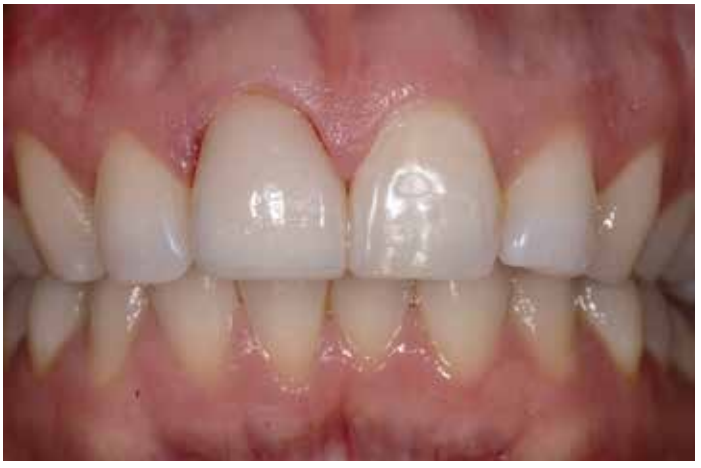

Figure 16: Immediately postoperative appearance of a bonded e.max crown.

Figure 17: Immediately postoperative close-up view of a right central incisor crown.

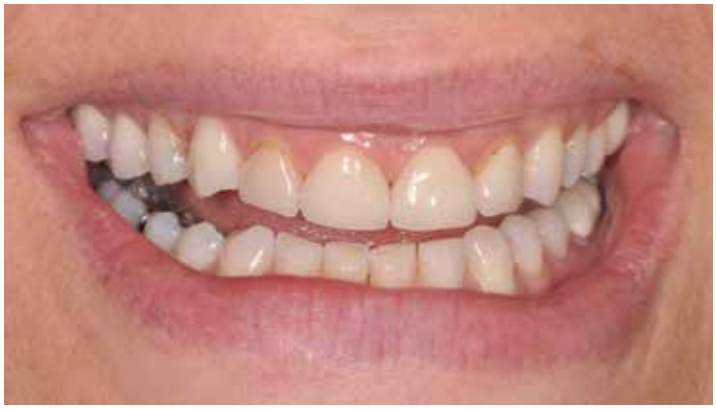

Figure 18: Preoperative appearance of "short" porcelain veneer preparations with poor length-to-width ratios that make the teeth appear square.

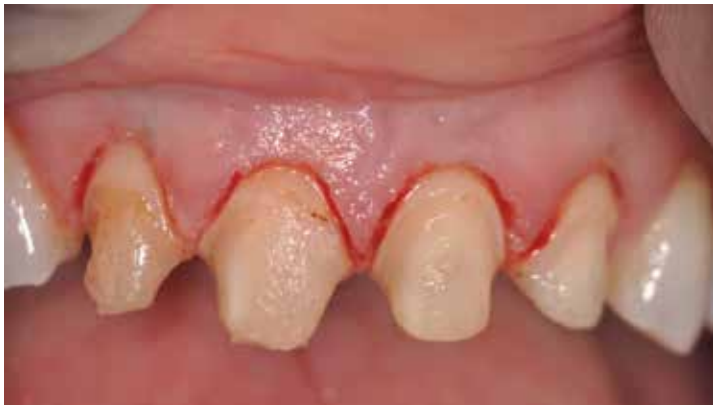

Figure 19: View immediately following completion of a laser crown-lengthening procedure and removal of veneers on all four maxillary incisors.

Clinical Case 3: Er:Yag Removal of Empress Porcelain Veneers

In this case, a 35-year-old female patient wanted to have short, leaking, and discolored veneers replaced on her maxillary anterior incisors (##7-10) **(Fig 18)**. Treatment options were discussed with the patient. The decision was made to remove and replace only the maxillary central and lateral incisor veneers due to financial considerations; therefore, the buccal corridor (canines and premolars) were not treated. In addition to replacing the failing restorations, the patient wanted to make the teeth longer. A "laser smile lift" or closed flap crown lengthening was performed with an Er:YAG laser to make the teeth longer.

The Hoya ConBio Er:YAG laser (2,940 nm) wavelength was used at a setting of 30 Hz and 40 mj (1.2 W) with a fine water spray to recontour first the soft tissue and then to correct the resultant biologic width problems. The resultant crown preparations are shown in **Figure 19**. The veneers were removed with settings of 30 Hz and 175 mj (5.25 W) in 30 to 60 seconds.

The decision to fabricate full-porcelain IPS Empress Esthetic crowns was made. The new porcelain restorations were bonded into place later, and the immediate postoperative appearance can be seen in **Figures 20 and 21**.

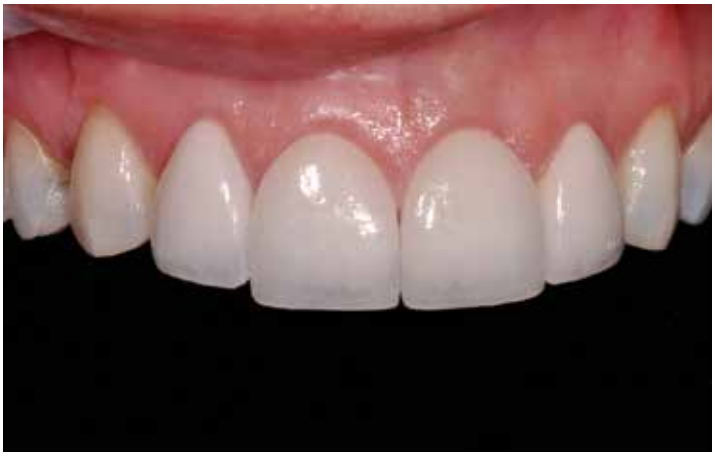

Figure 20: Postoperative view of new e.max lithium disilicate crowns in place with an improved width-to-length ratio.

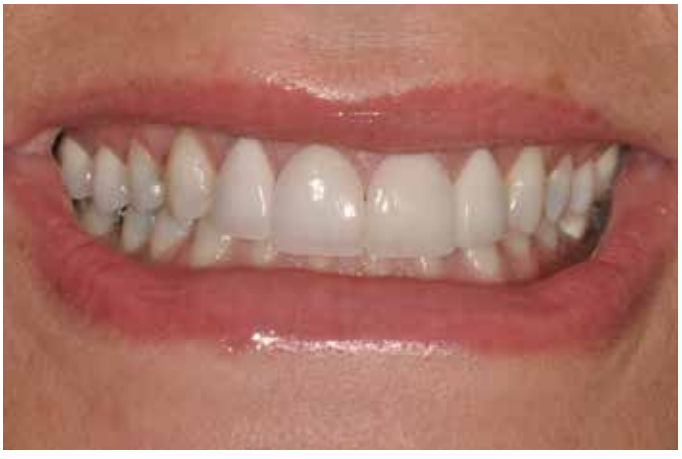

Figure 21: Note the improved smile appearance after new restorations were placed compared to the preoperative view.

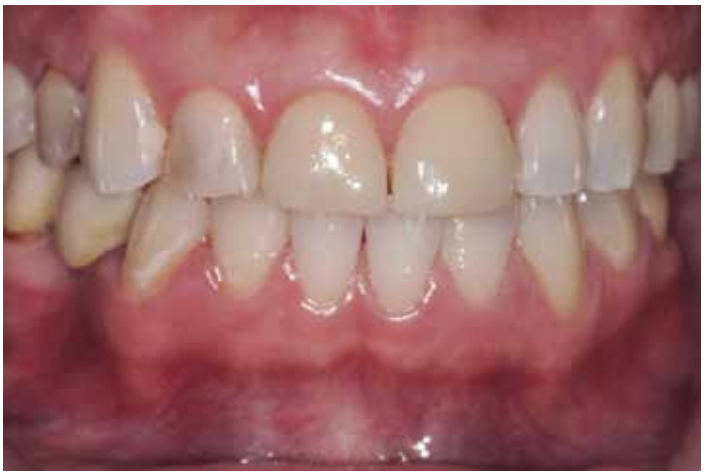

Figure 22: Preoperative view of the retracted smile prior to the "makeover."

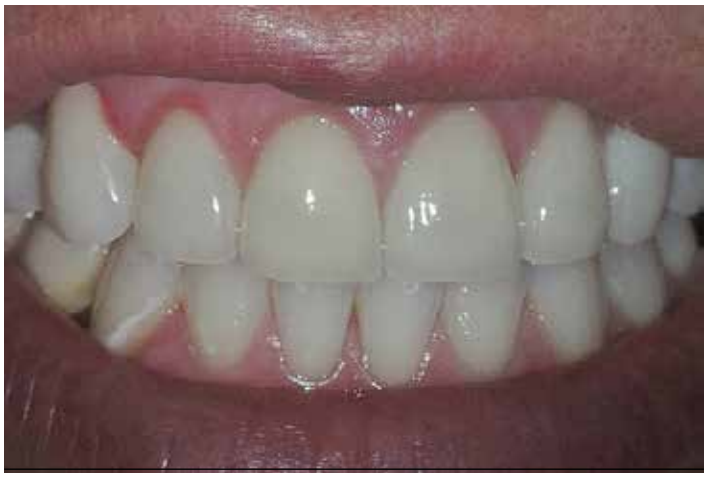

Figure 23: The patient had irreversible pulpitis on the right maxillary lateral incisor and was unhappy with "spots" seen under final incisor e.max crowns.

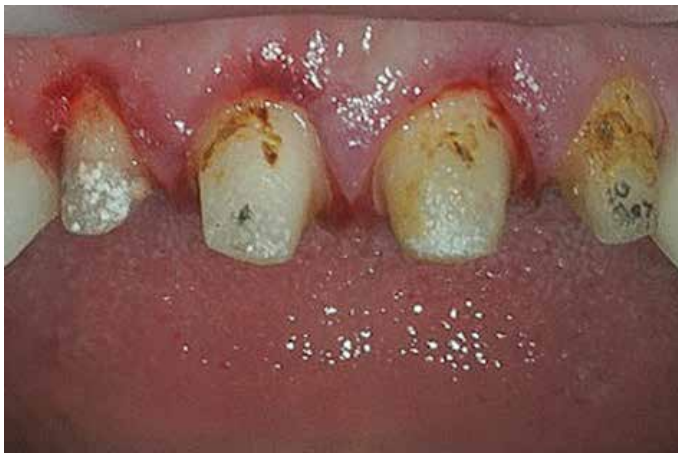

Figure 24: View after root canal therapy and laser removal of the lithium disilicate crowns were completed; note the "brown spots" of uncured resin cement on incisor preparations.

Figure 25: Four e.max crowns were removed via laser and sent back to the laboratory.

Clinical Case 4: Er:Yag Removal of E.Max Lithium Disilicate Crowns

A 40-year-old female patient wanted to pursue a "smile makeover." Her extensively restored anterior maxillary dentition from her first premolar to first premolar had numerous failing and discolored composite restorations. The patient received eight lithium disilicate (e.max) crowns placed on ##5-8 (##14-11 international) and ##9-12 (##21-24 international). After the final restorations were bonded into place, the patient developed irreversible pulpitis on the maxillary right lateral incisor and endodontic therapy was required.

The lithium disilicate crown was removed with an Er:YAG laser used for two minutes (60 seconds on the facial and lingual surfaces, with settings of 30 Hz and 200 mj; 6 W with air/water- spray). The endodontic therapy was completed on the tooth. Subsequently, the remaining three incisor crowns were also removed using the Er:YAG laser with similar settings. The patient had noticed "brown spots" on the facials of these teeth, which turned out to be uncured resin cement showing through. The patient's restorations were replaced, and the new lithium disilicate crowns were bonded into place **(Figs 22-26)**.

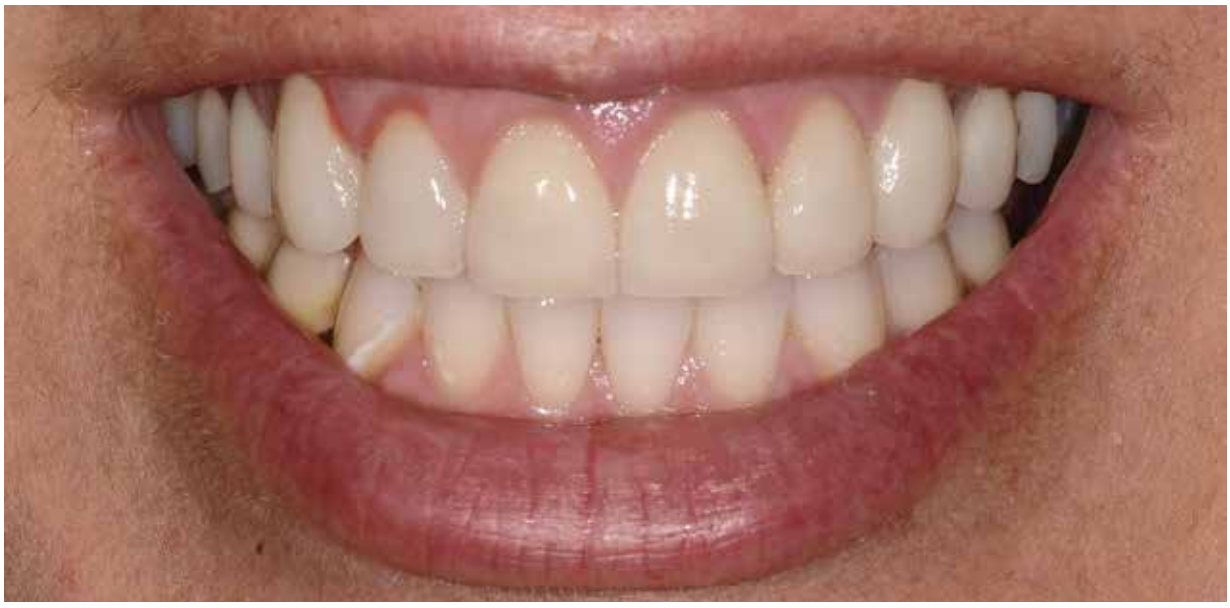

Figure 26: Final view of the patient's smile after placement of new e.max crowns fabricated at the laboratory.

Summary

Clinicians with access to erbium lasers in their practices have the ability to quickly and safely remove all porcelain restorations (glass ceramics, such as leucite-reinforced porcelain or lithium disilicate restorations) without fear of creating iatrogenic damage to underlying tooth structure. The role of the erbium laser in removing bonded porcelain restorations is promising, not only for the dentist but for the patient and laboratory as well. In some situations, restorations might be salvageable, even after bonding, if they require alterations in their position, shape, size, or color. Further research is required to determine whether lower settings without water (promoted by Morford et al.[42]) or higher energies (used by Oztoprak et al.[43]) will provide better results. However, there is no doubt that the use of erbium lasers for veneer removal is an exciting alternative to the traditional methods of using a high-speed handpiece.

Procedure Videos

The digital edition of this issue of *jCD* will provide links to videos showing procedures for

- **removal of the left central incisor porcelain veneer**
- **removal of the left lateral incisor porcelain veneer**
- **removal of an e.max crown.**

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Ultraconservative Dentistry Using "No-Prep" Porcelain Veneers

Accreditation Clinical Case Report, Case Type I: Six or More Indirect Restorations

Charles C. Cooper, DMD

> **"Patients today often request cosmetic solutions that do not require any tooth reduction."**

Figure 1: Preoperative portrait.

Introduction

One of the greatest challenges of the Accreditation process is identifying the "right" case. Examiners often discuss the importance of choosing a case that will allow the greatest chance for success. A minimal or no-preparation technique for the Case Type I requirement can allow an esthetic and conservative result. A desirable case requires tooth size discrepancies where additive dentistry can be the solution.[1,2]

Patients today often request cosmetic solutions that do not require any tooth reduction.[3,4] These patients frequently are adamant about their desire to have cosmetic "makeovers" with no preparation of their teeth. With the interest in more conservative cosmetic solutions, the public is demanding the preservation of their natural tooth structure. Frequently, patients present with small teeth in the esthetic zone that only need additive-type dentistry completed. To increase tooth size and shape and to create a more attractive smile, "no-prep" veneers have become commonplace in many dental practices.

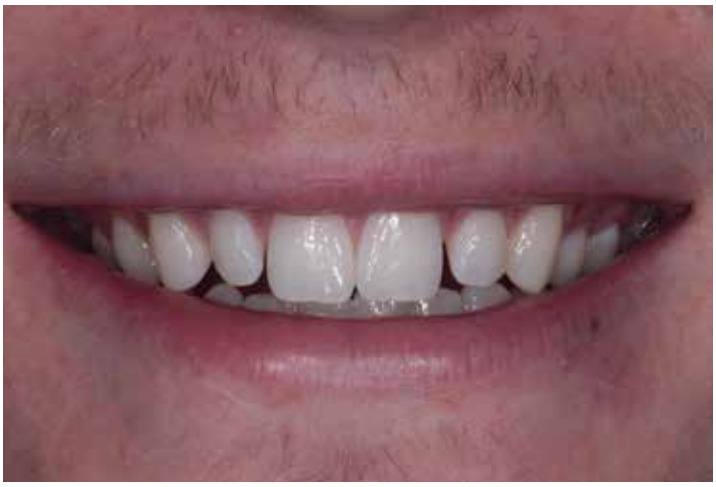

Figure 2: Preoperative smile.

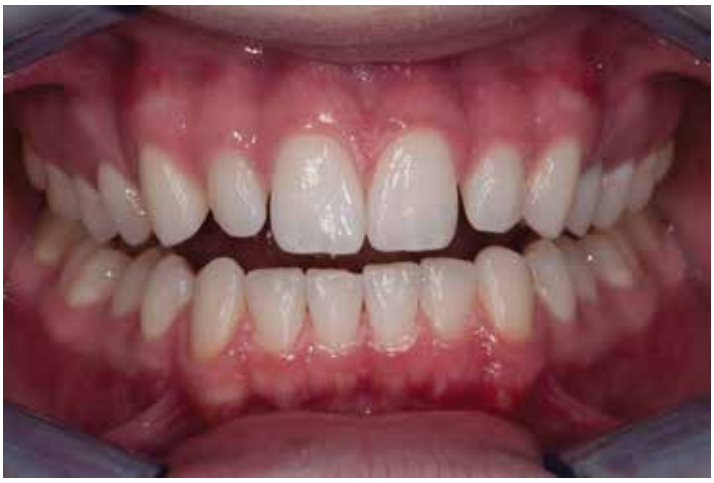

Figure 3: Preoperative 1:2 retracted view.

Figure 4: Preoperative 1:1 retracted view.

History

The patient, a 22-year-old man, wanted a cosmetic solution for his small front teeth **(Figs 1 & 2)**. His desire was to preserve his healthy tooth structure and to fix the "spaces" between his front teeth. He wanted whiter teeth with no spaces, and had heard of veneers that did not require any loss of tooth structure. His upcoming wedding was the impetus for the treatment. The patient was aware that composite bonding was an option, but liked the idea of using porcelain if his teeth would not be harmed. The patient was looking for a long-term solution and was hopeful that the process would give his teeth a more even, full appearance. He had previously had a crown placed on one of his teeth due to an accident and preferred not to go through that process again if at all possible. The patient was aware that porcelain veneers would be a significant investment and wanted an assurance that they would last for many years.

Diagnosis and Treatment

During his initial visit the patient underwent a full series of radiographs and photographs **(Figs 3-5)**. In addition, a joint vibration analysis was performed (BioJVA, BioResearch; Brown Deer, WI), which confirmed the absence of any temporomandibular joint dysfunction. Periodontal examination, including probing, confirmed good periodontal health. Intraoral examination revealed some wear, especially on the cuspids, and an obvious premature contact in the posterior area. The patient was aware that his teeth were chipping in some areas, but did not know why.

It was determined that teeth ##7-10 were relatively smaller than ideal for an attractive smile. By increasing the size of these teeth, it would be possible to make them more proportional to the remaining teeth in the smile zone. In addition, there was a lingual inclination of the teeth in the buccal corridor.

There are several criteria to consider when determining whether a case can be successfully treated without preparation of healthy tooth structure. These include minimal color change, small teeth, peg laterals, open contacts, and the absence of occlusal issues. All of these characteristics were noted at the examination phase. Conversely, had there been a need for extreme color change due to dark teeth, full-contour teeth in a protrusive position, a deep bite, or a history of severe bruxism, no-prep veneers would have been contraindicated.

A diagnostic wax-up **(Fig 6)** and the placement of a temporary "trial smile" **(Fig 7)** allowed the patient to preview the potential outcome. The patient was able to see the desired esthetic and functional results prior to treatment. Once the patient visualized the changes, he wanted to proceed with the proposed treatment.[5-7]

Treatment and Description

The proper approach to achieving the best smile possible for this esthetic case initially involved a full smile analysis.[8] After an analysis of mounted models, photographs, and a diagnostic wax-up, it was determined that the case would be completed using no-prep veneers on teeth ##2-11, #13, and #14. A full-coverage crown would replace the existing crown on #12. Using a matrix made from the diagnostic wax-up, a trial smile using PerfecTemp (Discus Dental; Culver City, CA) was placed to allow the patient to view the outcome prior to removing the existing crown. This allowed visualization of the changes in the size of the teeth in the anterior area as well as the buccal corridor. Using a lighter shade material than his natural tooth color also allowed the patient to visualize the change in the brightness of his smile.

Prior to starting the restorative procedure, a T-scan (Tekscan; South Boston, MA) was used to determine any premature contacts. The premature contact was determined to be the lingual cusp of tooth #14. Minor equilibration was performed and the interference was removed. Another T-scan afterwards confirmed a more balanced bite. The teeth were then anesthetized for patient comfort using lidocaine with 1:100,000 epinephrine and the crown on tooth #12 was removed and margins were defined. An NV diode laser (Discus) was used to contour the tissues. Before tissue removal, sounding to bone was performed to make sure that the biologic width was not affected. An Ultrapak retraction cord size #1 (Ultradent; South Jordan, UT) was placed and final impressions were taken using a polyvinyl siloxane impression material (Panasil, Kettenbach USA; Huntington Beach, CA). Photographs, shades, facebow **(Fig 8)**, and centric relation bites were taken and sent to the laboratory. Tooth #12 was temporized and the patient was released.

Laboratory Instructions

Excellent communication is essential to obtain optimum results. It is important that the patient, doctor, and ceramist discuss the functional and esthetic goals prior to treatment. In this case, the patient desired to have a natural-looking smile and to eliminate his "little" front teeth. As with all cases, clinical results are directly proportional to the communication between the doctor and his or her laboratory technician.[9] It was decided to use IPS e.max (Ivoclar Vivadent; Amherst, NY) for its esthetic qualities, and the shades were determined. In years past, the porcelain choice would have been IPS Empress due to its esthetic qualities, and its ability to mimic natural tooth structure. Modern e.max is extremely esthetic and is

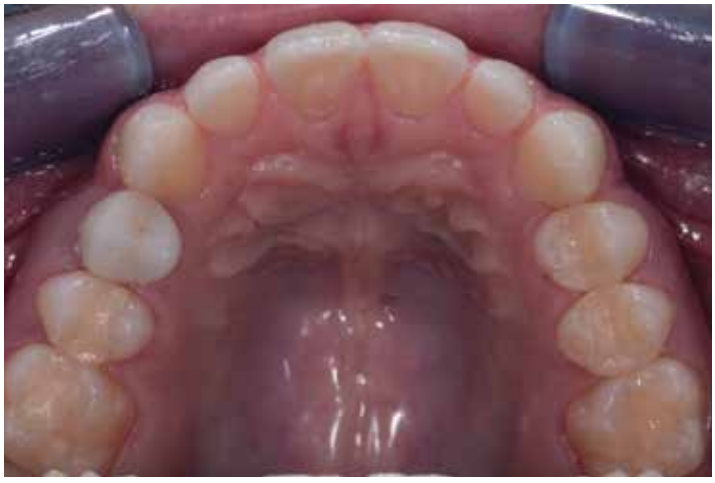

Figure 5: Preoperative occlusal view.

Figure 6: Diagnostic wax-up.

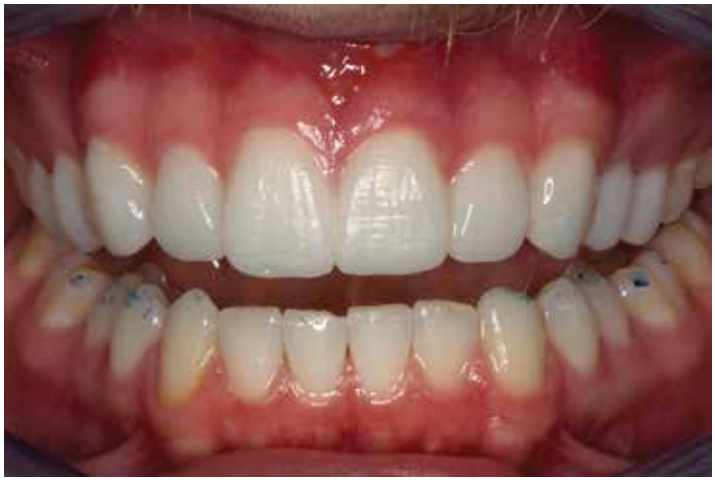

Figure 7: Trial smile; occlusion checked to confirm no interferences.

more fracture-resistant than other porcelain systems on the market.[10] Knowing that the restorations were going to be extremely thin, choosing a strong material was paramount.

A complete laboratory prescription was sent to the laboratory. It included the following:

- written details outlining the required outcome and patient wishes
- two sets of impressions and bite registrations
- facebow jig (Panadent; Grand Terrace, CA)
- color map drawing
- digital photographs of preoperative and preparation shades.

> **Choosing to complete Case Type I using minimal or no-preparation veneers can be more challenging than using traditional methods.**

Finishing

After inspection of the veneers and crown from the laboratory, the restorations were tried in using a glycerin gel to check the shade and fit **(Figs 9 & 10)**. All margins were checked for accuracy, as were the proximal and occlusal contacts. The patient viewed and approved the restorations. A water rinse was used to remove the traces of glycerin from the internal surface of the restorations **(Fig 11)**. A 35% phosphoric acid solution (Ultra-Etch, Ultradent) was lightly scrubbed on the internal surface of the restoration for 15 seconds, rinsed with water, and dried. RelyX silane primer (3M ESPE; St. Paul, MN) was placed on the internal surface of the restorations for two minutes and dried. Two coats of Excite (Ivoclar Vivadent) bonding agent were applied, the solvent evaporated, and the restorations were placed in a dark box until ready for delivery.

The teeth were isolated with a rubber dam (Patterson Dental; St. Paul, MN), etched with Ultra-Etch for 15 seconds, and rinsed for 30 seconds.[11] The teeth were lightly air-dried and two coats of Excite (Ivoclar Vivadent) bonding agent were placed and light-cured. The restorations were then loaded with RelyX translucent and placed on the teeth. A small brush was used to remove the excess material. Once the restorations were fully seated and margins sealed, a 1-mm tacking light was used on the incisal edge to tack them in place. Excess material was again removed. DeOx (Ultradent) was placed at the margins and a full 60-second cure was performed. A #12 Bard-

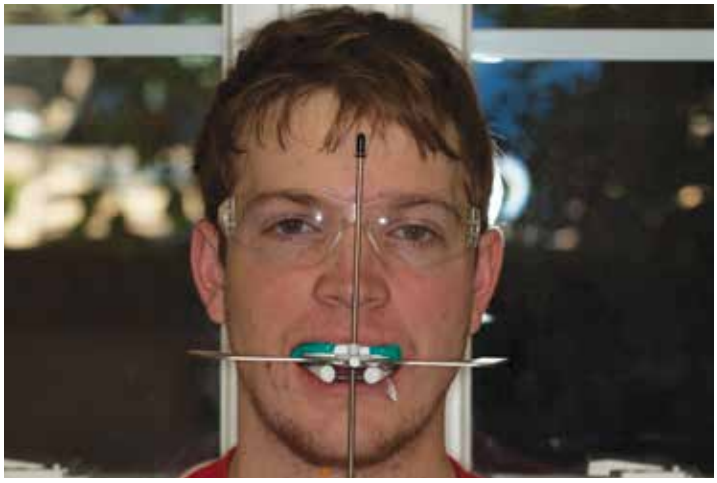

Figure 8: Facebow transfer.

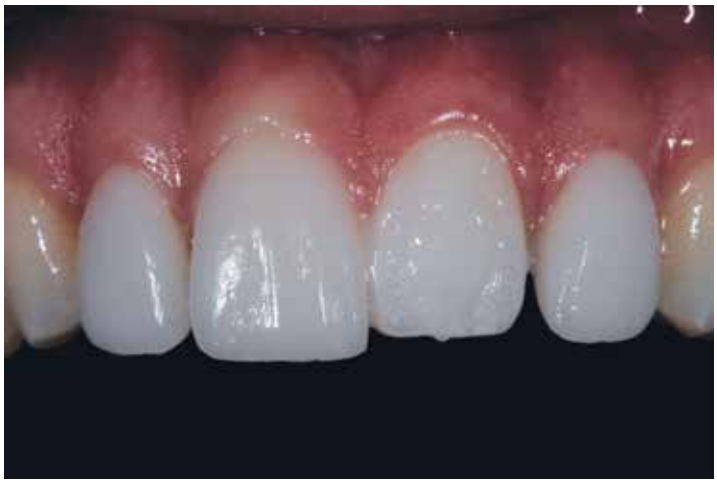

Figure 9: Trying in the porcelain restorations with glycerin to check fit. Notice the increase in size and length of the new porcelain restorations.

Figure 10: Simultaneous try in of all porcelain restorations.

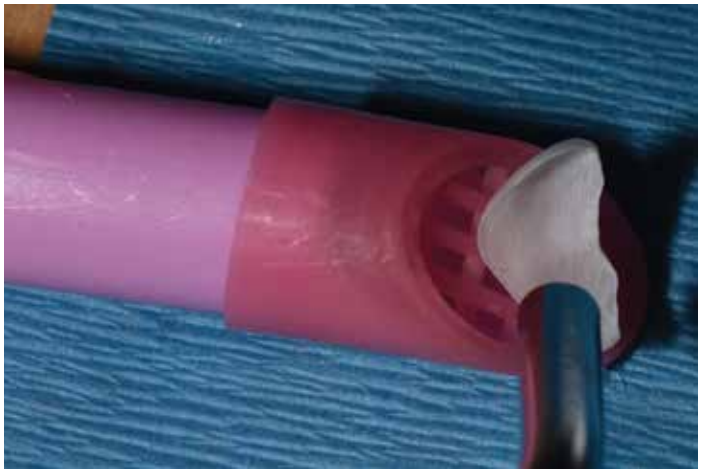

Figure 11: Cleaning the inside of a veneer.

Figure 12: Postoperative portrait image.

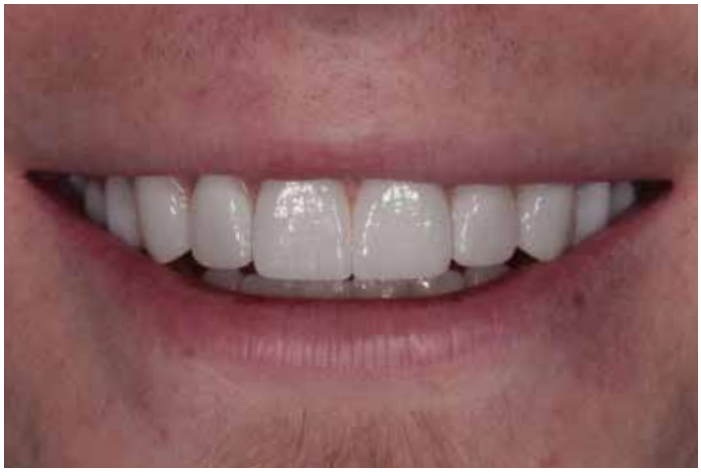

Figure 13: Postoperative smile image.

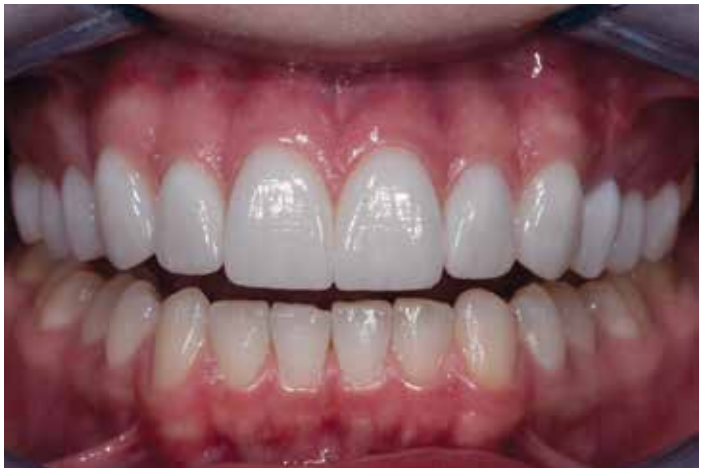

Figure 14: Postoperative 1:2 retracted view.

Figure 15: Postoperative 1:1 retracted view.

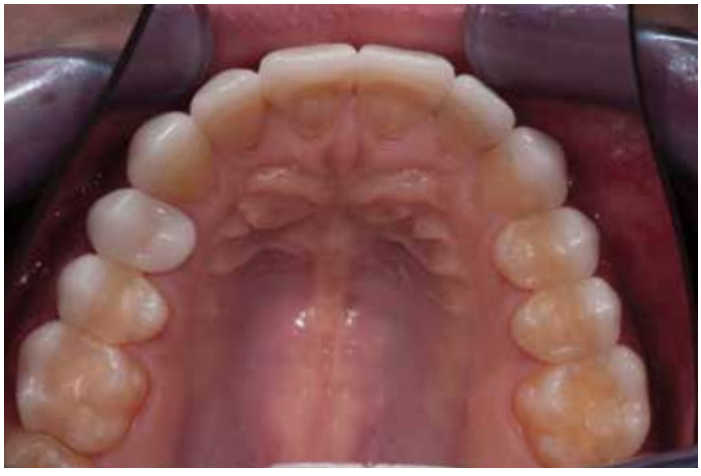

Figure 16: Postoperative occlusal image.

> **Excellent esthetic results can be obtained with careful diagnosis, planning, and execution.**

Figure 17: The happy patient, smiling with confidence.

Parker blade (Becton Dickinson; Franklin Lakes, NJ) was used carefully along the margins to remove any excess material. The cement in the interproximal areas was removed using FlexiStrips (Cosmedent; Chicago, IL). Final polish was obtained using Porcelize diamond polishing paste (Cosmedent) with a rubber cup. A final check of the occlusion was made with articulating paper. The patient was scheduled for a one-week postoperative check and to take final clinical photographs **(Figs 12-16)**.

Summary

Excellent esthetic results can be obtained with careful diagnosis, planning, and execution. Providing a patient with an esthetic outcome that does not involve removal of tooth structure is an added benefit. The planning must address the needs of the patient as well as involve the vision and education of the doctor performing the work.

Choosing to complete Case Type I using minimal or no-preparation veneers can be more challenging than using traditional methods. No-preparation cases are often more technique-sensitive and difficult for many dentists to complete.[12] However, if the restorative dentist is willing to embrace the paradigm shift toward more conservative dentistry, the end result can be very rewarding.[12]

In the end, the patient and the doctor both benefit from the journey. The doctor benefits by knowing he or she has provided an extremely conservative treatment and the patient benefits from being able to smile with confidence **(Fig 17)**.

Acknowledgments

The author gives special thanks to Andres Sosa, Od, and Pinhas Adar, CDT, for their help with this case.

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Dr. Cooper is a 1986 graduate of the University of Mississippi School of Dentistry. He practices at the Atlanta Center for Cosmetic Dentistry, in Atlanta, Georgia.

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Examiners' Commentary

Excellence of the Final Result

Playing Close Attention to Smile Design

J.A. Reynolds, DDS, AAACD

Porcelain veneers have long been considered the "bread and butter" of cosmetic dentistry. Veneers offer a clinician the opportunity to change someone's appearance as well as their occlusal function. So many esthetic dilemmas can be improved with indirect anterior restorations when a clinician teams with a like-minded ceramist. Coordinated dentist/ceramist communication using photography, video-conferencing, diagnostic wax-ups, and trial smiles can certainly take much of the guesswork out of providing a superior service.

With veneers, the patient can improve his or her smile in a multitude of ways. The shape, color, natural irregularities, or whatever the patient desires, can be conservatively achieved.

Case Type I is defined as six or more indirect restorations.[1] Remember, though, that this is a case about smile design. Many times, six restorations are not sufficient to achieve a beautiful natural smile. It is all about being "seamless" with the natural dentition and it is often important to include first and/or second premolars in the treatment.[2]

As with all five Accreditation case types, case selection is paramount. Look for a case that will provide a superior result without having to overcome superfluous issues such as unesthetic tissue heights or extremely dark teeth. Dr. Cooper chose such a case. Keep in mind that the examiners do not evaluate the case based upon how difficult and complex it is, but rather, upon the excellence of the final result.

Dr. Cooper's patient wanted a larger and brighter smile if he could be treated without damaging his teeth. Esthetic dentists often encounter patients with

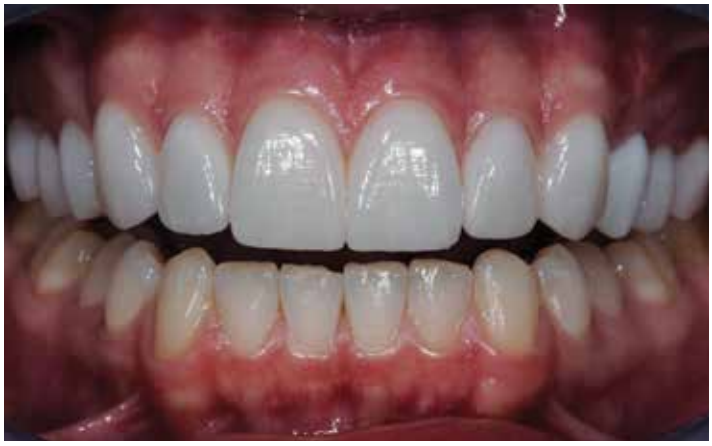

Figure 1: Postoperative 1:2 retracted view.

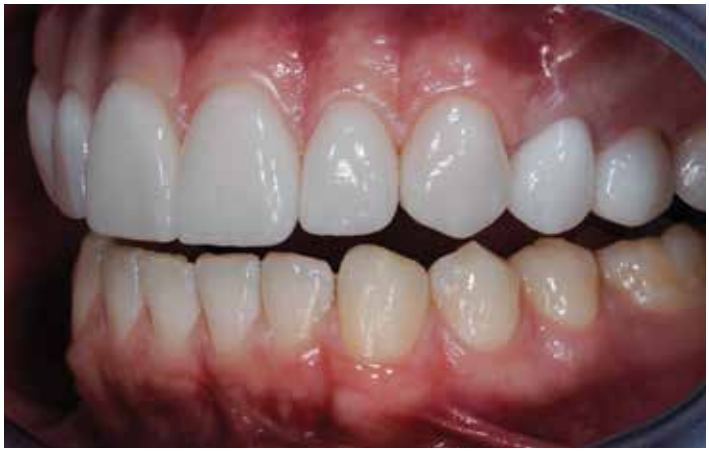

Figure 2: Postoperative 1:2 left lateral retracted view.

> **Examiners do not evaluate the case based upon how difficult and complex it is, but rather, upon the excellence of the final result.**

healthy teeth who want to improve the appearance of their smiles. When these opportunities present themselves, it is incumbent upon every clinician to evaluate his or her comfort level in altering healthy teeth for esthetic reasons alone. Responsible esthetics, espoused by our Academy, can conservatively deliver what our patients desire. In this case, the circumstances allowed for an extremely conservative ("no-prep" veneers) treatment.

The outcome was well within the "zone of excellence" advocated by our credential. The patient wanted a more prominent smile, correcting spacing and brightness issues. Dr. Cooper did an excellent job managing the smile design and all technical aspects of no-prep porcelain veneers. The inherent tooth color, spacing issues, and additional effects prescribed by smile design principles set this case up well for a no-prep porcelain veneer technique.[3] He teamed with his ceramist to provide a beautiful result for the patient **(Figs 1 & 2)**.

The examiners passed this case unanimously with the following notes as they relate to the Accreditation criteria:

- Criterion #53: The color (hue, value, and chroma) selection is inappropriate and unnatural (monochromatic).
- Criterion #44: The surface finish, polish, and luster are inappropriate.

Most examiners' comments were concerned with the fact that there are no chroma gradients gingivally or distally in the arch and that the appearance of the full crown (#5) is bright and lacks warmth. Also, the surface finish appears overly rough as compared to the natural dentition. Only minor deductions were noted.

Dr. Cooper was able to provide a true gift to his patient using today's techniques, materials, and technologies.

Dr. Reynolds is an AACD Accredited Member and has been an AACD Accreditation Examiner since 2003. Dr. Reynolds practices in Franklin, Tennessee.

Disclosure: The author did not report any disclosures.

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Concepts of Design for Contemporary Anterior All-Ceramic Restorations

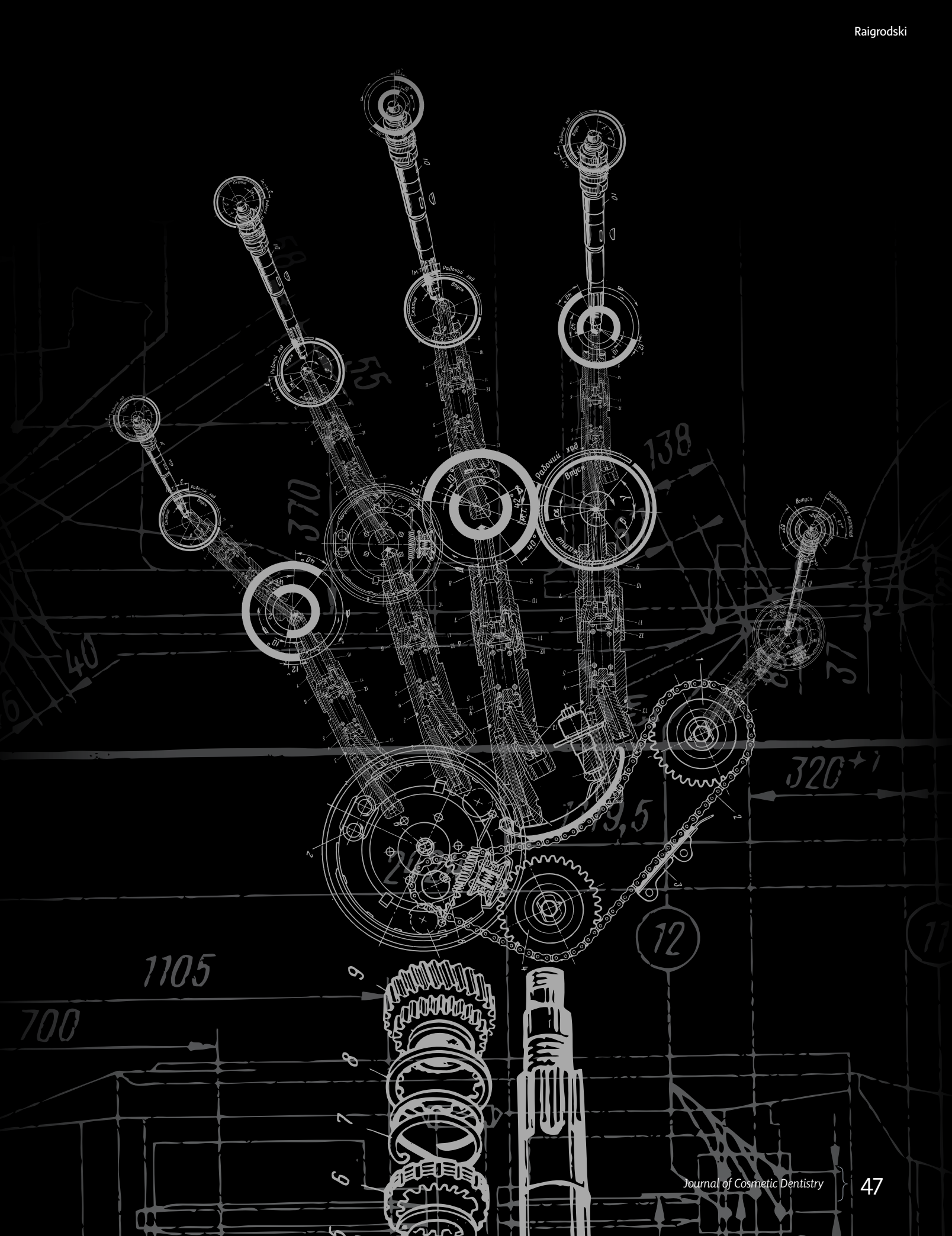
Advantages and Limitations of New Technologies and Materials

Ariel J. Raigrodski, DMD, MS, FACP

Abstract

Clinicians and dental technicians are constantly challenged with harnessing new technologies and materials with the goal of providing patients with indirect restorations that have superior biomechanical and optical properties. This visual essay focuses on concepts of restoration design for complete-coverage restorations and demonstrates appropriate restorative materials selection from a biomechanical and esthetic perspective while maintaining sound restorative concepts for fostering a successful long-term treatment outcome.

Key Words: all-ceramic, bi-layered restorations, monolithic restorations, zirconium dioxide, lithium disilicate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Introduction

The continuous evolution of all-ceramic systems in the last 20 years has been driven by increasing patient demand for metal-free restorations and the ongoing development of restorative materials, concepts of restoration design, and restoration manufacturing technologies. One of the main advantages of such restorations is their ability to facilitate an esthetic treatment outcome at the soft-tissue restorative interface, especially when patients present with a thin, translucent gingival phenotype.

Numerous considerations, which may require the involvement of multiple dental disciplines, must be weighed during the treatment-planning phase prior to commencing treatment. One such consideration is restoration design and material selection for complete-coverage restorations such as crowns and fixed dental prostheses (FDPs), both tooth- and implant-supported.[1] With the use of either computer-assisted design/computer-aided manufacturing (CAD/CAM) technology or the waxing and heat-pressing technique for their processing, all-ceramic restorations may be designed using two major concepts. To date, heat-pressing technology may provide superior control of restoration contours and occlusal contacts versus CAD/CAM technology, an area in which virtual waxing with three-dimensional imaging and display is still evolving.

Concepts of Restoration Design

Bi-layered Approach

All-ceramic restorations may be designed and fabricated as a bi-layered system, much like metal-ceramic restorations. Such systems utilize an infrastructure substitute in the form of high-strength ceramic to support the corresponding veneering porcelain. The veneering porcelain may be applied using one of three techniques: conventional layering with a powder and liquid; waxing and heat pressing to the high-strength ceramic infrastructure; and digital veneering, which fuses a partially sintered milled veneering ceramic with the high-strength ceramic coping.[2-4] In the esthetic zone, the bi-layered approach relies mainly upon the skills of the dental ceramist for a customized ceramic layering and allows the fabrication of highly esthetic restorations.

However, from a biomechanical perspective, the veneering porcelain is relatively weak compared to high-strength ceramics and may be susceptible to cohesive fractures, as well as adhesive failure due to the presence of an interface between the framework and the veneering porcelain. Moreover, adequate framework design to support the veneering porcelain is required.[5,6] In addition, one must consider that the occlusal surfaces and contacts are made of weaker material and, if the infrastructure is conventionally layered, control of occlusal contacts may not always be ideal.

Monolithic Approach

All-ceramic restorations can also be designed and fabricated as a monolithic system, such as cast gold restorations. With this approach, a high-strength ceramic material is used to provide a complete contour restoration all the way from the intaglio surfaces to the proximal and occlusal surfaces. This approach may facilitate the ability of clinicians to provide a more durable restoration, since the occlusal surfaces and contacts are made of a high-strength ceramic material. In addition, with the technologies currently used for fabricating such restorations, a more accurate reproduction of the occlusal surfaces and occlusal contacts is facilitated (particularly with the waxing and heat-pressing technique). However, such an approach may be accompanied with some esthetic limitations, as characterization of the restoration is mainly limited to external staining.

Hence, these two concepts of restoration design present with their relative advantages and limitations. The bi-layered approach may be more appropriate in the anterior segment, where internal characterization, translucency, and color matching are critical and occlusal forces are relatively low. The monolithic approach may be more appropriate in the posterior segments, where esthetics may be a lesser concern and occlusal forces are relatively high. However, in some clinical scenarios, patients may present with evidence of occlusal parafunction or occlusal dysfunction in the anterior segment. In such situations, prudent management of anterior and canine guidance is critical to the longevity of the restorations. Yet, esthetics is an equally essential element when it comes to achieving adequate color matching, translucency, and characterization.

The Hybrid Design

Therefore, in such clinical scenarios, a hybrid restoration design may be preferred. A monolithic, high-strength surface is designed and fabricated at the functional palatal aspects of the restoration to ensure that the palatal anatomy of the restorations coincides with the patient's envelope of parafunction and to ensure optimization of the mechanical properties of the occlusal contacting areas of the restorations. The remaining ceramic infrastructure at the facial and incisal aspects of the restoration may be conventionally layered with the corresponding veneering porcelain to facilitate internal characterization, translucency, and color match with the adjacent and opposing dentition.

Materials

To date, lithium disilicate and zirconium dioxide-based restorative systems have gained popularity in the dental market as high-strength ceramic materials for crowns and FDPs using both the monolithic and the bi-layered approach for restoration design.[7] Both materials vary in terms of mechanical properties, optical properties, wear properties, and bio-

“In the esthetic zone, the bi-layered approach relies mainly upon the skills of the dental ceramist for a customized ceramic layering and allows the fabrication of highly esthetic restorations.”

Figure 1a: Preoperative facial view of two failing metal ceramic crowns on #8 and #9. Note the gingival recessions and inadequate margins as well as the opacity of the restorations.

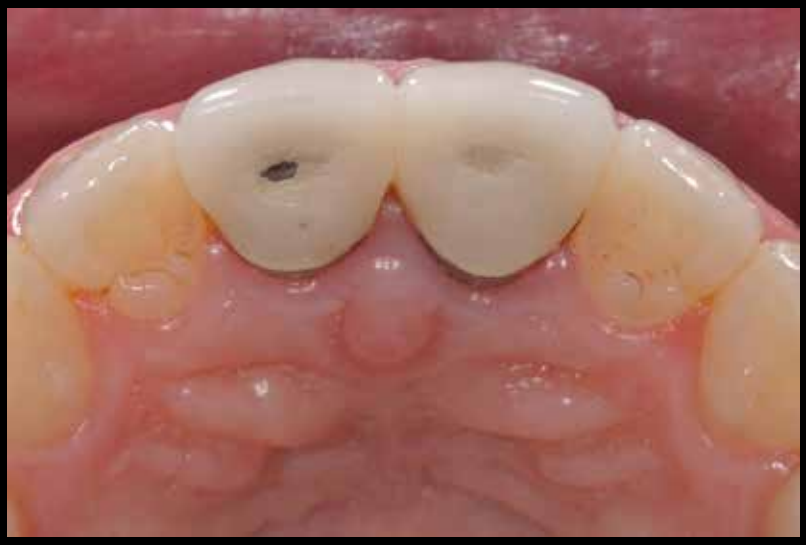


Figure 1b: Preoperative occlusal view of the two failing metal ceramic crowns. Note the wear patterns on the palatal aspects of the crowns.

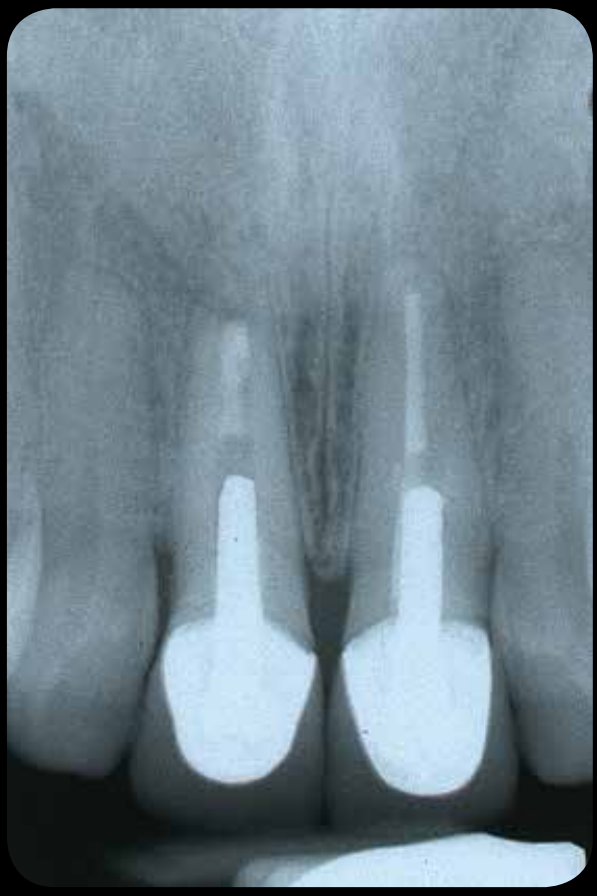


Figure 1c: Although #8 and #9 were asymptomatic, a preoperative radiograph indicates a failing endodontic treatment and less-than-adequate marginal integrity on the crown of #8.

compatibility. These variations affect their indications and limitations, as well as some of the clinical procedures applied while using them, including preparation design and delivery procedures (conventional versus adhesive cementation).[1,7]

Lithium Disilicate

Lithium disilicate may be designed and processed with either the lost wax and heat-pressing technique or via CAD/CAM technology. Although inferior to zirconium dioxide in terms of mechanical properties, this material allows for the fabrication of relatively translucent restorations with favorable wear properties as related to the opposing dentition.[7-9] Lithium disilicate restorations may be fabricated using the monolithic, bi-layered, or hybrid design approach. The latter two include the use of nano-fluorapatite porcelain as a veneering material. The intaglio surface of the lithium disilicate monolithic or layered restoration may be etched for 20 seconds with 9.5% hydrofluoric acid and subsequently adhesively cemented to enhance strength and longevity.[1] In the esthetic zone, it is the author's preference to employ this material for single crowns exclusively using the hybrid design approach in the following clinical scenarios:

- When the abutment tooth is translucent and gingival health is adequate enough to not compromise the bonding procedure, use a more translucent lithium disilicate ingot.
- When the abutment tooth is discolored and gingival health is adequate enough to not compromise the bonding procedure, use a more opaque lithium disilicate ingot.

Zirconium Dioxide

With excellent biocompatibility, zirconium dioxide may be designed and processed via CAD/CAM technology.[7] Superior to lithium disilicate in terms of mechanical properties, zirconium dioxide currently allows for the fabrication of less translucent restorations for both crowns and FDPs.[10,11] However, new zirconium dioxide materials are being developed with improved optical and mechanical properties. In addition, the wear properties of zirconium dioxide are improving as related to the opposing dentition.[12,13] With zirconium dioxide, restorations might be fabricated using the monolithic, bi-layered, or hybrid design approach. The latter two include

Figure 2a: The failing restorations were removed, and the severity of the discoloration was noted for #8. The lack of adequate fit of the cast post and core for both teeth was determined as well.

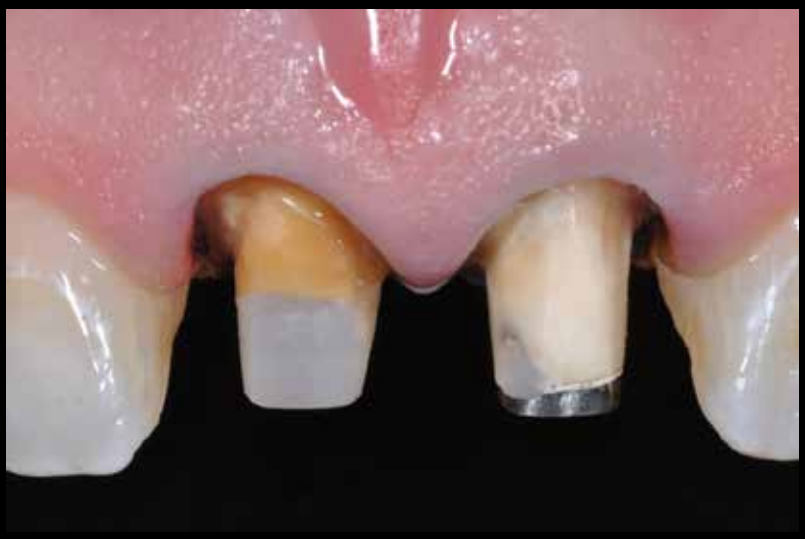


Figure 2b: The cast post and core has been removed from #8 and the endodontic therapy was remade. Subsequently, internal bleaching procedures were performed, followed by the placement of a fiber post and composite-resin core. Due to the complexity of the post removal and the concern about possible complications, it was decided not to remove the cast post and core from #9. The tooth preparations were refined, and a master impression was made.

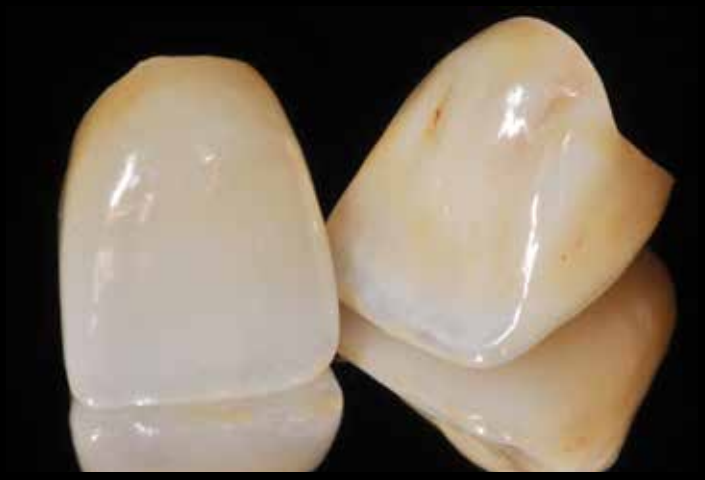


Figure 3a: Lithium disilicate ceramic material was selected for the fabrication of definitive all-ceramic crowns on #8 and #9. Medium-opacity lithium disilicate ingots (MO1, IPS e.max Press, Ivoclar Vivadent; Amherst, NY) were selected for the fabrication of partial monolithic all-ceramic crowns.

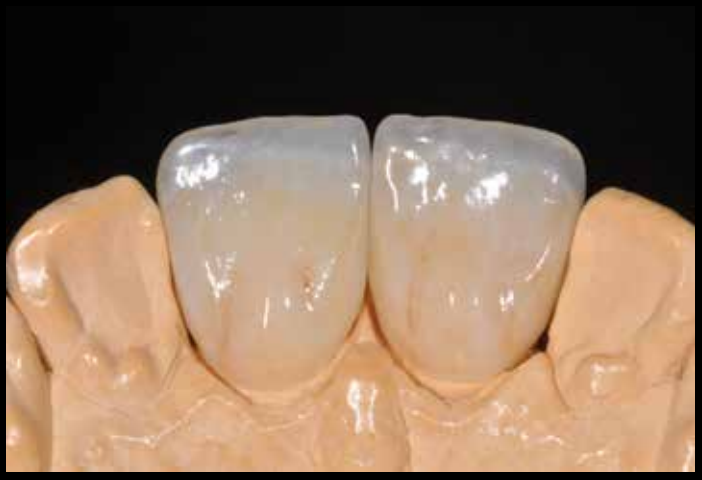


Figure 3b: A monolithic approach was used for the design and fabrication of the functional palatal aspects of the crowns to ensure that the palatal anatomy of the restorations coincided with the patient's envelope of parafunction. This was reproduced using the provisional restorations and to ensure optimization of the mechanical properties of the occlusal contacting areas of the restorations. The facial and incisal aspects of the crowns were conventionally layered to facilitate internal characterization, translucency, and esthetics using nano-fluorapatite-layering ceramics (IPS e.max Ceram).

Figure 4a: The restorations were tried in the patient's mouth to assess color match and esthetics and internal and proximal fit, and to assess occlusal contacts. Functional, esthetic integration with the adjacent and opposing dentition, as well as integration at restorative soft-tissue interface, was noted.

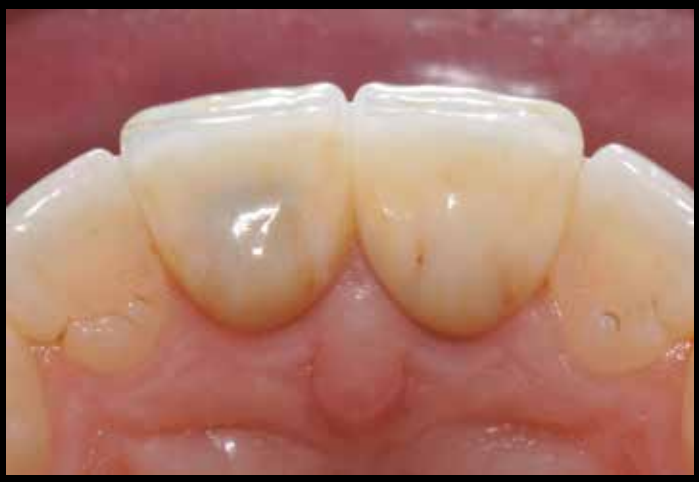
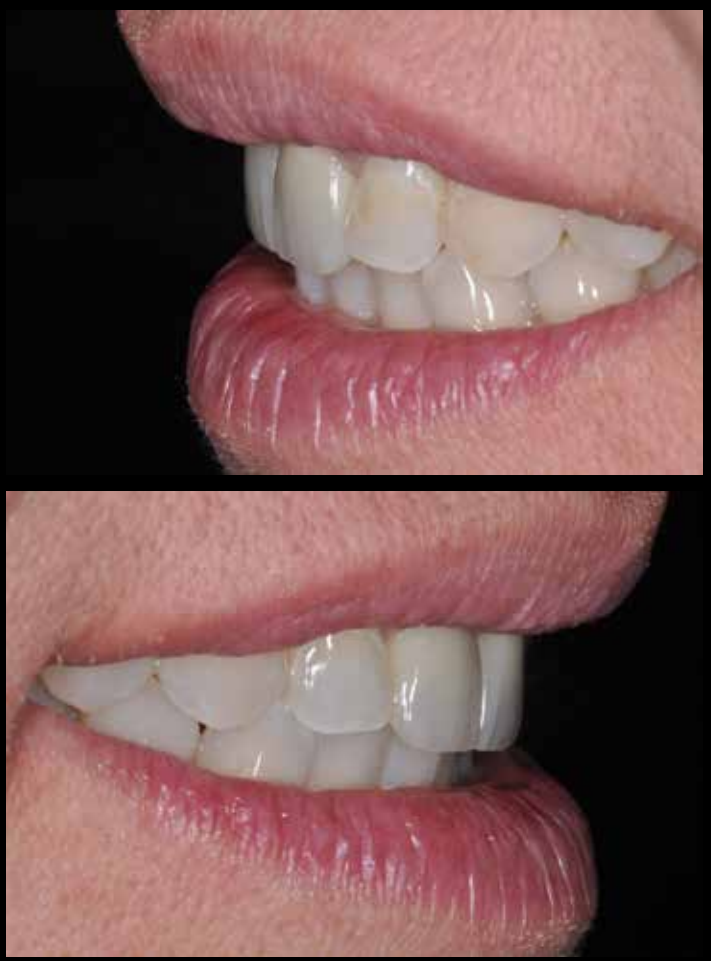


Figure 4b: Once verified, the restorations were bonded with dual-cured translucent composite-resin cement (RelyX Ultimate, 3M ESPE; St. Paul, MN). However, it was also noted on the palatal aspect of the crown on #8 that the discolored tooth projected a low value through the restoration due to the translucency of the restorative material.

Figure 5a: A frontal view demonstrates both high translucency at the incisal areas and characterizations at the facial aspect of the restorations; this was the result of the artistic capabilities of the dental ceramist who layered the restorations' facial and incisal aspects.



Figures 5b & 5c: Right and left lateral views of the patient's partial smile demonstrate the successful integration of the restorations with the upper and lower lips.

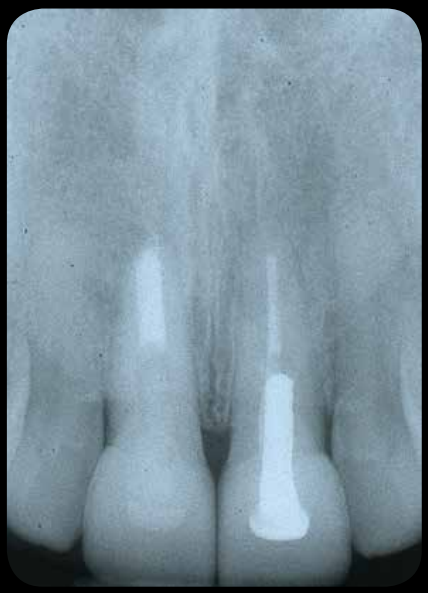


Figure 6: A postoperative radiograph underscores the success of the endodontic therapy and the new fiber post and core on #8, as well as the excellent marginal integrity and the complete excess cement removal.

Figure 7: A preoperative facial view of esthetically failing metal ceramic crowns on #6, #10, and #11; and a failing metal ceramic FDP on #7 (retainer), #8 (pontic), and #9 (retainer). Note the opacity of the restorations, which were made and remade a few times previously.

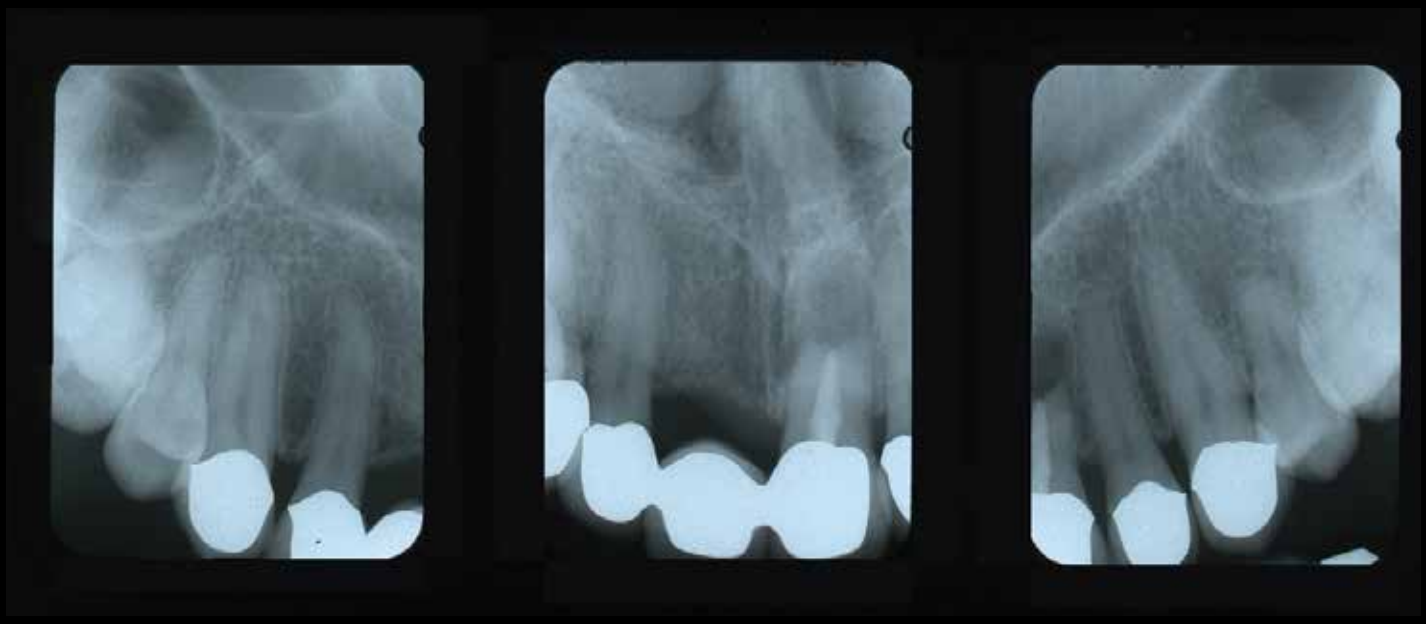


Figure 8: The patient had a history of trauma to the six anterior maxillary teeth. Although they were asymptomatic, a preoperative radiograph demonstrated an endodontic treatment on #9 with a history of periapical surgery.

the use of feldspathic porcelain as a veneering material, and it has been reported that the use of leucite-containing veneering porcelain may reduce the likelihood of cohesive porcelain fractures.[14] Although zirconium dioxide cannot be etched, it can be treated tribochemically[15,16] or with special methacryloxydecyl phosphate (MDP) monomer adhesives to facilitate bonding.[17,18] In addition, due to the superior mechanical properties of zirconium dioxide, these restorations can be conventionally cemented without compromising their longevity.[10,11,19] In the esthetic zone, it is the author's preference to use this material with the hybrid design approach in the following clinical scenarios:

- If the abutment tooth is discolored and gingival health is adequate enough to not compromise bonding procedures, use a coping thicker than 0.6 mm on the facial aspect.
- If the abutment tooth is discolored and gingival health is inadequate enough to compromise bonding procedures, use a coping thicker than 0.6 mm on the facial aspect.
- If the abutment tooth is translucent and gingival health is inadequate enough to compromise bonding procedures, use a coping thickness of 0.3 mm on the facial aspect.

These restorations are not limited to single crowns exclusively, as they have been shown to be successful for both anterior and posterior FDPs.[10,11]

Summary

Acknowledging the advantages and limitations of the different ceramic core materials and harnessing new technologies and restoration design philosophies are key elements for a successful contemporary practice. This visual essay demonstrates how these concepts can be applied to different clinical scenarios, as suggested herein for multiple crowns and FDPs. By following sound concepts of material selection and restoration design, clinicians and ceramists may customize the design of restorations in the esthetic zone based upon each patient's individual needs and, as a result, promote both restoration longevity and esthetics.

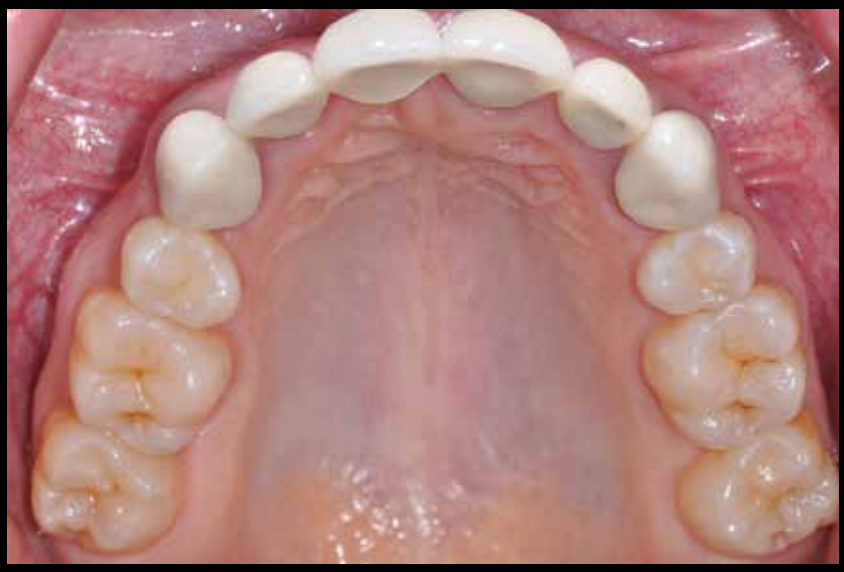


Figure 9: A preoperative occlusal view of the failing metal ceramic restorations. Note the wear on the crowns' palatal aspects as well as the lack of color match with the adjacent dentition.

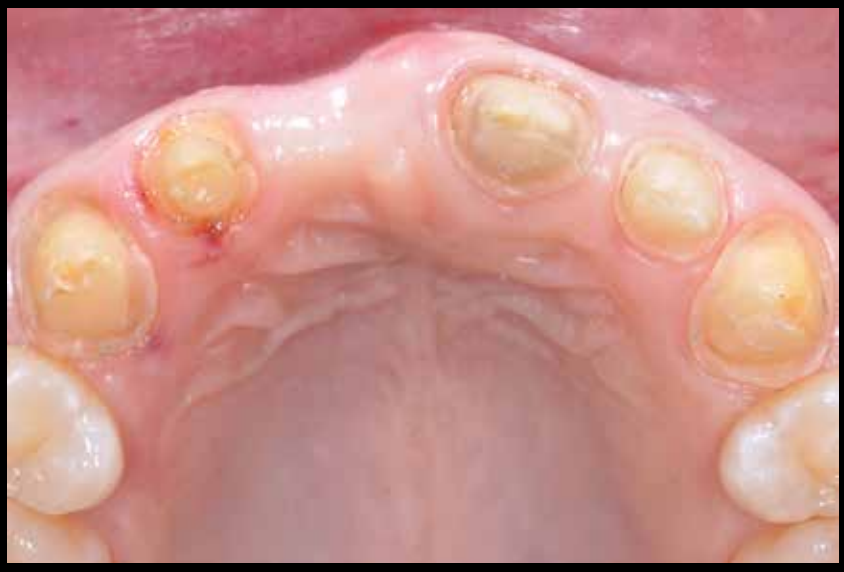


Figure 10: The failing restorations were removed and the severity of the horizontal residual alveolar ridge deficiency at the site of #8 was noted.

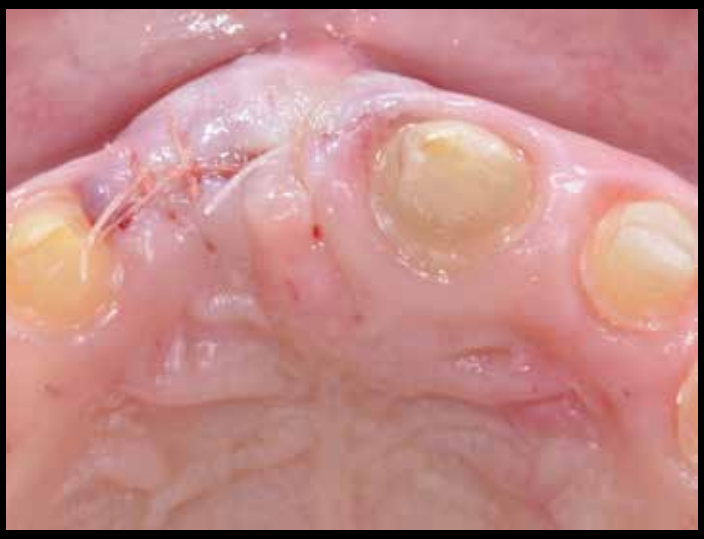


Figure 11a: Soft tissue augmentation of the residual alveolar ridge was performed using acellular dermal matrix (Alloderm RTM, Lifecell, Biohorizons; Birmingham, AL) to eliminate the horizontal ridge deficiency at the pontic site.

Figure 11b: A provisional restoration was delivered with the pontic shortened at the cervical aspect to eliminate pressure at the augmented site. After three months, once the tissue healed, the pontic site was trimmed with a KS4 extra-coarse football-shaped diamond bur (Brasseler USA; Savannah, GA) and a direct composite resin was added to the cervical part of the pontic to mold the tissue at the pontic site. The tissue was left to heal for an additional three months.

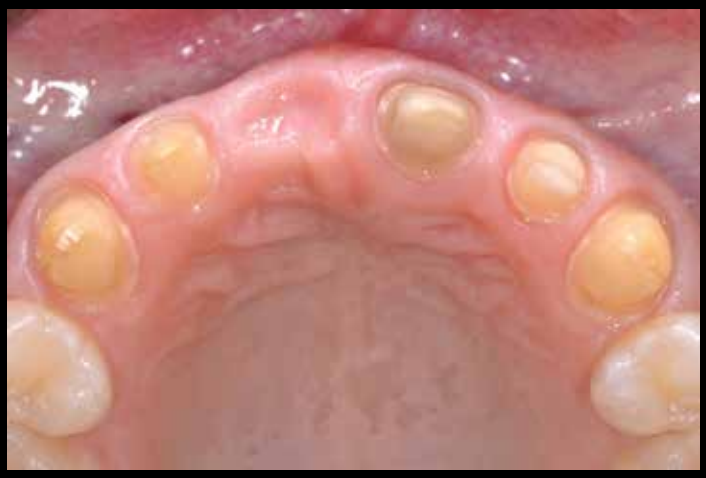


Figure 12: Once the pontic site was completely healed, the tooth preparations were refined and a master impression was made for a zirconium dioxide-based, four-unit FDP for #7 (retainer), #8 (pontic), and #9 (retainer); and zirconium dioxide-based crowns on #6 and #11.

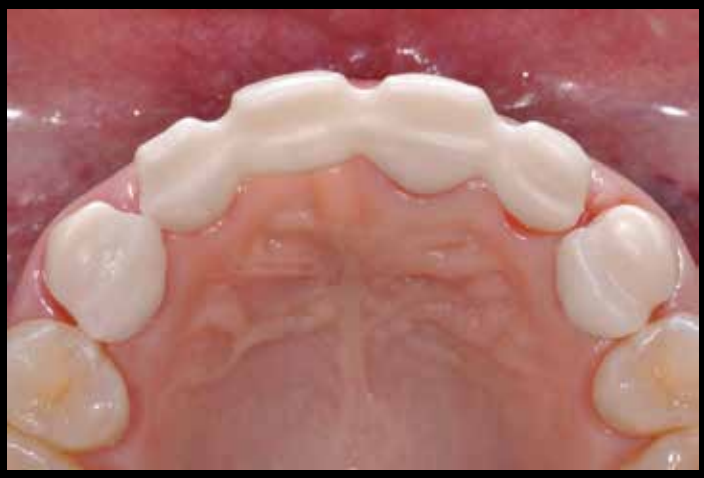


Figure 13: A zirconium dioxide framework with extensive palatal and interproximal struts was designed and milled with a CAD/CAM system (Lava, 3M ESPE). The framework and copings were tried in the patient's mouth for fit and for soft tissue evaluation at the pontic site. A monolithic approach was used for the design and fabrication of the restorations' palatal aspects.

Figure 14: The zirconium dioxide framework was conventionally layered with a corresponding veneering porcelain (Creation ZI-F, Jensen Dental; North Haven, CT). The zirconium dioxide-based crowns were layered using a digital veneering approach (Lava DVS digital veneering system).

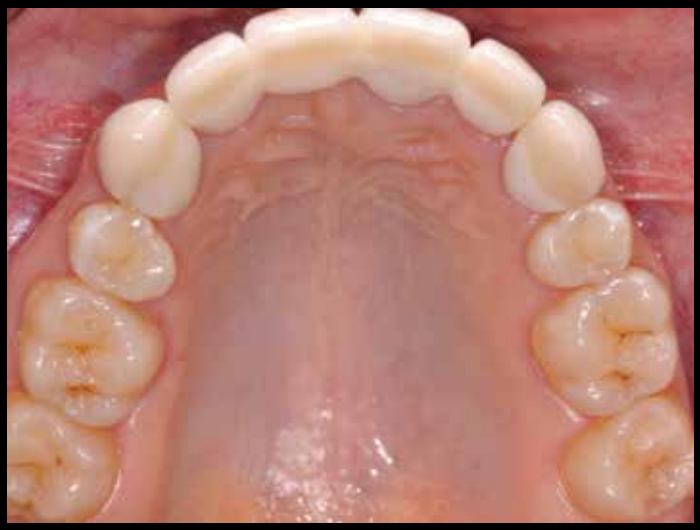


Figure 15: The restorations were conventionally cemented with self-etching, self-adhesive, dual-cured composite resin cement (RelyX Unicem 2).

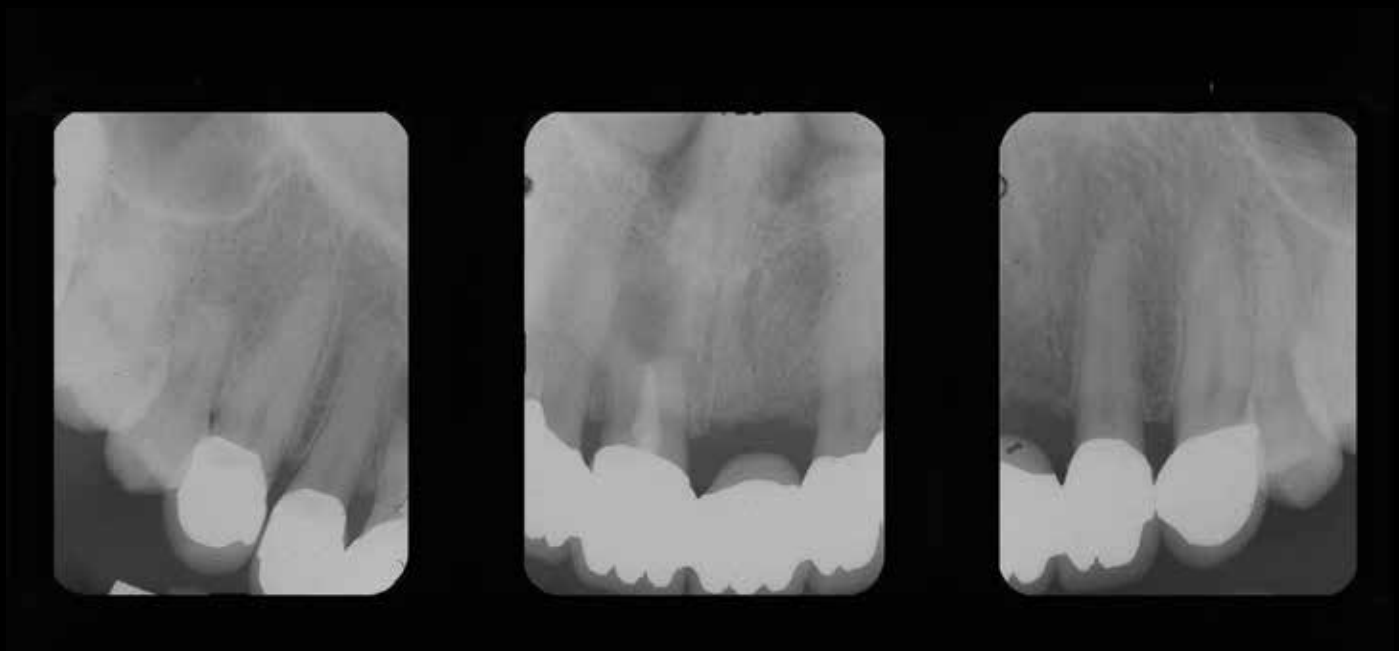
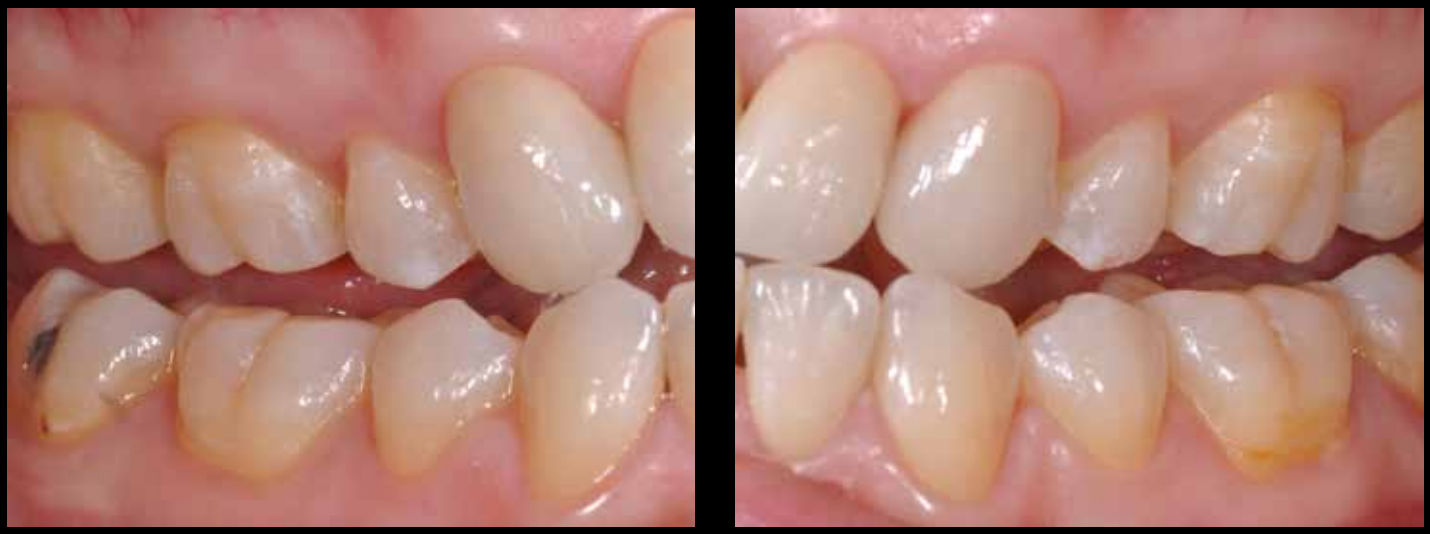


Figure 16: Excellent marginal integrity and excess cement removal were confirmed.



Figures 17a & 17b: The patient was provided with a mutually protected occlusion with canine guidance in lateral excursions and anterior guidance in protrusive movement.

Figure 18: The ceramist layered the facial and incisal aspects of the restorations so as to provide characterizations and translucency to the patient's satisfaction.

Acknowledgments

The author expresses his sincere gratitude to Dr. Michael Cohen for the surgical procedures performed in the second case. The author also thanks master ceramists Harald Heindl and Sang Jun for fabricating the restorations presented in the first case and second case, respectively; and Dr. Matthew Mandel for the endodontic therapy of tooth #8 in the first case.

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Achieving Lifelike Anterior Composite Restorations

Considerations and Technique Concepts

Newton Fahl Jr., DDS, MS

Abstract

The application of direct composite procedures has experienced a noticeable comeback during the past decade. New systems are available that allow clinicians to conservatively and esthetically restore flawed dentition. Advances in the physical properties of composites coincide with improvements in their optical and shade characteristics, allowing dentists to emulate natural dental tissues. There are many esthetic composite systems available today with a wide shade range, which affords numerous restorative possibilities. This article describes the fundamental color and physical properties of state-of-the-art composite restoratives, crucial for the successful clinical restoration of anterior direct challenges. A step-by-step Class IV case using a supra-nanofilled composite is presented.

Key Words: composites, properties, Class IV, layering

> When dentists understand the optical and physical characteristics of specific direct composite materials, they can select the most ideal option for treating the case at hand.

Introduction

When dentists understand the optical and physical characteristics of specific direct composite materials, they can select the best option for treating the case at hand. Considering that such cases may present with teeth lacking enamel and/or dentin, each of which affects tooth strength and esthetics in specific and different ways, selecting direct restorative materials that replicate the characteristics of natural tooth structure contributes to lifelike results in terms of durability, esthetics, and function. Likewise, these same characteristics—and the manner in which the selected direct composites are applied—facilitate predictability of necessary procedural steps, including sculpting, curing, finishing, and polishing.

The Restorative Challenge

Dental restorations in the anterior region require precise incorporation of color and form to provide a seamless blend with the surrounding dentition.[1] Improvements in the material characteristics of composite resin, including enhanced optical properties, allow today's dentists to create highly esthetic direct restorations.[2-4] However, optical and physical characteristics also should be considered when choosing a composite material. These include color, shade, strength, and durability. It is the clinician's responsibility to understand the artistic and scientific principles involved with composite materials and their application so as to realize their many advantages for minimally invasive and esthetic direct dental procedures.[5,6]

Properties of Composite Systems

Handling

Particular material characteristics, including handling and sculptability, relate to degrees of viscosity and, therefore, denote specific manipulation techniques devised to influence the final restorative result.[7] Layering the composite incrementally facilitates manipulation and sculpting of each increment to ideal contour and volume prior to light-curing.[8]

Polymerization Shrinkage

Postoperative sensitivity and marginal leakage result from polymerization shrinkage, another important consideration when performing direct restorative procedures.[2] Shrinkage stress on the walls of a preparation cause composite to pull away from the surface, leaving openings for leakage. Precise and reliable marginal adaptation and control of this shrinkage are required to reduce or eliminate this problem.[9] Consequently, the volumetric shrinkage of current systems ranges from 0.9% to 1.5%,[10,11] reducing the probability of disrupting the hydrodynamics of the tubuli.[11,12]

Fracture and Wear Resistance

When composites are used in stress-bearing areas, fracture and wear resistance are crucial in influencing the durability and lifespan of restorations.[13] Often the material of choice for restoring the incisal edges of anterior dentition, resin composites are consistently exposed to masticatory and occlusal forces. Astute selection of a durable and wear-resistant restorative material is, therefore, imperative.[14]

Polishability

A necessary characteristic of composite resin materials is high polishability, which is required to simulate the gloss of natural enamel.[15] It is essential that any composite indicated for final veneering layers possess characteristics such as surface smoothness, polishing ease, and long-lasting gloss retention. Specific finishing and polishing techniques may provide discernible differences in surface smoothness and gloss. Depending upon the intensity of tertiary anatomy anticipated by the clinician, the surface texture of a composite restoration may vary from irregular to exceptionally smooth. Regardless of the micro-morphological aspect of the restorative surface, the ideal composite should achieve the highest gloss attainable while displaying long-term immutability. Micro and nanohybrids can

attain a distinguished luster and polish even under acidic environments and unfavorable oral conditions,[16,17] when developed with material characteristics including longevity,[18] wear resistance,[19] and improved polishibility.[20]

Color Stability

Most newly developed state-of-the-art composite systems exhibit balanced color stability,[21] reducing concern about color changes during the aging process. While composite exogenous staining susceptibility[22] varies among composite structure and brands,[23] procedures such as light polymerization[24] and finishing and polishing techniques,[25] as well as patient attention to dietary restrictions,[26] may limit potential discoloration.

Composite Types

Available composite systems vary according to filler particle size and shapes. While each demonstrates diverse characteristics, material selection is determined by the type and location of restoration to be performed and the specifics of the case.[27]

Microfills

Traditionally the material of choice for cases requiring surface smoothness and high polishability,[28] microfills provide high sculptability and excellent wear resistance,[29] all characteristics required for direct veneer restorations.[30] In addition, microfills demonstrate high translucency, and their color stability has proven reliable for more than 20 years.[29] Lower fill, however, results in lower fracture resistance. Therefore, microfills are not recommended for monolithic use to build up the incisal edge, for restorations over the incisal edge, or in other heavy load-bearing areas.[31] Reinforced microfills, however, demonstrate higher fracture toughness due to a higher filler load and, therefore, may be used in high stress-bearing areas for selected cases.[32]

Conventional Hybrids

Unlike microfills, a key benefit of hybrid composites is fracture toughness or resistance, which makes them ideal in clinical situations such as Class IV and incisal edge augmentation procedures.[5,29] In addition to providing strength, the larger particle size and distribution equip hybrids with more lifelike optical esthetics than microfills. Although material characteristics vary according to the composite system chosen, color stability and sculptability prove sufficient.[29] Wear resistance and polishability, however, prove inadequate due to heavy loading of larger particles,[33] which causes pitting of the finished surface[34] and fails to sustain a polished state long term.[29]

Microhybrids and Nanohybrids

Filled with 70% to 80% 0.04-µm and 1-µm to 5-µm particles,[35] hybrid composite resins are characterized by an initial high polishability that dulls with time. Introduced in an attempt to maximize surface smoothness and gloss, microhybrids and nanohybrids were developed to address this issue while retaining the strength characteristics of their predecessors.[16,36] Microhybrids provide strength, high luster, and improved handling, as well as improved polishability compared to conventional hybrids.[37,38] The final polish and luster of the microhybrid composite resin mimics the appearance of natural tooth enamel.

Nanohybrids combine the best of the hybrid and microfill composite systems, producing a state-of-the-art hybrid category. While retaining the fracture toughness and color stability of their predecessors, the sculptability and wear resistance have also been improved.[39] Although the increased content of nanoparticles in nanohybrids does, in fact, produce a better polish, microfills still remain uncontested with respect to long-term gloss.

To maximize durability and polishability of composite materials, nanoparticles were added to hybrid mixtures. However, discrepancies in filler size and shape among commercially available restorative systems claiming to be microhybrids or nanohybrids often result in disparate unevenness in clinical polishing performance.[40]

Nanofills

Improvements in the strength and polishability of composite materials have been achieved using nanotechnology. Modifying the organic resin matrix has resulted in[41-44] reduced polymerization shrinkage,[45,46] enhanced sculptability,[47] and improved opacity/translucency[48-50] and refractive indices[51,52] to recreate more reliable, predictable, and lifelike tooth structures.[53] Although there are few nanofilled products available, particle size and shape are the most important characteristics of these composites, ultimately allowing the best polishability.[29] Due to their smaller particle size, nanofills exhibit excellent fracture and wear resistance.[29] These composites also demonstrate color stability.[29] Because not all systems exhibit the same properties and there is no one perfect material for all indications,[54] it is ultimately the dentist's

responsibility to evaluate each system to maximize predictability and esthetics.[54]

Color and Optical Properties

Restorative success is predicated on an understanding of the optical properties of natural dentition and the selected composite material.[55] An integral part of dental esthetics is how light is transmitted, reflected, diffracted, refracted, and absorbed through natural enamel and dentin.[56] The interplay of light with enamel and dentin at their varying thicknesses along the clinical crown produces variations in color hue, chroma, and value, the latter being directly related to a fourth dimension of color, namely translucency/opacity.[56]

Several composite layering techniques have been proposed for anterior restorations. In the late 1980s, systems keyed toward the VITA Classical shade guide (Vident; Brea, CA) were introduced to make shade selection easier and to produce more predictable esthetic results. The VITA designation for color-coding composite systems still prevails and is indicated for both dentin and enamel shades. However, a few non-VITA enamels are available to supplement the VITA system as effect enamels. With these systems, the color of the final composite restoration (i.e., hue and chroma) is generated using an artificial enamel of the intended shade, according to the VITA designation. For deeper cavities missing the natural dentin, a VITA-based dentin is used as a foundation for chroma and opacity beneath the VITA enamel. The combination of artificial VITA dentin and enamel produces the final compound color result.

In the mid 1990s, other layering techniques were introduced that advocated the use of non-VITA enamels as value and chroma modifiers to achieve the final color.[57-59] Termed the "natural layering concept," these approaches are extensively used by clinicians worldwide.[59] Although non-VITA optical characteristics of the enamel composites closely resemble those of natural enamel and can elicit high-quality esthetics in the hands of a knowledgeable and skilled operator, there remain limitations to the technique.

As with nature, the non-VITA composite enamels only modify chroma and value, containing no hue pigment themselves. Thus, it is the thickness and opacity of the composite enamel overlaying the dentin core that results in the perceived hue, chroma, and value of a restoration. To master the use of systems with non-VITA enamels, the clinician must be extremely proficient in color theory and how opacity/translucency, chroma, and value interrelate to generate polychromatic variations within a restoration.

It is extremely difficult to replicate a VITA Classical shade using layering techniques.[60] Therefore, the key to clinical and esthetic success lies in the clinician's ability to master the composite system being used.

Class IV Technique Using Estelite Omega

A supra-nano universal composite, Estelite Omega (Tokuyama Dental America; Encinitas, CA), was recently introduced to the market. It is composed of spherical supra-nano fillers (200 nm), a radical amplified photo-polymerization initiator system, and a Bis-GMA/TEGDMA compomer.[29,36] With a filler weight of 82% (i.e., 78% by volume). Its physical properties include compressive strength of 410 MPa, a flexural strength of 117 MPa, and a flexural modulus of 8.8 GPa.

Ideal for use with layering techniques, the comprehensive supra-nano composite demonstrates outstanding polishability after 60 seconds of abrasion,[61] high gloss retention over time,[62] high wear resistance,[63] and minimal shrinkage (less than 1.5%). It also has been shown to demonstrate exceptional translucency, opalescence, and radiopacity.[38]

Complementing the supra-nano composite's ideal physical and handling characteristics is its range of 11 shades, which creates limitless possibilities for producing highly esthetic restorations using layering techniques. Additionally, to ensure the long-term esthetic predictability of restorations, the material has color stability well within clinically acceptable standards (i.e., a ΔE below 3.3).[63,64]

To further facilitate the creation of precise direct composite restorations, the composite accommodates an extended working time under operatory light, yet a reduced curing time. Available in both syringes and preloaded tips, the composite system simplifies the layering process.[60]

Clinical Case Presentation

A 24-year-old female patient presented with a disharmonious smile line due to the uneven incisal edge position of the upper central incisors **(Fig 1)**. The right central incisor showed minor wear of the natural enamel. The left central incisor contained a defective Class IV composite restoration, whereby a fracture line could be seen due to undue tooth preparation and in-

Figures 1 & 2: Views of the patient's preoperative condition.

Figure 3: The defective restoration was removed and the tooth prepared using a 2.0-mm facial bevel. The bevel was applied up to the DEJ to allow adequate thickness of the composite material over the tooth-composite transitional line.

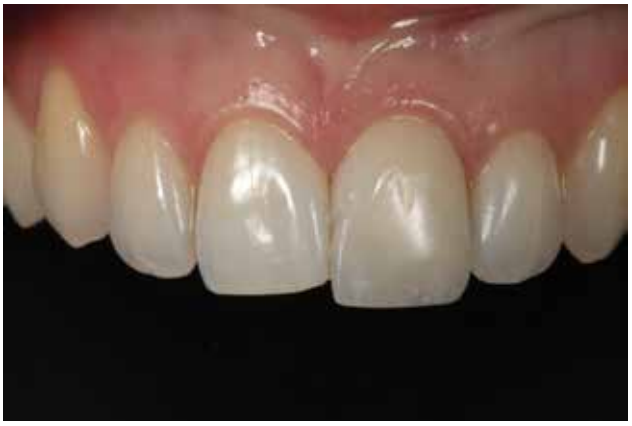


Figure 4: A color mock-up was created.

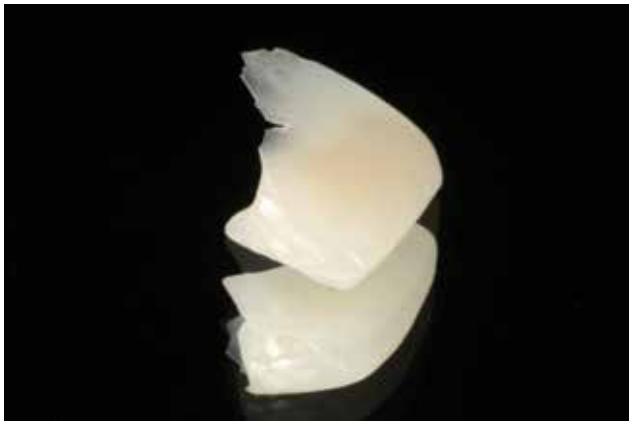


Figure 5: Not bonded onto the tooth, the color mock-up was flaked off and the actual thickness of each layer was evaluated from both the inner and outer aspects.

Figure 6: To provide a three-dimensional perception of the layered shade, a silicone matrix was fabricated from the waxed-up model.

correct selection/application of the restorative composite **(Fig 2)**.

Clinical Protocol

The defective restoration was removed and the tooth prepared using a 2.0-mm facial bevel. The bevel was applied up to the dentoenamel junction (DEJ) to allow adequate composite thickness over the tooth-composite transitional line **(Fig 3)**. Utilizing a coarse finishing disc, the aprismatic enamel was removed from the right central incisor.

To corroborate the shades selected with customized shade tabs (Omega Shade Guide), a color mock-up was created **(Fig 4)**. The color mock-up is an ideal means by which to preview the accuracy of each dentin and enamel shade selected. It also provides the opportunity to "rehearse" the contour and thickness of each dentin and enamel layer, as well as to ascertain the color outcome of the associated shades. Because the color mock-up is not bonded onto the tooth, it is flaked off and the actual thickness of each layer is evaluated from both the inner and outer aspects **(Fig 5)**. Usually a 5-to-15-minute procedure (depending upon the skills of the operator), a color mock-up saves time and money by preventing the need for remakes at follow-up appointments.

A silicone matrix (Zetalabor, Zhermack; Badia Polesine, Rovigo, Italy) was fabricated from a waxed-up model to provide a three-dimensional perception of the layered shades **(Fig 6)**. Next, a three-step, total-etch, dentin-enamel adhesive (Optibond FL, Kerr; Orange, CA) was applied. A single increment of an effect achromatic enamel (Estelite Omega MW) was layered and sculpted to ideal contours over the facial, incisal, and lingual aspects **(Fig 7)**.

Figure 7: A single increment of an effect achromatic enamel was layered and sculpted to ideal contours over the facial, incisal, and lingual aspects.

Figure 8: The lingual shelf was created using a non-VITA enamel.

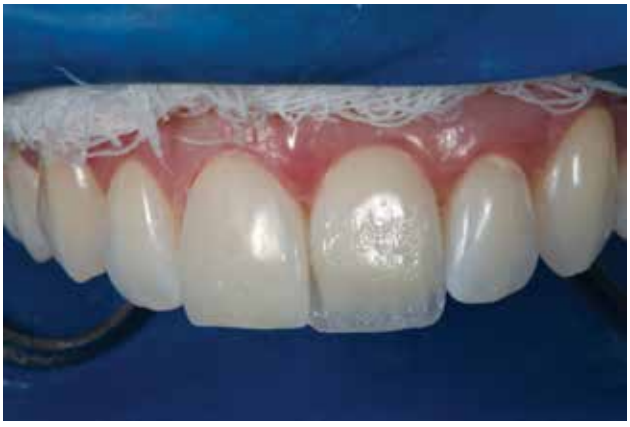


Figure 9: Dentin composite one chroma higher than the desired final chroma was applied along the contour of the natural DEJ, the proximal aspects, and incisal edge, as well as the facial contour; dentin mamelons were also sculpted.

Figure 10: An opalescent effect enamel was plunged into the depressed areas between the MW enamel and the dentin composite.

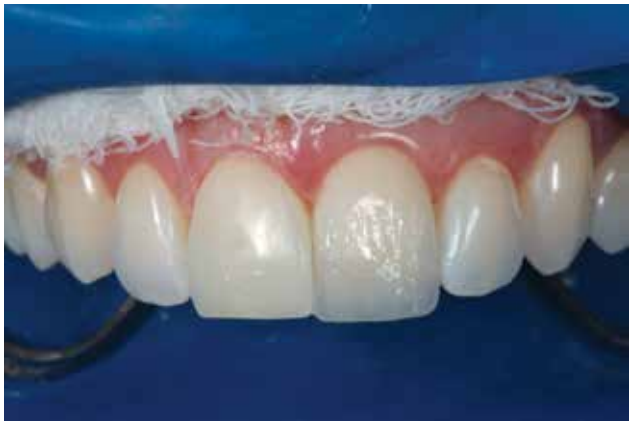


Figure 11: Because Estelite Omega does not undergo a major color change after light-curing, it provided the opportunity to pre-visualize the intended effect and to adjust for errors.

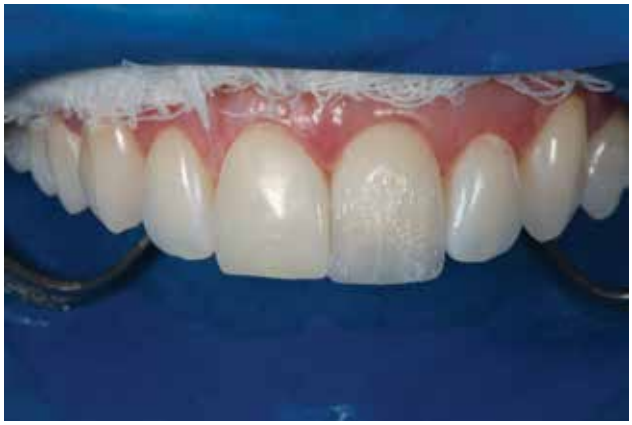
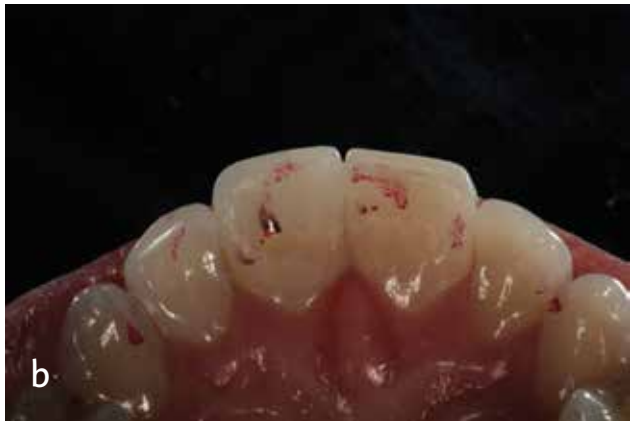


Figure 12: Craze lines and white decalcification spots can be replicated using white tints or high-opacity composite masses.

Figure 13: The final VITA enamel was applied beyond the beveled enamel, brought to full contour, then cut back.

Figure 14: Slightly thicker to provide latitude for proper finishing, the same effect enamel shade used on the palatal aspect was applied along the incisal one-third.

Figure 15: Anatomical landmarks were imparted and the restorations were finished.



Figures 16a & 16b: Views of the restorations after the final finishing and polishing.

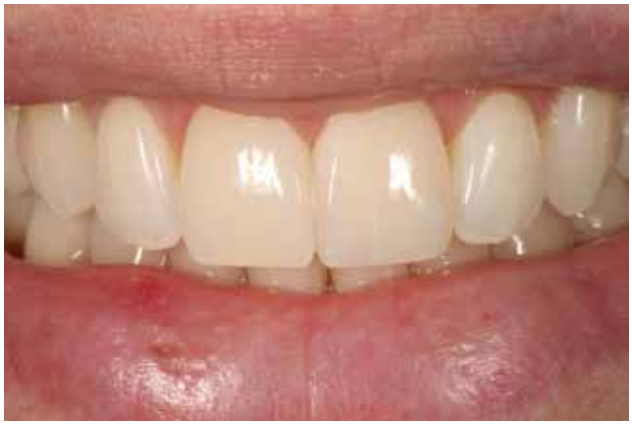


Figure 17: A successful anterior composite restoration must satisfy key parameters, including a perfect color match, preservation of initial brilliance/polish, and maintenance of functional pathways.

Figure 18: Final posteroperative view of the restoration.

> "Material selection may seem overwhelming, considering the numerous composite materials available. However, a comprehensive knowledge of composite characteristics relieves some of the frustration involved."

The restoration was light-cured (VALO, Ultradent; South Jordan, UT), finished, and polished to primary anatomy.

A non-VITA enamel (Estelite Omega MW) was used to create the lingual shelf **(Fig 8)**. Applied to an even thickness not exceeding 0.3 mm to 0.5 mm, it approximates the actual average histological width of the natural enamel along the tooth thirds. An exception is if a more marked incisal halo is intended and, as a result, the milky-white layer is thickened along the edge and up interproximally, blending with the natural enamel.

A dentin one chroma higher than the intended final chroma of the restoration was applied (Estelite Omega DA3) by following the contour of the natural DEJ along the proximal aspects and incisal edge, as well as the facial contour. Dentin mamelons were sculpted accordingly at this stage to mimic those of a reference contralateral tooth **(Fig 9)**. Applying the dentin increment over the beveled enamel just enough to prevent any shine-through is fundamental to achieving a seamless transition.

An opalescent effect enamel (Estelite Omega Trans) was plunged into the depressed areas between the MW enamel and the dentin composite **(Fig 10)**. At this point, to prevent overemphasizing the translucency of this area, care must be taken not to make this layer too thick. Because Estelite Omega does not undergo a major color change after light curing, it is possible for the clinician to pre-visualize the intended effect and adjust for errors in thickness and contours **(Fig 11)**.

At this point, craze lines and white decalcification spots can be replicated using white tints or high-opacity composite masses. A bleach shade of higher value (Estelite Omega Bleach 1) can be applied and thinned or thickened as necessary to achieve the effects desired **(Fig 12)**. The final VITA enamel (Estelite Omega A1) was laid over and somewhat past the beveled enamel, brought to full contour, then cut back over the areas where an achromatic, non-hue-bearing enamel should be perceived in the natural adjacent teeth **(Fig 13)**. This step ensures complete masking of the tooth-composite transition while allowing room for a layer of effect enamel that will impart achromaticity, milky-whiteness, and depth.

The same shade of effect enamel used on the palatal aspect (Estelite Omega MW) was applied along the incisal one-third, blending with the VITA enamel, and brought to final morphology while made slightly thicker, providing latitude for proper finishing **(Fig 14)**. Anatomical landmarks, such as vertical transitional line angles and point angles, were meticulously created. The restorations were finished, closing to perfect symmetry **(Fig 15)**. Secondary anatomy and texture were placed as needed, and final finishing and polishing performed.

As with any restoration subjected to sliding and shear forces of the anterior envelope of function, composite restorations must be properly adjusted to eliminate any interference that might cause undue wearing or chipping. Adjusting the opposing dentition to create a functional path that leads to an ideal edge-to-edge relation is of paramount importance for preserving the esthetic and functional integrity of restorations on the upper anterior arch **(Figs 16a & 16b)**.

To deem an anterior composite restoration successful, it must meet specific key parameters, including a perfect color match, preservation of initial brilliance/polish, and maintenance of functional pathways without compromising the original morphology **(Fig 17)**. The selection of a supra-nano composite bearing suitable optical, color, and physical properties for this anterior case proved satisfactory for the patient and clinician **(Fig 18)**.

Summary

Material selection and placement technique are two critical factors influencing the success of Class IV anterior restorations, one of the most challenging procedures in dentistry. Material selection may seem overwhelming, considering the numerous composite materials available. However, a comprehensive knowledge of composite characteristics relieves some of the frustration involved. The ideal material for a Class IV anterior restoration provides ease of sculptability, exceptional fracture strength, high polishability, color stability, and superb esthetics. In this case, the new supra-nanofilled, resin-based Estelite Omega composite contributed to a functional and esthetic anterior restoration for a satisfied patient.

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> "The ideal material for a Class IV anterior restoration provides ease of sculptability, exceptional fracture strength, high polishability, color stability, and superb esthetics."

Dr. Fahl has a Certificate in Operative Dentistry and a Master of Science degree from the University of Iowa. He is the owner and director of the Fahl Center in Curitiba, Brazil.

Disclosure: The author has consulted for Tokuyama Dental America in the development of Estelite Omega.

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Myths VS. REALITIES

Bond Strengths and Their Practical Implications

Michael B. Miller, DDS
Sabiha S. Bunek, DDS

Introduction

Bonding procedures play a central role in our readers' practices, and understanding the importance of bond strengths is a challenge facing many clinicians today. Is bond strength a reliable measure? What truly are the measures of effectiveness? Consider how your own perceptions may affect your results. In the quest to learn more about this topic, *jCD* asked Dr. Michael Miller of REALITY Publishing and Dr. Sabiha Bunek of *The Dental Advisor* to share their perspectives on the significance of bond strength.

"Bond strength is, like many laboratory tests, just a tool."

Key Words: Bond strength, test methods, adhesive bonding, microleakage, bonding agent

Opening Comments from Dr. Miller

There is an emerging trend in dentistry and dental product manufacturing to revisit the chemistries of earlier generations of bonding agents, such as so-called fourth-generation bonding agents. The reason is because these products have withstood the test of time despite not having improved tremendously over the years. What has changed, however, are dentists' needs and desires to perform adhesive bonding protocols in more efficient ways. As a result, dental publications—whether traditional print or online versions—are replete with manufacturer advertisements for adhesive bonding products designed to eliminate steps while still producing necessary bonding characteristics. *Bond strength* is among the terms used to qualify a bonding agent's ability to succeed. Depending upon what is actually being tested, how, and when, the term *bond strength* and the results used to support a product's use could be misleading.[1,2]

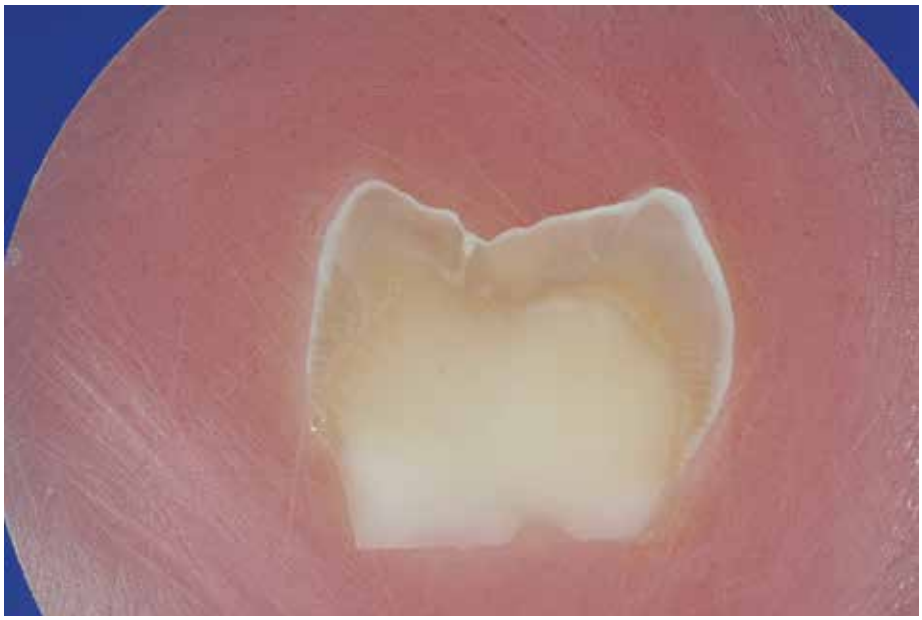

Figure 1: Typical flattened extracted tooth for bond strength testing.

Myth
Bond strength is a definitive measure of whether a bonding agent will succeed or fail.

Reality
Bond strength is, like many laboratory tests, just a tool.[1] It is not the end-all, be-all indication as to whether a product will succeed or fail. It actually indicates what probably will fail better than what will succeed. For example, years ago when single-component bonding agents were introduced, an original formula of a bonding agent was essentially considered a universal bonding agent. However, our laboratory was interested in the clinical applications of that particular bonding agent. An experiment was conducted in which cylinders of self-cured composite were bonded to extracted human teeth **(Fig 1)**, then moved to a testing machine (e.g., Instron; Norwood, MA). We quickly discovered that proper adhesive bonding would not occur with self-cured or with dual-cured materials if they were applied in too thick a layer; we observed such critical failures as test restorations falling off before they could be placed in the testing machine. As a result of repeated clinical failure of self-cured or dual-cured composite materials, the manufacturer released a dual-cure activator, which solved the problem with that product line. In this case, the bond strengths had only confirmed what we had seen clinically.

Some manufacturers claim higher bond strength than similar products as a marketing ploy, but that is not necessarily a reliable measure, as we cannot be certain of what values are necessary for clinical success.[2] Additionally, there is no standard by which bond strengths are tested, so there are variances in measurements as well.[3]

The myth is that bond strength defines whether a bonding agent will succeed or fail. The reality is that laboratory testing of bond strength can provide only a small amount of insight into how the product performs, but is certainly not the final word.

Myth
24-hour bond strength tests are good enough.

Reality
When we opened our laboratory in 1998, many dental schools, manufacturers, and independent testing facilities considered 24-hour bond strength tests to be sufficient indicators as to whether a bonding agent would work in a practical setting.[4] This is still the case today. The inherent problem with relying on 24-hour bond strength test results is that in direct dentistry (assuming it was a light-cured restoration), the tooth would be prepared, the bonding agent applied and light-cured, and the composite material applied and light-cured. This would immediately be followed by using a handpiece for finishing. Handpieces, despite how far they have come in reducing vibration, still produce a considerable amount. Therefore, what a dentist really needs to know about a bonding agent is how it will perform immediately after light-curing.[5]

That was our laboratory's motivation in 1998 for testing these products in a way that would reflect how they are actually used in a dental practice. Clinicians must be confident that, regardless of a material's high bond strength as reported by the manufacturer, the just-placed restoration or core buildup will not "pop out" when they take an impression, remove a provisional, or finish a definitive restoration with a handpiece. We discovered that initial bond strengths (i.e., immediately after light-curing) can be significantly lower than in the same products when tested after 24 hours or more.

Although 24-hour tests may still have some value in the assessment of bonding agents, their application in direct dentistry is minimal at best.

Myth
Small changes in test methods have little effect on bond strength.

Reality
When many manufacturers initially test the strength of their bonding agents, it is done in their own laboratories. These tests are often performed not by dentists, but by the chemists who developed the product. Most of these chemists have never worked inside the mouth with these products, so often the methods they use to test their products

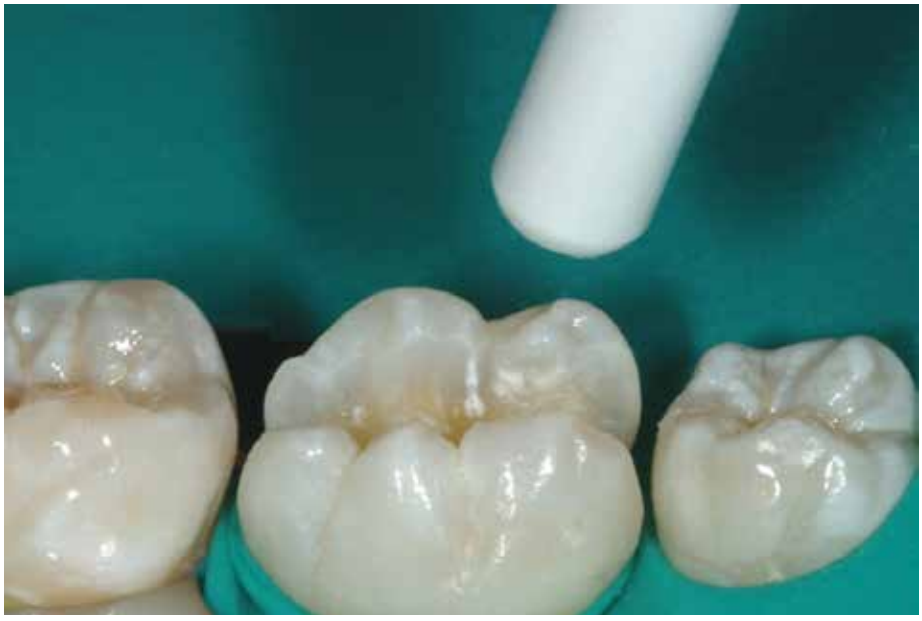

Figure 2: Air syringe tip is placed about 0.5 inches from the tooth for solvent evaporation.

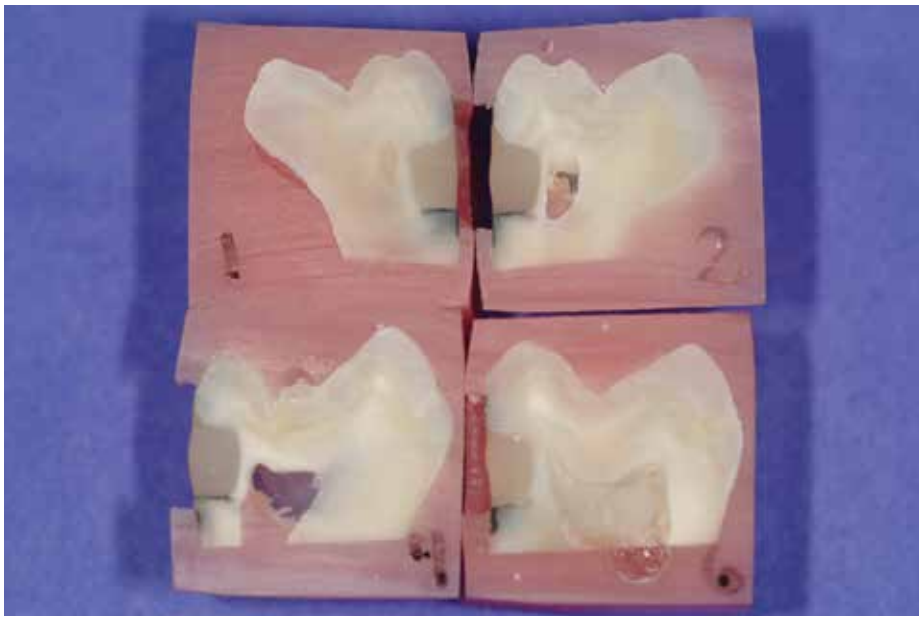

Figure 3: Sectioned teeth after microleakage testing show virtually none at the enamel margins, but severe leakage at dentin margins.

may be slightly incorrect procedurally, or be missing an important step clinically. They also are not working under the same restrictions regarding time, space, and availability of equipment as a dentist would in a practical setting.[6]

For example, when manufacturers' representatives demonstrated bonding agents at our laboratory, the author often noticed errors being made when the time came to evaporate the solvent. These errors included individuals beginning to express air from as far as 12 inches away from the tooth, and then moving closer while drying the tooth. That is not correct. The human mouth usually can accommodate only about one-half inch of space around the teeth, so when testing bonding agents in our laboratory, the rule is to stay within one-half inch of the tooth to make results more practically relevant **(Fig 2)**.

To date, no air syringe is available with calibration, so the amount of air expressed depends solely upon the pressure applied by the operator of the instrument. We immediately discovered that it is very easy to accidentally apply too much air on the tooth. If that occurs in a practical setting, the dentist could easily blast the adhesive off the tooth surface without knowing, leaving the dentin improperly hybridized. This leads to poor or failed seals and post-procedure sensitivity, which often may be blamed on the adhesive, when the fault actually is due to the intricate technique of the application procedure.[7]

Small changes in testing methods can have catastrophic, failure-causing implications.

Myth

Bond strength and microleakage go hand-in-hand.

Reality

Bond strength is a laboratory term, not a clinical term. Bond strength within the mouth is difficult, and arguably unethical, to test. The closest dentists have come to testing bond strength in vivo has been to bond small cylinders of composite material to animal teeth, euthanize the animal, then place the animal's head in a testing machine and perform the tests.[8]

Animal testing is rarely performed today, but when it was, what was often observed was that these cylinders only had to be tightly bonded in a small area to have high bond strength. However, if those same samples were tested

for microleakage—which is tested in a completely different way—there would be a tremendous amount of microleakage around the periphery of the tooth. From a clinical perspective, this means the restoration has failed.[9]

The amount of microleakage also depends largely upon which tooth structures are being bonded to restorations. When a restoration is placed, particularly one performed partially on dentin and partially on enamel, the bonding agent can perform differently.[10] When restorations are bonded to enamel, the seal is very leak-resistant and often leakproof. On the other hand, due to the structure of dentin and the way bonding agents seal—or fail to seal—the dentin, bonding can have significantly higher microleakage **(Fig 3)**.[11]

It seems to be a common misconception that if an adhesive bonds very well it will not leak. That is not the case; unfortunately, the properties of bond strength and microleakage do not go hand-in-hand.

Conclusion

There is no easy way to perform adhesive bonding. Even with the recently introduced, so-called universal bonding agents, a specific protocol must be observed in laboratory testing and clinical practice. Some improvements could include using more realistic specimens for study, and certainly utilizing dentist-operated laboratories for testing new or improved products, as dentists understand more about how to manipulate products within the mouth.

The most important lesson to take away from the myths and realities discussed here is that the highest priority in modifying these products and procedures should be the use of a standardized, step-by-step protocol that all facilities must follow in testing new products, specifically dental bonding agents. Although this amendment would not make the procedure faster or easier, it would, at least, make the product information more relevant.

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> **An ongoing challenge in the art of bonding might be described as "technique sensitivity."**

Key Words: zirconia, adhesives, bond strength, self-etching adhesives, technique sensitivity

Dr. Bunek Discusses the Realities of Understanding Bonding Material

It is no myth that dentistry encompasses both art and science. The art and science of bonding are often supported by laboratory and clinical studies. An ongoing challenge in the art of bonding might be described as "technique sensitivity."[1] Parameters that affect technique sensitivity include patient and placement variables. The ability of an adhesive to minimize technique sensitivity often affects its success in both direct and indirect bonding procedures. Clinicians' perceptions may also affect the success of bonding.

Table 1: Shear Bond Strengths of Self-Cured Clearfil Esthetic Cement with Clearfil Ceramic Primer to As-Sintered Zirconia with Different Treatments.

Treatment	Bond Strength,* MPa	
	24 Hours	Thermal Cycling
Cement only-as-sintered zirconia	14.0 (3.0)* [100A]	9.6 (2.0)[b] [100A]
Primer/Cement-as-sintered zirconia	23.0 (6.1)a [97A/3C]	11.7 (1.4)b [100A]
Primer/Cement-bur ground zirconia	26.9 (5.0)a [96A/4C]	18.6 (6.4) [100A]
Primer/Cement-sandblasted zirconia	36.4 (9.2) [96A/4C]	27.4 (8.2) [100A]
*Means with standard deviations in parentheses (n=8). A=adhesive failure, C=cohesive failure in cement.		

Myth
It is not possible to bond to zirconia restorations.

Reality
Recent major advances in resin cements and substrate primers are now allowing clinicians to bond zirconia restorations with confidence. As the demand for esthetic restorations is increasing, so are options in all-ceramic materials. Silica-based glass ceramics (i.e., lithium disilicate, leucite-reinforced, feldspathic) have an etchable surface, enabling a strong bond. Oxide-based ceramics (zirconia and alumina), on the other hand, do not have an etchable surface, and many clinicians assume that they cannot be bonded.

When tooth preparations exhibit good retention and resistance form, self-adhesive resin cements (containing MDP monomers) are recommended.[1] Although laboratory testing shows self-adhesive resin cements have lower mechanical properties than adhesive resin cements, they offer clinicians other benefits, such as low technique sensitivity, low postoperative sensitivity, and easy cleanup.[1]

Long-term performance studies conducted by *The Dental Advisor* for self-adhesive resin cements have shown excellent results. In an eight-year recall of 1,094 zirconia restorations bonded with a self-adhesive resin cement (Unicem; 3M ESPE; St. Paul, MN) without use of a ceramic primer, it was reported that postoperative sensitivity was less than 1.1%, marginal discoloration was 8%, and retention was 97.6%.[2] In a one-year recall of 78 zirconia restorations bonded with a self-adhesive resin cement (G-Cem, GC America; Alsip, IL) without use of a ceramic primer, it was reported that postoperative sensitivity was less than 1.3%, marginal discoloration was 0%, and retention was 100%.[3] In a one-year recall of 196 zirconia restorations bonded with a self-adhesive resin cement (Clearfil SA Cement; Kuraray America; New York, NY) used with a ceramic primer (Clearfil Ceramic Primer), it was reported that postoperative sensitivity was 1.0%, marginal discoloration was 0%, and retention was 98.5%.[4]

When retention and resistance form are not ideal, cementation with adhesive resin cement is recommended with the use of a zirconia primer (e.g., Z-Prime Plus, Bisco; Schaumburg, IL; Monobond Plus, Ivoclar Vivadent; Amherst, NY; Clearfil Ceramic Primer).[1] Zirconia primers contain phosphate monomers that form covalent bonds with zirconia and double bonds that bond to the resin cement.[5] Studies show that the use of a zirconia primer significantly improves bond strength to zirconia.[6,7] A 2008 study **(Table 1)** shows that sandblasting zirconia can provide higher shear bond strength, rather than using primer and cement only.[8]

Myth
Using a strong adhesive with good long-term clinical data ensures success.

Reality
This statement is true most of the time. However, recent attention has been drawn to how the improper use of light-curing units may negatively influence successful adhesive outcomes. In a 2010 study,[9] 20 operators (10 dentists and 10 dental students) were instructed to use three new curing lights on Class I and Class V simulated restorations. The results showed no statistical difference between dentists and dental students; however, there were statistically significant differences in energy delivered to the restoration among operators. Some

Figure 1: Check light tip frequently for debris or damage.

Table 2. Effect of Air-Blowing Intensity on Microtensile Bond Strength (MPa) of Two Self-Etching Adhesives.

Intensity	Clearfil Tri-S Bond (Kuraray)	Fluoro Bond Shake One (Shofu)
Gentle	4.1 (2.4)*	13.1 (3.1)
Intensive	42.6 (3.8)	5.4 (2.9)

* Means with standard deviations in parentheses.
Adapted from Shinkai K, Suzuki S, Katoh Y. Dent Mater J 25(4):664-668, 2006.

operators delivered only 20% of the energy achieved by other clinicians using the same unit and same location. It was concluded that operator technique, choice of curing light, and location of preparation were the reasons for the large degree of variation.[9] The results are cause for concern, as they show that inadequate polymerization adversely affects the resin's physical properties and reduces bond strength, along with other implications.[10-12]

It is our responsibility as clinicians to understand all the variables that influence successful adhesive outcomes. Something as simple as using a curing light that is not properly calibrated can be the demise of our restorations. It is critical to regularly check the output of the light-curing unit, inspect the tip for debris or damage **(Fig 1)**, pay attention to distance,[13] and aim the beam perpendicular to the resin surface.

Myth

Total-etch adhesives are more technique-sensitive than self-etch adhesives.

Reality

Self-etch adhesives do not require a separate etching step, which is different from total-etch (etch-and-rinse) adhesives. Consequently, clinicians consider them to be more user-friendly and less technique-sensitive. Because self-etching systems are water-based, and not highly susceptible to volatilization, they require a different technique to remove the solvent than do total-etch systems.[14] Studies have shown that variables such as air-drying (gentle versus aggressive)[15] **(Table 2)**, duration of air-drying,[16,17] active or passive application of adhesive,[18,19] application time,[20] and number of layers[20] all have an effect upon bond strengths.

Application of the self-etching adhesives is technique-sensitive and requires meticulous attention to instructions. Although they have fewer components, clinicians need to pay as much attention to application technique as they do with total-etch systems.

Myth

Self-etching adhesives do not exhibit good long-term performance.

Reality

Clinical long-term performance is the true test of an adhesive. In a clinical setting, adhesives must survive in the oral cavity, including the complexity of different bacteria, changes in pH, and occlusal forces; and must demonstrate ability to survive in a warm, moist, or wet environment.[12] The hydrophilicity of self-etching adhesives is a concern because the bond may degrade over time, as these materials are more susceptible to water sorption.[21] Although some laboratory data show degradation of some self-etching adhesives after thermocycling,[22] there are long-term clinical studies that show promising success with certain other commercial self-etching adhesives.[23-26]

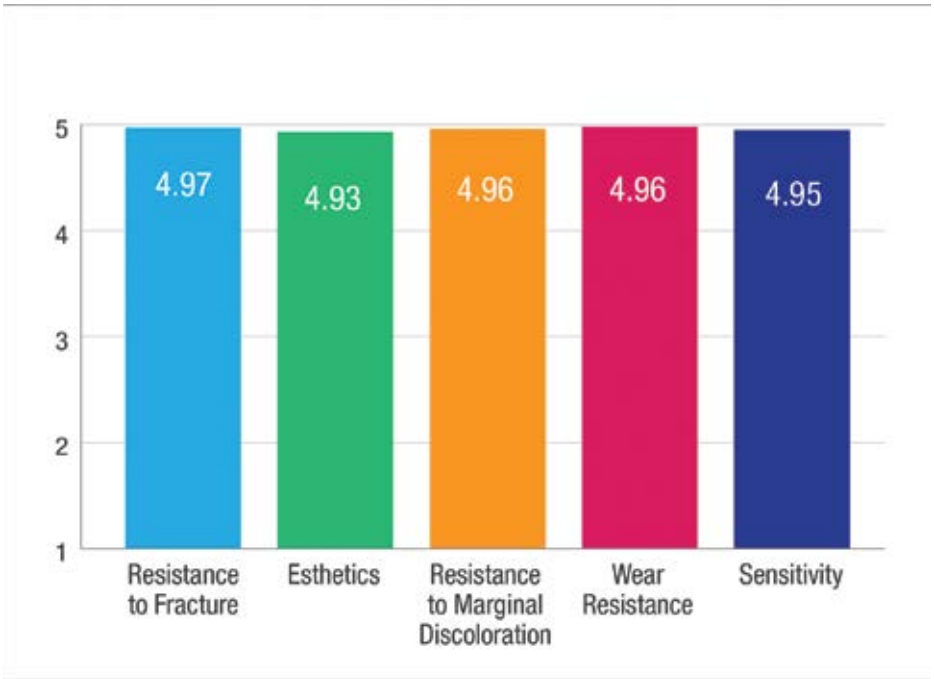

Figure 2: Clearfil Majesty Posterior at two-year recall.
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In a four-year clinical evaluation,[23] a one-step self-etch adhesive was compared to a two-step etch-and-rinse adhesive. In this study, 165 Class II restorations were placed with both adhesives. At the end of the study, no significant difference was seen in overall clinical effectiveness between the two adhesives.[23] In another study, a two-step self-etch adhesive was used with and without selective etching in 100 non-carious Class V restorations.[24] After five years, the clinical effectiveness of the two-step self-etching adhesive remained excellent. It was noted that additional etching of the enamel cavity margins resulted in an improved marginal adaptation on the enamel side; however, this was not critical to the success and longevity of the restorations.[24] In continuation of this study,[24] the restorations were recalled three years later. After eight years in function, it was concluded that the clinical effectiveness of the adhesive remained excellent with selective etching.[25] In a two-year clinical study conducted by *The Dental Advisor*, 605 Class I, II, and V restorations were placed using one-step self-etch adhesive (Clearfil S3) and restored with Clearfil Majesty Posterior (327 restorations were available for evaluation at 24 months). All restorations exhibited excellent esthetics and resistance to marginal staining and fracture, and no sensitivity was reported at recall **(Fig 2)**.[26]

Summary

Improvements in physical, chemical, and mechanical parameters are attractive in laboratory studies; however, the real test of a material's success is in a clinical setting. The material not only has to withstand the conditions in the oral cavity, but it also must be manipulated properly by the dental team. As highlighted in some of the cases discussed above, technical errors can work against material advancements. It is therefore extremely important for the entire dental team to understand basic material science and how to properly manipulate a material.

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"The material not only has to withstand the conditions in the oral cavity, but it also must be manipulated properly by the dental team."

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Disclosure: Dr Bunek is part owner of Dental Consultants Inc., which publishes *The Dental Advisor*.

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Writing for Peer-Reviewed Publications

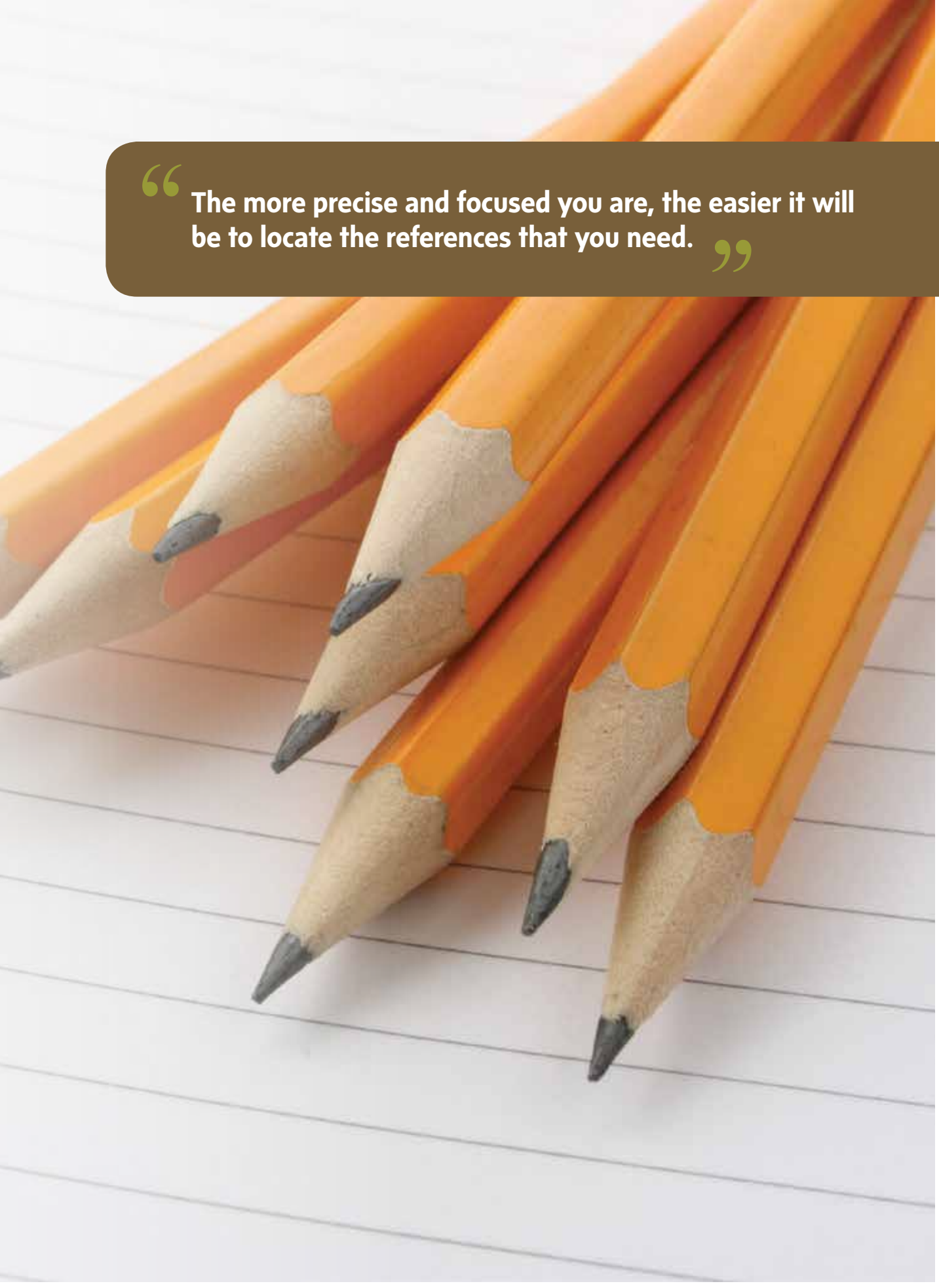
Tips to Simplify the Process

Allison M. DiMatteo, BA, MPS

Key Words: PubMed, peer-reviewed articles, dental literature, references, U.S. National Library of Medicine

Introduction

This article reviews several steps and common practices to help you research and write about the information peer reviewers and readers will want to see in your article. It includes suggestions for planning your writing, as well as helpful hints for using PubMed to identify references about and supporting the information you are providing.



> **“The more precise and focused you are, the easier it will be to locate the references that you need.”**

When you read a case presentation article in a dental journal or magazine, what are some of the things that you would like to see included? Chances are that you want to know about the patient, details of the condition he or she presented with, the problem diagnosed by the dentist or author, and why the dentist chose to treat the condition in the manner he or she did. Additionally, you likely want to know how the dentist/author accomplished the treatment plan.

It is no surprise, then, that most dental publications—especially those that are peer-reviewed—require that article submissions offer educational value. To satisfy that criterion, articles for submission to peer-reviewed publications often include descriptive case information preceded by a well-developed background section that introduces the reader to the problem presented by the case. Usually contained in the introduction section of case presentation articles, this information is garnered by reviewing the dental literature.

The purpose of a literature review is to summarize available information and research about a particular topic. This helps to form the basis for treatment decisions, diagnosis, material selection, etc., and aids in developing the foundation for the case presentation.

As the name implies, an introduction typically discusses and introduces a problem, challenge, background, or historical perspective that is significant to what you are writing about and important to your audience. It can discuss certain conditions, problems encountered using a certain type of material, or difficulties with a particular treatment. Some article topics require more detail and information in the introduction than others so that readers can understand the overall concept of the article.

However, how do you narrow the focus of what you are researching and reviewing? Furthermore, once you have narrowed your focus, how do you find what you are looking for? You can accomplish both objectives by knowing the details, issues, and challenges involved with the case you are writing about and by efficiently using online publication citation retrieval systems.

Focusing Your Writing and Literature Review

There are several things to consider before you begin researching and writing. First, contemplate what you are writing about. This can be a general subject or topic, such as performing a Class IV restoration with a new type of composite, or it could be staging a full-mouth reconstruction with different types of crowns and veneers.

Next, once you know what you want to write about, consider the ideas and concepts related to your general subject (e.g., preparation designs for Class IV restorations, strength requirements for Class IV restorations, etc.). Do not worry about the order of these ideas or concepts just yet. Rather, focus on listing all the types of information, topics, and ideas that are important to the decisions you made in the case, you are presenting.

Finally, consider the details of the case itself, such as: what was done to arrive at your diagnosis and treatment plan, how you prepared the teeth, or what you selected as the restorative material. These details could come from the patient chart or file for the case, or from product brochures about a material you used and want to discuss.

This focused list of ideas, concepts, and topics will form the basis for searching for and finding the literature references needed in your article. The more precise and focused you are, the easier it will be to locate the references that you need.

Using PubMed to Find References

PubMed is a Web-based retrieval system containing more than 22 million records developed by the National Center for Biotechnology Information (NCBI) at the U.S. National Library of Medicine. It is a database of bibliographic information, mostly from the life sciences literature, but its scope covers dentistry, microbiology, diseases, anatomy, and a broad range of other topics. Additionally, PubMed contains links to full-text articles when they are available from the publisher. There are also links to libraries.[2]

(Note: Although PubMed is the most comprehensive retrieval system for finding literature references, there are others. In addition, Google Scholar can direct you to possible literature citations and library retrieval systems that can be used. While this article discusses finding references on PubMed, the recommendations for conducting a literature search can be applied to other literature retrieval options.)

An article listing in PubMed will typically include specific information about the citation. This information includes the article's title; author names; abstract; keywords or search terms; publication name and month, year, volume, and page numbers; author(s) affiliations; and other information.

It is beyond the scope of this article to provide a comprehensive overview of PubMed and how it can be used. However, an easy-to-navigate and understandable PubMed tutorial is available on the PubMed Web site (www.ncbi.nlm.nih.gov/pubmed). It provides invaluable information and instructions on completing detailed and advanced literature searches—something that can save you much time and frustration.

Peer Review

- **Peer review is the process by which experts in the topic of a particular paper or article are asked to review it to determine the paper's worthiness of being published.**
- **Reviewers also may provide recommendations for improving a paper or article.**
- **Reviewers comment on a paper's strengths, weaknesses, and areas requiring revision using an evaluation form.**
- **Peer reviewers also advise whether a paper should be accepted for publication or be rejected.[1]**
- **Reviewers typically are members of the publication's editorial board. When articles undergo the peer-review process, authors and reviewers usually are not aware of each other's identities. Typically, at least two reviewers evaluate an article and both are experts in one or more areas addressed by the article (e.g., experts in direct/indirect restorations, smile design, the specific clinical condition addressed, etc.).**

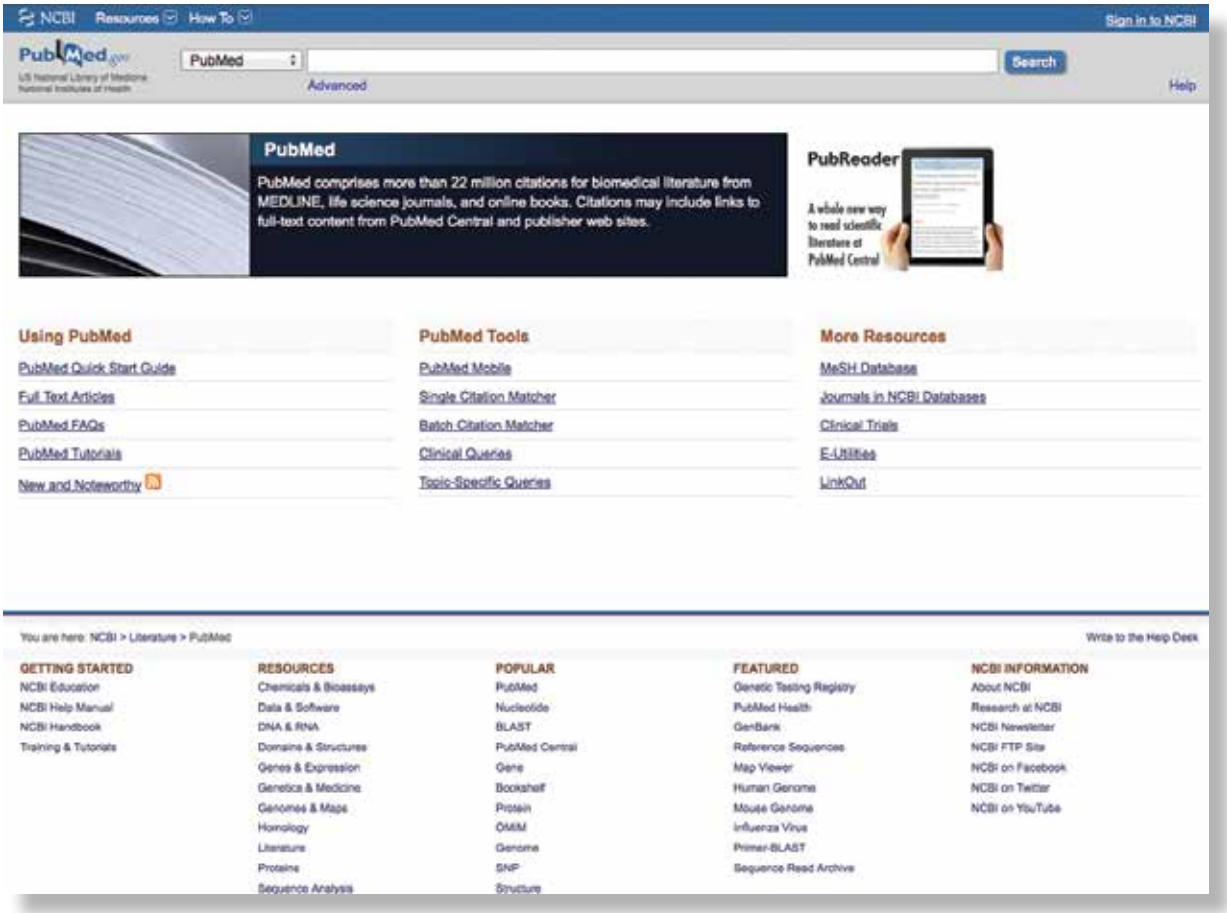


Figure 1: The PubMed home page contains a search bar in which to enter a concept or idea for which you would like to find a reference. The bottom of this page contains links to helpful information about PubMed.

However, to perform a basic search for references using PubMed, you will want to develop a search strategy. As aforementioned, narrowing the focus of your article and identifying the key concepts and ideas you want to write about is the basis for your search strategy. To begin:

1. Determine the key concepts and ideas you will be writing about.
2. Consider different terms used for those concepts and ideas.
3. Decide how current you want your references to be.

When you are ready to search for articles on PubMed, visit www.ncbi.nlm.nih.gov/pubmed. There, you will be able to enter the terms for your concepts and ideas in the search box, which is available on any PubMed page. PubMed will give you suggestions as you type in your terms, but you are not required to use them **(Fig 1)**. For example, enter the term "different indications for all ceramic restorations."

Because PubMed contains millions of literature citations, it helps to keep your terms as specific as possible. However, you can type in any combination of words or phrases into the search box. After you have entered your terms, click the Search button or Enter key, which begins the search.

When the search is completed, if any articles contain or discuss the terms you have entered, a list of those articles will appear **(Fig 2)**. Note that for the term entered, 18 specific citations related to this topic were identified.

In the display settings link at the top of the page, you can select how many citations appear on a page, change how the citations are ordered, and choose whether or not any abstracts for the citations will be displayed. However, clicking on a citation entry will retrieve an abstract for that particular article if one is available **(Fig 3)**.

Citation abstracts summarize what is discussed in the particular article, such as treatment techniques, research findings, etc. They contain sufficient detail to enable you to determine if the article would support or be applicable to what you will be writing about. In some instances, the full text of the article may be available—either for free or for a per article fee—via a link in the upper right that will bring you to the Web site of that article's publisher **(Fig 3)**.

From there, if the article is available in full text format immediately, you will be able to view it in its entirety or download a PDF version. If it must be purchased, instructions from the publisher on how to complete that transaction will be available.

When References Are Needed

A reference is required when:

- you assert something as fact
- you directly quote or paraphrase specific information or concepts from a specific article or book
- there is a need to show that research and past experience has demonstrated that something you have done and are describing in the article is appropriate or valid.

References are cited within the text using a superscripted number at the end of a sentence or phrase; the corresponding number is then inserted at the end of the manuscript in the reference list. References are numbered at the end of the article in the sequential order in which they are referred to in the text. If a reference is cited—or referred to—more than once in the text, the same number is used again.

Example #1: This is an example of a sentence with references at the end that were previously cited earlier in the article.[2,3,22,23]

Example #2: One reference is cited again for this sentence, followed by a new reference, for demonstration purposes.[2,24]

References are usually articles or chapters that have appeared in published dental journals, magazines, or books. References included in the reference list at the end of an article should include the following information:

- last name and first/middle initials of authors
- complete title of the article or chapter
- name of the journal (abbreviated), magazine, or book
- year of publication
- volume number and edition or issue
- page numbers of the article or chapter
- city/state and name of the publisher, if from a book.

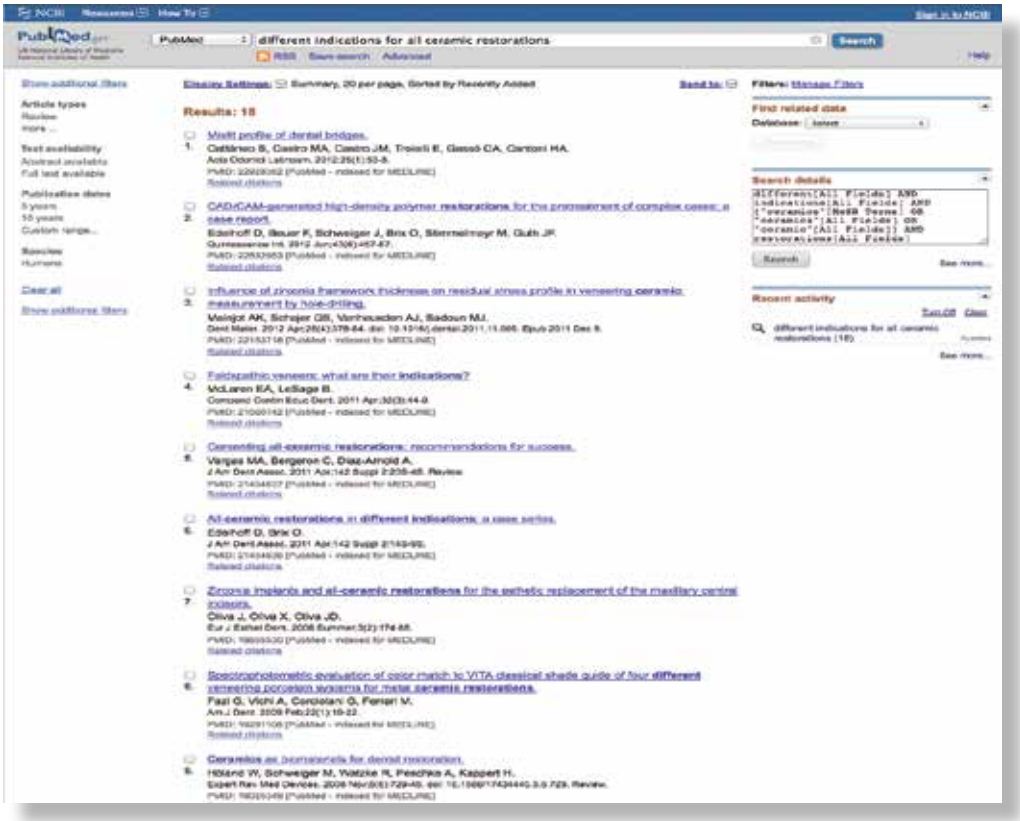


Figure 2: If any articles containing the terms or phrases you entered are found, PubMed will retrieve a list of their citations.

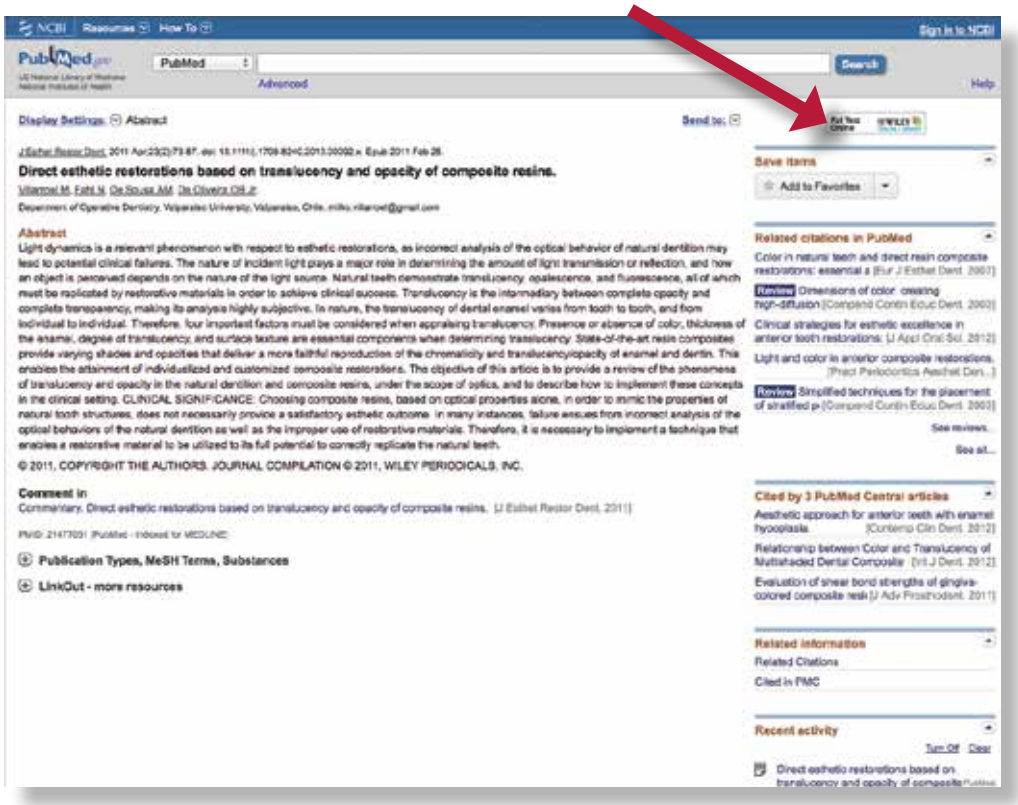


Figure 3: Clicking on a specific citation in the list generated by PubMed will retrieve the abstract for that article, if one is available. If the full text of the article is available, either for free or for a fee, an icon (see arrow above) will appear in the upper right that will link you to the Web site of the article's publisher.

What is Required for a Peer-Reviewed Case Presentation?

- **Sufficient, descriptive, and observational information that is not intended to discuss original research conducted by the author.**
- **Interesting and new perspectives that might encourage research.**
- **Useful information or protocols of specific interest to the publication's readership.**
- **A referenced and researched literature review of the background and issues involved in treating the case.**
- **Details that will enable readers to reproduce what is described in the article.**

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1. American Medical Association (AMA). American Medical Association manual of style. 9th ed. Chicago: AMA; 1998. p. 4, 175-6.
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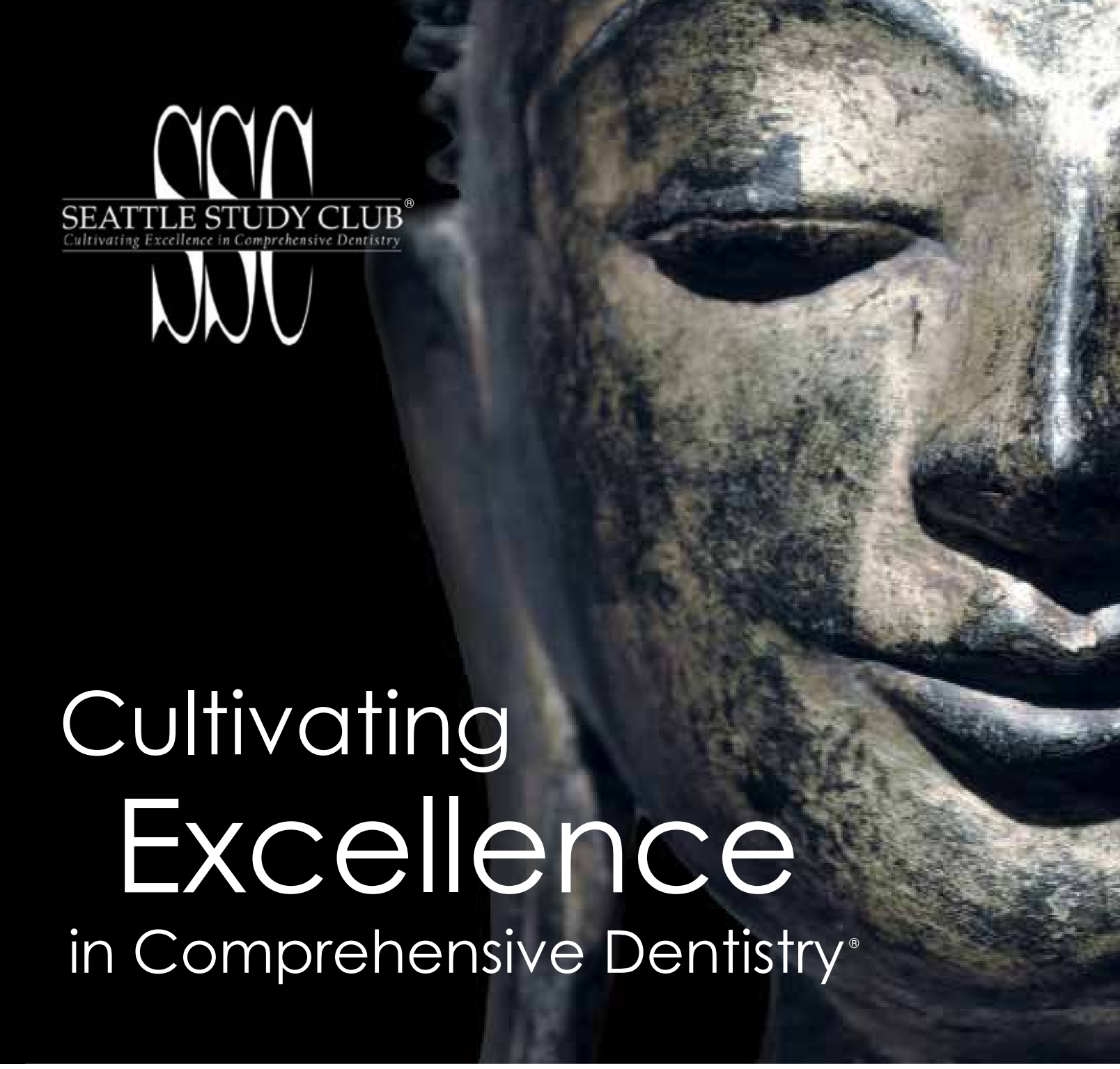

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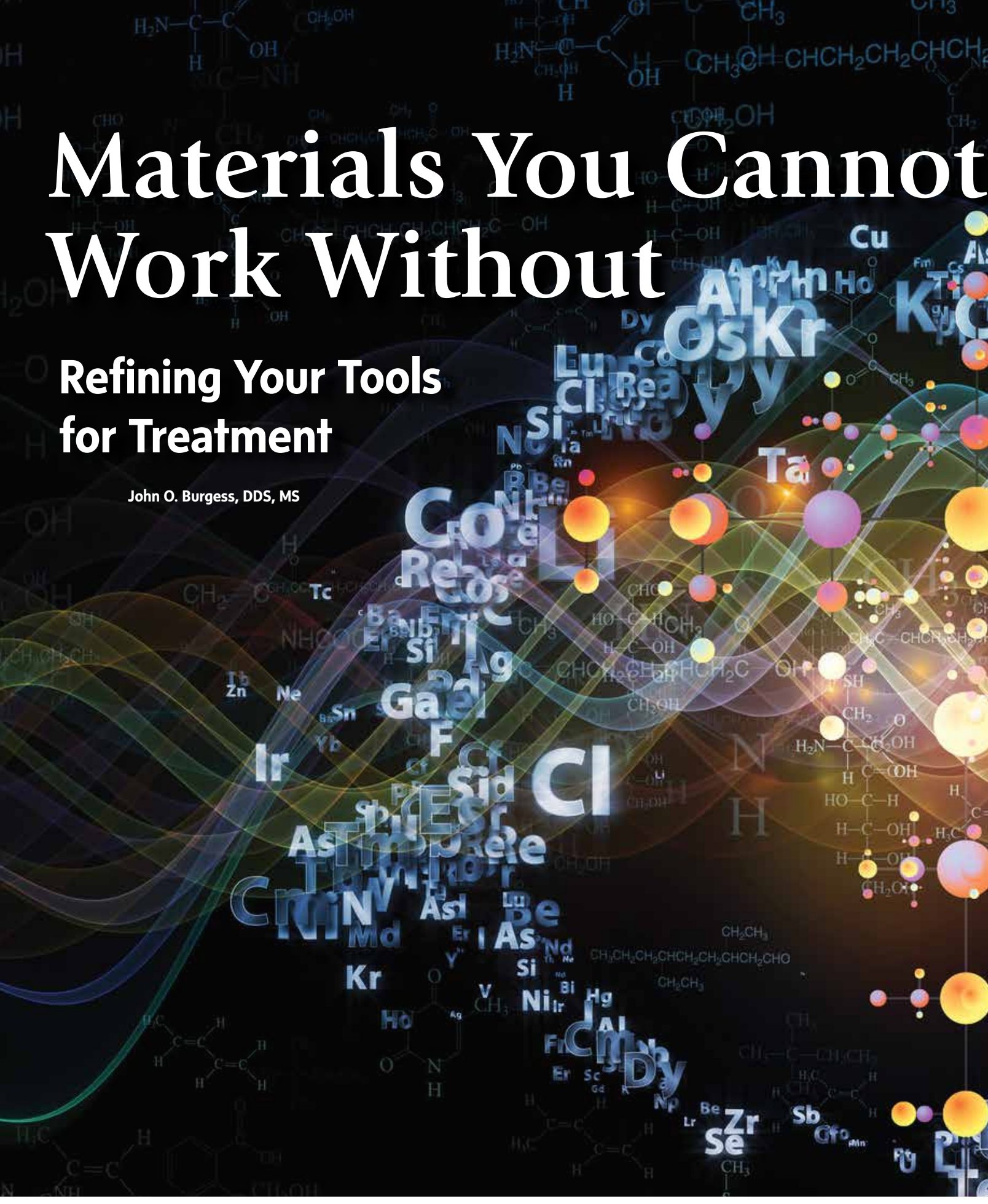

Abstract

Dental materials are constantly evolving and improving. This article evaluates materials from several product classes that have significantly improved properties that will help the busy practice improve care, shorten treatment time, and preserve oral health. Beginning with the newest adhesive (the Universal adhesives), materials are compared and two are recommended. These adhesives bond direct and indirect restorations by producing a low film thickness and all can be applied using a total-etch, self-etch, or selective etch technique. Composite resin can now be bulk-filled and cured to depths of 4 to 5 mm. These promising restorative materials may shorten placement time yet provide successful, durable esthetic composite resin restorations. Vital pulp therapy includes direct and indirect pulp-capping procedures. Two new calcium silicate materials, Biodentine and TheraCal LC, are useful for vital pulp therapy and provide an effective seal, higher strength, and lower cost than older materials. Maintaining restorations is difficult and it is difficult to provide preventive materials that are effective, especially for patients suffering from dry mouth. Preventive materials containing a combination of calcium, phosphate, and fluoride seem to provide the minerals necessary for remineralization and are especially useful for xerostomic patients.

Key Words: Universal adhesives, bulk-filled composite resins, vital pulp-capping materials, preventive materials

Introduction

Material development has produced significant advances for the practice of clinical dentistry. This article describes several classes of restorative materials with potential to change your practice of dentistry by improving and protecting the restorative treatment, and decreasing treatment time.

Universal Adhesives

Scotchbond Universal Adhesive (3M ESPE; Seefeld, Germany) was the first "universal" single-bottle adhesive. Currently, Scotchbond Universal, All-Bond Universal (Bisco; Schaumburg, IL), and Prime and Bond Elect (Dentsply Caulk; Milford, DE) are available, with more sure to be marketed **(Fig 1)**. Universal adhesives can be applied using a total-etch, self-etch, or selective-etch technique. Total-etch and self-etch systems have been used with different adhesive systems for years, but the selective-etch procedure is a relatively new concept in which the enamel is etched with phosphoric acid and rinsed, followed by applying the self-etching adhesive to the enamel and dentin. Universal adhesives have a higher pH than traditional adhesives **(Table 1)** and consequently most bond to etched enamel better than unetched enamel. Many self-etching adhesives produce lower bond strengths to phosphoric acid etched dentin. When a self-etching adhesive is applied to cut dentin, etched intentionally or unintentionally, bond strengths to the etched dentin are reduced. A selective-etch technique applies phosphoric acid etchant to enamel and sclerotic dentin and, after rinsing, the adhesive is applied to etched enamel and unetched dentin, agitated, dried, and cured. Two "universal" adhesives (Scotchbond Universal and All-Bond Universal) contain a phosphate monomer that allows them to bond to multiple substrates. Scotchbond Universal contains silane to bond to ceramic without a separate silane application. During our testing we discovered that hydrofluoric acid provides most of the bond strength to ceramic, with silane providing an additional smaller bond. Bonds with Scotchbond Universal to glass-containing ceramic are improved when a coat of silane is applied to the ceramic surface. Scotchbond Universal bonds directly to zirconia and alumina oxide abraded metal. All-Bond Universal will bond to zirconia but requires a separate application of Z-Prime (Bisco), a phosphate-containing monomer **(Fig 2)**. Two of the currently marketed "universal" adhesives (Scotchbond Universal and Prime and Bond Elect) use a dual-cured activator with chemical or dual-cured cements, core materials, or composites. While little is known

Figure 1: Three Universal bonding agents: Scotchbond Universal, All-Bond Universal, Prime and Bond Elect.

Figure 2: Z-Prime is a phosphate-containing monomer that is required when using All-Bond Universal to bond to zirconia.

about the clinical durability of these adhesives, we are conducting a clinical trial with Scotchbond Universal and have had no loss of retention after the six-month recall to restored noncarious cervical lesions. We are completing one-year recalls at this time with no loss of retention or marginal discoloration in the restored teeth.

Bulk-Filled Composite Resins

Stress

Polymerization shrinkage in composite resins has decreased to .9 to 2.7% for highly filled composites, whereas flowables range from 3.1 to 6.7%. Shrinkage stress produced by the polymerization of composite cured in cavity preparations has also declined.[1] Although these terms are frequently used interchangeably, free shrinkage is not the same as the stress or force produced during polymerization, which causes margin fracture and pulls cusps together. During finishing of the composite, fine particles of composite fall into the cracks produced by shrinkage stress, causing a white line to be seen around the restoration. As polymerization shrinkage and the stress produced during polymerization decreased, so has white line formation. Various methods have been used to control the stress, which tears enamel, composite, or the adhesive. Curing lights with ramp, soft, and pulse delay curing modes evolved but, unfortunately, these approaches to controlling polymerization shrinkage proved clinically ineffective in reducing marginal adaptation or marginal staining in clinical studies.[2,3]

Shrinkage and Strain

The C factor (ratio of bonded to unbonded surfaces in the preparation) and compliance (the ability of the remaining tooth to bend) determines the strain produced to the marginal areas by the shrinking composite resin.[4] Class I and Class V preparations have the greatest bonded-to-free surface ratio (5:1) and composite resin cured in these preparations produces the greatest strain. When a composite resin is irradiated with blue light from a curing unit, photons activate the photo-initiator (usually camphoroquinone), which initiates free radical polymerization of the composite. As the composite resin forms a polymer, it changes from a viscous gel to an elastic solid. During the polymerization process, as monomer links together to form a polymer, the polymer eventually stretches from one side of the preparation to the other side. As the modulus increases in the developing polymer and the chain stiffens, stain to the surround-

> “Universal adhesives can be applied using a total-etch, self-etch, or selective-etch technique.”

Table 1: Comparing Universal Adhesives.

	Scotchbond Universal	Prime and Bond Elect	All-Bond Universal
Low film thickness	5-7 µ	3-5 µ	< 10 µ
Compatible with chemical and dual-cured composites?	no, needs dual-cure activator	no, needs dual-cure activator	yes, no dual-cure activator needed
pH	2.7	2.5	3.2
Solvent	ethanol	acetone	ethanol
Refrigeration required?	no	recommended	no

ing tooth structure occurs. This stage in the polymerization reaction is called the *gel point*. Before the gel point, the developing polymer can flow from any free surface. On a Class I restoration, for example, this results in a meniscus on the occlusal surface. However, as the polymer continues to cross link the gel point is reached where the stress (force) created from the developing polymer creates strain (deformation) to the surrounding tooth, pulling tooth cusps together and deforming the marginal interface. Shrinkage occurs due to reduced molecular vibration of the units forming the polymer and is determined in large part by the filler volume of the composite, the degree of conversion of the monomer, and the amount of diluent added to the composite resin, which influence the amount of stress formed.

An incremental placement and curing of 2-mm layers of composite has been used since the late 1980s, but current work demonstrates that the strain developed while curing 2-mm increments of composite resin is similar to curing 4-mm increments in bulk-placed composites.[5] Many curing methods have been advocated to control or reduce polymerization shrinkage, including three-site polymerization, trans-enamel polymerization, ramp or soft curing and pulse delay; however, these methods were examined in a 2005 study[6] that reported that these different light-curing methods produced reduced shrinkage by a modest decrease in the final conversion rates of the composite resin.

Low and High Viscosity

Bulk-fill composites can be classified into two types: low and high viscosity. Low-viscosity materials like Venus Bulk Fill (Heraus Kulzer; Hanau, Germany), Filtek Bulk Fill (3M ESPE), and SureFil SDR (Dentsply Caulk) **(Figs 3a-3c)** are placed in 4-mm increments, have lower filler rates, and most wear more than highly filled composites.[7] Low-viscosity composites are generally used as dentin replacement layers or are recommended for small occlusal restorations. The first bulk low-viscosity flowable, SureFil SDR, covered the 4-mm layer of bulk-filled and cured SDR with a wear-resistant composite "enamel layer" to provide wear resistance of the restoration. This enamel layer produces the same polymerization strain as other composites. High-viscosity bulk placement materials such as Tetric EvoCeram Bulk Fill (Ivoclar Vivadent; Amherst, NY) and SonicFill (Kerr; Orange, CA) handle like highly filled composite resins, can be used to restore large preparations, and have 4-mm depths of cure depending upon the shade and curing light used. The most

a

b

c

Figures 3a-3c: Low-viscosity bulk-fill composites.

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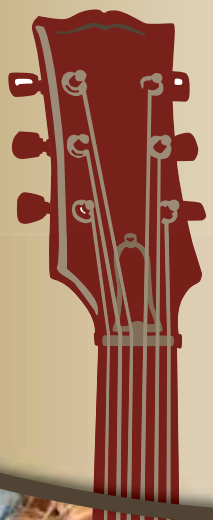

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commonly used method to increase the depth of cure of a composite is by increasing composite translucency, which allows light to penetrate further. The depth of cure with bulk-filled composite resins can be achieved by adding additional camphoroquinone but this imparts a yellow color to the composite. Adding new photo-initiators like Ivocerin (Ivoclar Vivadent) increased the depth of cure for Tetric EvoCeram Bulk Fill, while combining this with a photo-inhibitor creates adequate working time. Although little clinical information is available on bulk-placed and cured composite resins, we have completed a three-year clinical examination of 100 SureFil SDR with very good clinical results. At this time the recommended low-viscosity bulk-fill resin is SureFil SDR **(Figs 4-7)**, while EvoCeram Bulk Fill is the choice for high-viscosity bulk-filled materials **(Figs 8-10)**.

Vital Pulp-Capping Materials

Vital pulp therapy is often used with direct and indirect pulp-capping procedures. Direct pulp-capping procedures are 10 to 15% less effective than indirect pulp-capping procedures. The most effective materials used for these procedures are calcium hydroxide-releasing materials like Dycal (Dentsply Caulk) or ProRoot MTA (Dentsply Tulsa Dental Specialties; Johnson City, TN). Recently, two new calcium silicate materials, Biodentine (Septodont; Lancaster, PA) and TheraCal LC (Bisco), similar in composition to MTA with sustained calcium hydroxide release, have been introduced. Both have lower cost than MTA and Biodentine has better mechanical properties than MTA.[8] According to our tests Biodentine has significantly greater compressive strengths at 35 minutes, 24 hours, and 28 days than Dycal or MTA. Biodentine can be placed directly over an exposed pulp and used to seal the cavity up to the cavosurface margin for six to seven months since it has approximately the same wear resistance as glass ionomer **(Figs 11-14)**. Biodentine is a powder/liquid system with the powder supplied in an amalgam-like capsule. The liquid is placed into the capsule and the mixture is triturated for 10 seconds. The capsule is removed and the material scooped out and placed directly over the exposed pulp. Biodentine's delivery is difficult and the 10-12 minute setting time before the material can be finished is significant. However, Biodentine's durability, seal, and effectiveness are impressive. Its durability allows the vital pulp procedure clinical time to determine whether it will be successful. TheraCal LC is a light-cured calcium silicate **(Fig 15)** that can be placed directly over the exposed pulp and light-cured in 1-mm increments.

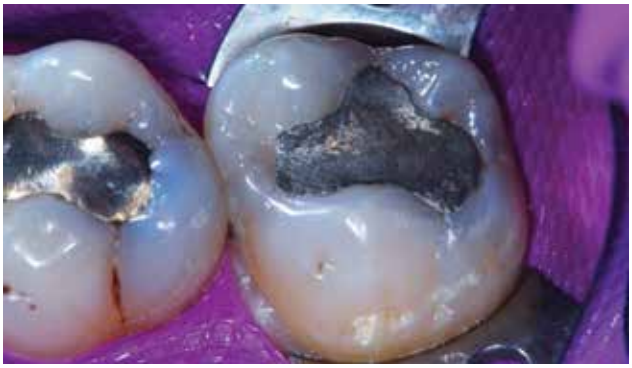

Figure 4: Carious lesion on mesial occlusal (MO) #2.

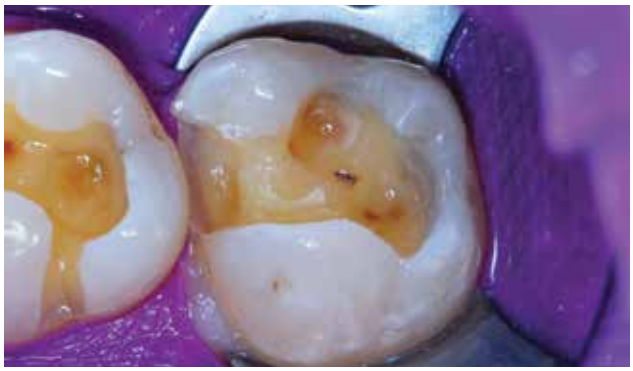

Figure 5: Preparation, MO #2.

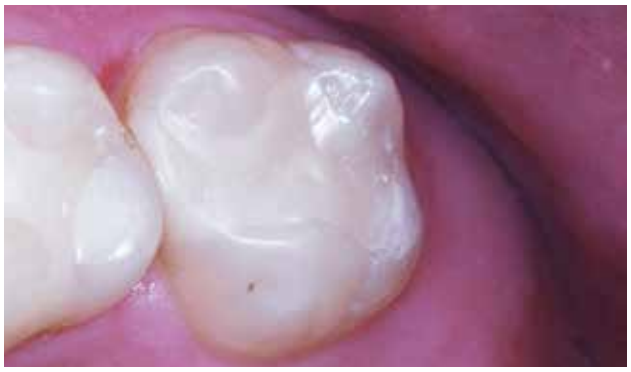

Figure 6: SDR and EsthetX initial placement.

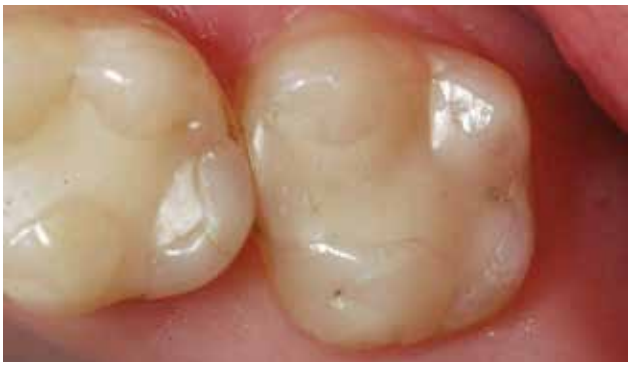

Figure 7: Three-year recall on MO #2 (SDR and EsthetX HD).

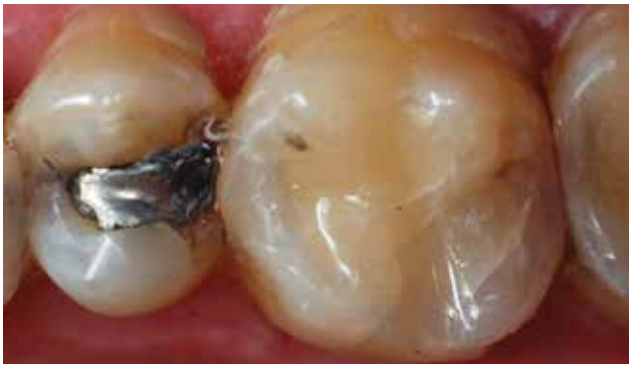

Figure 8: Defective amalgam.

Figure 9: Preparation.

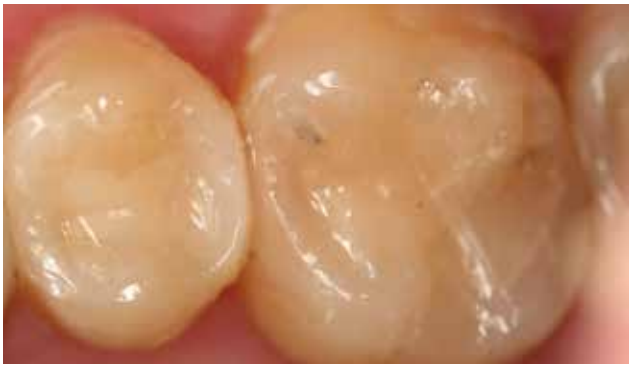

Figure 10: Completed Tetric EvoCeram Bulk Fill restoration.

Figure 11: Biodentine.

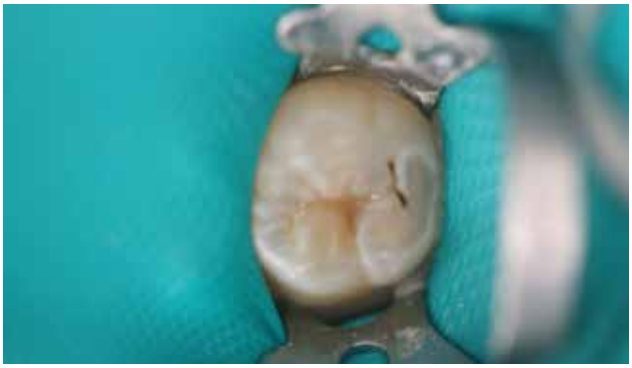

Figure 12: Exposure visible on #14.

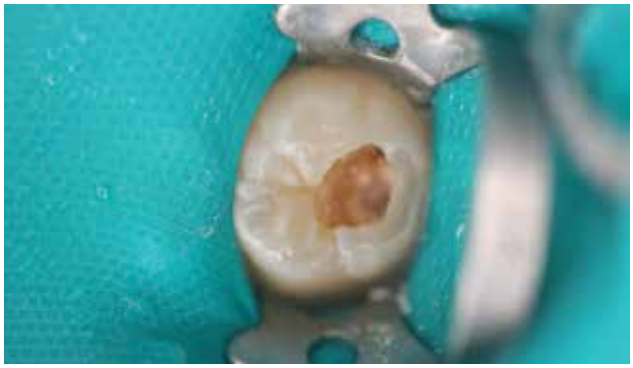

Figure 13: Biodentine placed over the exposure to seal the cavity.

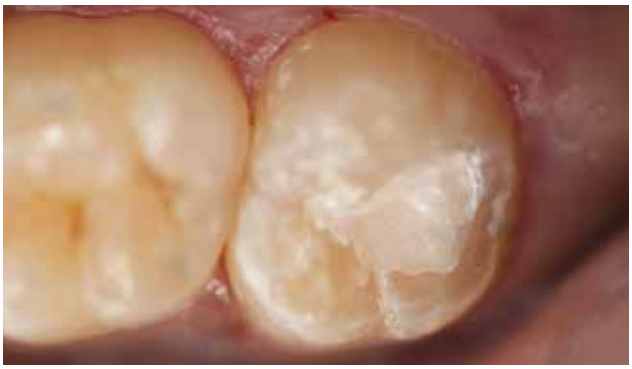

Figure 14: Biodentine-sealed direct pulp cap at seven months.

Figure 15: TheraCal LC.

Generally this material is used as a base. Since it has a limited depth of cure it can be placed over the exposed pulp and a restorative material is placed over it. The TheraCal LC delivery system is the easiest of the calcium silicate materials to use due to its efficient syringe placement and is light-cured. Both TheraCal LC and Biodentine, like all calcium hydroxide-releasing materials, upregulate mesenchymal cells to form odontoblasts and stimulate new dentin formation. Both materials are very useful in an active clinical practice.

Preventive Materials

Caries Prevalence

Caries is the most common dental disease and the focus of preventive dental materials and strategies. Caries incidence and severity in the United States has been followed using the National Health and Nutrition Examination Survey (NHANES) and the National Institute of Dental and Craniofacial surveys using variations of the decayed, missing, and filled index.[9,10] The most current NHANES survey,[10] conducted between 1999 and 2004, reported that by age six, 51% of primary teeth were affected with dental decay. Dental caries affects 96% of adults aged 50 to 64 and root caries affects 21% of adults aged 50 to 64. These reports clearly demonstrate that our fight against tooth decay is not over.

Incidence of Recommended Preventive Measures

A survey of practitioners enrolled in Dental Practice-Based Research Network asked dentists to identify the percentage of their patients to whom they had administered or recommended dental sealants, in-office or at-home fluoride, chlorhexidine rinses, or xylitol gum.[11] The survey reported that 84% of children and 36% of adult patients received in-office fluoride, and 69.5% of children and 13.6% of adult patients received sealants. Xylitol gum was recommended to 8% of the children and 17.3% of the adults. Chlorhexidine rinse was prescribed to 35% of the children and 32.2% of adult patients. This demonstrates that a wide range of products and procedures are recommended as adjuncts for controlling caries; and one, xylitol, has recently been reported as ineffective in the adult.[12]

Risk Assessment

Clinicians should conduct a caries risk assessment to determine if a patient is at risk. For high caries-risk subjects, clinicians should weigh the balance between benefits and risks prior to implementing any preventive strategy. Because a patient's risk for caries can change, the form should be updated by assessing the subject's caries risk frequently. Only then will the dentist be able to accurately determine which preventive treatment to select. For patients with dry mouth, more than fluoride[13] is needed to reverse the demineralization produced by acid secreted by plaque bacteria using sucrose as an energy source. The secreted lactic acid removes calcium and phosphate from the tooth, producing a subsurface white spot lesion, which ultimately cavitates as the lesion progresses. Mi Paste™ Plus with RECALDENT™ (CPP-ACP)(GC America; Alsip, IL) and Clinpro 5000 (3M ESPE) **(Figs 16 & 17)** contain calcium, phosphate, and fluoride, which rematerialize dematerialized tooth structure by supplying the components necessary for remineralization.[14] Fluoride is necessary for remineralization but in salivary-deficient individuals, little calcium and phosphate is present in the saliva; this limits remineralization and makes calcium- and phosphate-containing preventive materials particularly useful. These materials can best be applied with a toothbrush, by tray, or by simply applying the paste directly to the teeth with a finger just before bedtime. They should not be rinsed after applying.

Lesion Treatments

Lesion treatments for enamel caries focus on remineralization using topical applications of fluoride or amorphous calcium phosphate and emphasizing oral hygiene procedures. However, the success of these treatments is dependent upon the patient's compliance, which is especially difficult in the proximal areas where plaque removal is difficult. Typically, most small proximal lesions observed are located entirely in enamel and only preventive measures are recommended rather than restoration of the lesion unless the lesion progresses. If the lesion continues, a larger lesion frequently develops. As the restoration breaks down, new caries forms around the restoration and the cycle of restoring and replacing the failed restoration begins. The restoration enlarges each time it is replaced until the tooth needs an indirect restoration. As these treatments progress through the life cycle of the tooth, the tooth pulp may be exposed; this often requires either extraction or root canal therapy. Both the loss of tooth structure and its replacement, or endodontic treatment and tooth restoration, involve multiple appointments and considerable expense. A procedure that neither depends upon patient compliance nor increases the lesion size would be a micro-invasive treatment such as resin infiltration of the subsurface lesion. A surface-infiltrating resin has been developed (Icon, DMG America; Englewood, NJ) to treat these small enamel or early dentin lesions **(Figs 18 & 19)**. The infiltration technique is a noninvasive system requiring no irreversible removal of tooth structure and eliminates drilling and most pain associated with tooth restoration. Evidence is building that this system stops or slows proximal carious lesion progression. A 2010 study[15] evaluated the effectiveness of resin-infiltrated carious proximal lesions for 18 months using standardized radiographs and digital subtraction. The researchers concluded that a resin infiltration into the inner half of enamel or the outer third of dentin is an effective way

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Figure 16: MI Paste Plus.

Figure 17: Clinpro 5000.

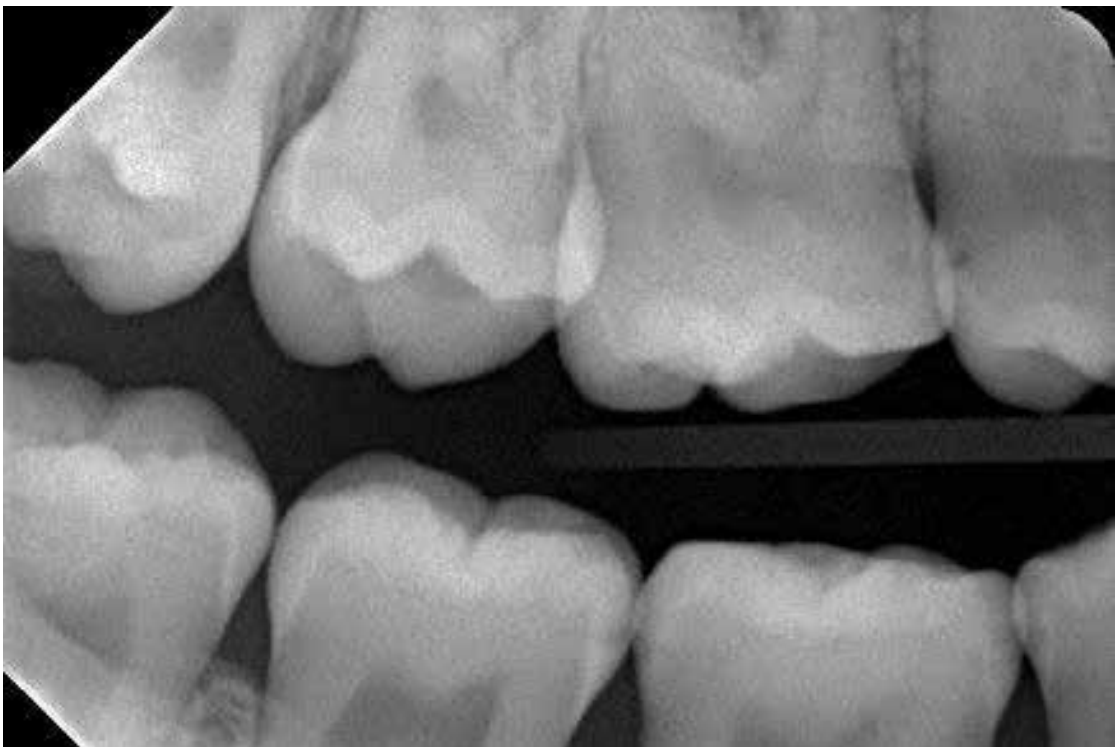

Figure 18: Mesial #31 and distal of #30—lesions that may be treated with Icon.

to reduce carious lesion progression. Another recent study,[16] using a radiographic comparison technique, reported that a caries-infiltrating resin was a more effective method for treating proximal enamel lesions than sealing or flossing over a two-year period. A third 2010 study[17,18] compared resin infiltration and fluoride varnish to fluoride varnish alone in primary molars after one year and concluded that resin infiltration and fluoride varnish was 35% more effective than fluoride varnish alone. These studies demonstrate that the resin-infiltration system may be a viable option for treating small carious lesions without relying upon patient compliance and with little patient discomfort.

Icon infusing resin is similar to a sealant and is applied to small carious lesions on the proximal and facial surfaces of teeth etched with hydrochloric (HCL) acid. This infusing resin penetrates and arrests the carious lesions. The tooth is isolated with a rubber dam, the proximal lesion is separated from the adjacent tooth and the HCL etch is applied for four minutes. After rinsing, the HCL etchant, Icon dry, an alcohol solution, is applied to remove excess water. This is dried and the Icon resin is applied **(Fig 20)**, light-cured, reapplied, and cured. Any excess resin is removed with scalers and disks.

Conclusions

This is an exciting time in dentistry as new materials and techniques evolve that improve and simplify restorative dentistry. Universal adhesives (Scotchbond Universal, Prime and Bond Elect, and All-Bond Universal) promise to simplify bonding by using only one material for direct and indirect restorations and providing a substantial bond to ceramics, metal, and tooth structure. Bulk-filled composite resins shorten the time required to produce excellent esthetic posterior composite resin restorations. When bulk-filled composites are paired with "universal" adhesives, a simplified delivery system is produced that simplifies staff training. The ability to stimulate new tooth structure with calcium silicate materials like Biodentine and TheraCal LC may save teeth condemned to extraction. These vital pulp therapy materials are durable and, at a minimum, provide a longer evaluation time before electing to restore or provide root canal treatment for the compromised tooth. Preventive materials have moved from fluoride applications to pastes containing calcium, phosphate, and fluoride. Calcium concentration may be the most important element for remineralization of demineralized tooth structure. Both MI Paste™ Plus and Clinpro 5000 contain these essential building blocks for the tooth and are extremely helpful when treating the salivary-deficient patient.

Figure 19: Icon system for treating Class II lesions.

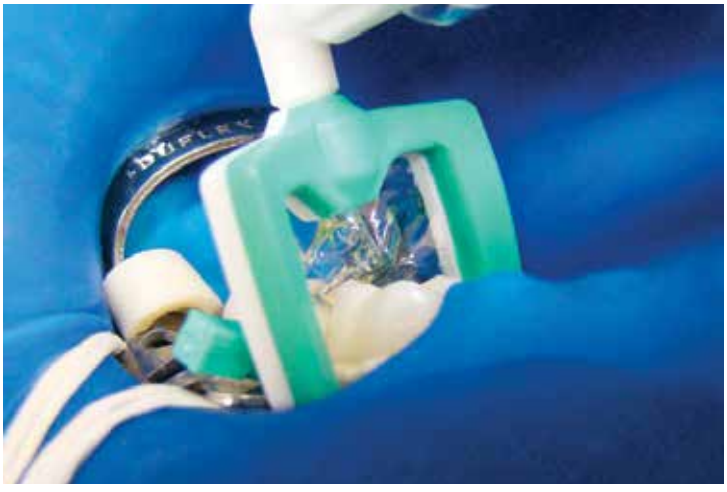

Figure 20: Applying the Icon infusing resin.

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> "The ability to stimulate new tooth structure with calcium silicate materials…may save teeth condemned to extraction."

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Features of a Good Composite Material

How to Prove them with Laboratory Tests

Siegward D. Heintze, DDS, Dr.Med.Dent., PhD

Abstract

Composites are the most frequently used materials in dentistry. Today, the quality of contemporary composite resins from respected and major dental companies from Europe, the U.S., and Japan is very high and not comparable to resins from the 1980s or 1990s. Manufacturers have to comply with regulations established by European, American, and Japanese authorities. Therefore, the overall quality of modern composites is superior and similar between brands, although they may differ regarding handling and esthetic properties. Dentists should know the requirements of a good composite resin and be able to assess and interpret laboratory data on these materials. ISO standards, which define threshold levels concerning flexural strength, depth of cure, susceptibility to ambient light, color stability, water sorption and solubility, and radiopacity, are important, and some tests have a clinical correlation (e.g., flexural strength). A flexural strength below 80 MPa is combined with increased frequency of material fractures. Other tests, such as those that determine bond strength values, are less important, as they are not correlated to any clinical parameter and can vary considerably from one laboratory to another. Marginal gaps are only correlated with marginal staining, not marginal caries, and microleakage has no clinical relevance whatsoever. Dentists can test important clinical features like handling characteristics, esthetics, polishability, and even depth of cure in their own practices with hand-made specimens. The goal of this article is to provide the general practitioner with advice and recommendations on how to select an adequate dental material, based upon laboratory tests that have clinical relevance. Dentists can perform some of these tests in their own practices.

Key Words: composite resin, in vitro test, clinical relevance, flexural strength, bond strength

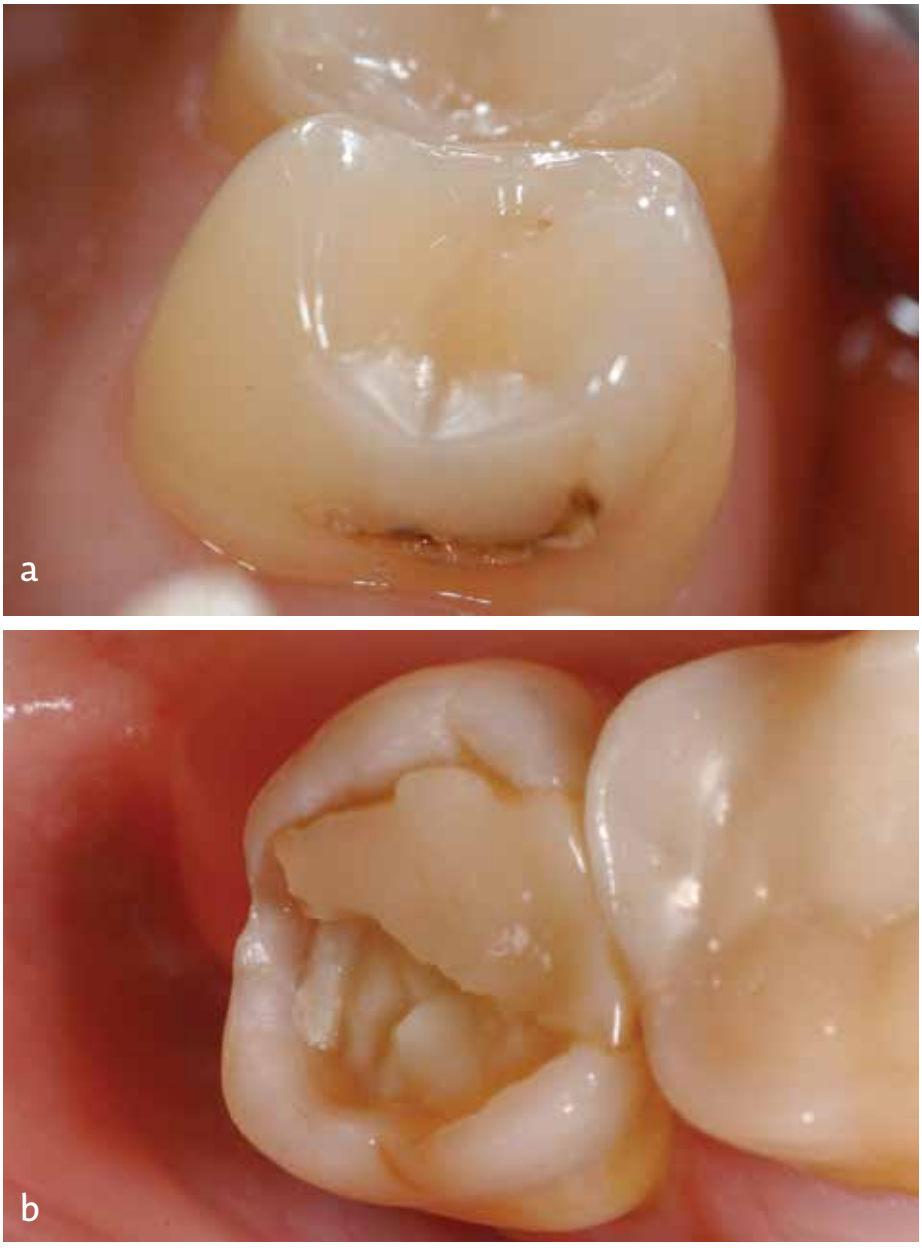
"The direct placement of a composite restoration is the most frequently performed medical procedure in the human body."

Introduction

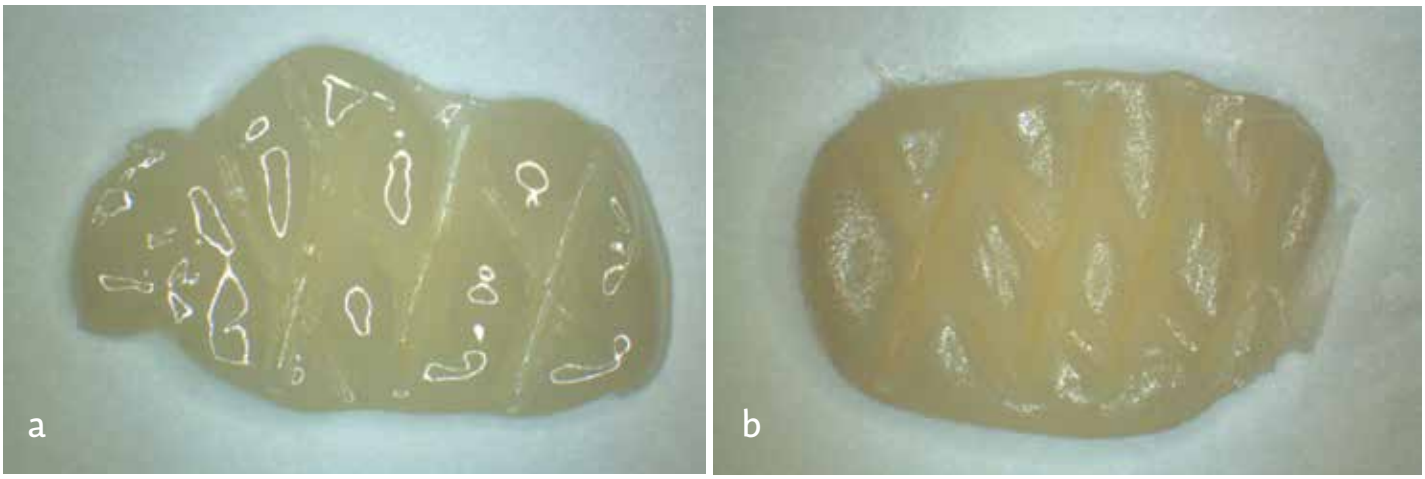
The direct placement of a composite restoration is the most frequently performed medical procedure in the human body. Composite has widely replaced amalgam, although amalgam is still used in many countries. Nearly 280 million composite restorations and 240 million amalgam restorations are placed annually worldwide.[1] Considering that placement of resin restorations is a common daily procedure, general practitioners and patients alike should know which materials and techniques are especially sufficient to ensure both ease of handling and longevity of the restorations.

Composite resin restorations may fail in the long run but only at a very low frequency if they are placed correctly. Studies conducted at universities show that, on average, approximately 8% fail over 10 years of service, 3% fail due to caries at the margins, 3% fail due to material fractures, and 2% fail because of other reasons (e.g., tooth fractures, endodontic treatment, color match, wear) **(Figs 1a & 1b)**.[2]

With adhesive technology, it has become very easy to place restorations, as cavity preparations can be restricted to the carious or erosive defect, making them minimally invasive. Small restorations are less complicated to place and have a higher longevity rate than large ones. Adhesive technology also makes it possible to repair small defects (e.g., caries at the margins, fractures) instead of replacing the entire restoration, which is more complicated and more unpleasant for the patient. It has also been recently proven that repaired restorations have a greater longevity rate than replaced restorations and the placement of rubber dam (compared to relative isolation with cotton rolls)



Figures 1a & 1b: The most frequent failures of composite restorations: (a) caries at the margin; and (b) material fracture. Caries is observed at the distal gingival floor of a Class II composite restoration in a premolar. Marginal caries at this site is eight times more frequent than at the occlusal site.
Images courtesy of B. Zimmerli (Bern, Switzerland); and A. Peschke, Ivoclar Vivadent.



Figures 2a & 2b: Testing the form and shape stability of a composite on a mixing pad with a spatula: (a) the contours of the notches of this material are not stable; and (b) the contours of the notches of this material are stable.

helps to reduce bulk fractures of the composite in the long run.[2]

How can the general practitioner know which characteristics of a composite and/or adhesive systems are important and which test results describe them best? This article aims to give the general practitioner advice and recommendations on how to select an adequate dental material, based upon clinically relevant laboratory tests. Dentists can perform some of these tests in their own practices.

Handling

The handling of a material, including consistency and viscosity, is an important criterion for a practitioner to consider prior to choosing a material. There are, however, no standardized tests to describe the handling characteristics. Each dentist has to take the material in his or her hands and play with it on a mixing pad **(Figs 2a & 2b)**. It is advisable to establish a written checklist with scores to better compare the materials. As dentists have different perspectives on these characteristics, the handling results vary tremendously from one dentist to another **(Table 1)**.

Table 1: Checklist of Handling Characteristics to Test a Fine-Particle Hybrid Composite.

Extrudability from applicator	Highly extrudab le	Extrudable only with some force	Extrudable only with high forces
Viscosity	ideal	slightly too firm	too firm/too soft
Stickiness to instrument	not sticky	slightly too sticky	very sticky
Packability	good	satisfactory	not packable at all
Sculptability	good	satisfactory	not sculptable
Stability of form and shape	does not flow	flows a little bit	flows heavily
Crumbliness	not crumbly	little bit crumbly	very crumbly
Gloss after modelation	glossy	dull	dry, no gloss

"Composite resin restorations may fail in the long run but only at a very low frequency if they are placed correctly."

Esthetic Requirements

The esthetic requirements are very important for a composite resin, especially for restorations in the anterior teeth. Manufacturers offer a variety of different colors, shades, and transparencies. Six to seven shades and two transparencies are sufficient to treat most clinical cases. The dentist should compare flat specimens made of the cured composite with the shade guide. Often, there are discrepancies.

Bond Strength

A sufficient and durable bond strength of composite materials and cements to dentin and enamel is always required in clinical situations where there is a non-retentive preparation, such as for cervical restorations, anterior edge build-up restorations, overlays, and adhesive bridges. Bond strength is normally tested in the laboratory by bonding composite cylinders on dentin or enamel and—after a given period of time (5 minutes, 24 hours, or 3 or 6 months in water)—these are pulled or sheared away with an appropriate test machine.[3] The importance of bond strength tests is highly overestimated. The values, as such, vary tremendously between different research facilities.[4,5] Only approximately one-third of the variability is explained by the material to be tested.[6] The correlation of those tests with the retention rate of cervical fillings is very low.[6,7] Therefore, practitioners should not rely strongly on the results of these tests. Also, the absolute values are completely uninteresting. A material with 40 MPa bond strength is not better than one with 20 MPa. More valuable is the ranking of bond strength values generated at the same facility. The ranking should always include the results of one or two well-established adhesive systems with a good clinical record. However, if the bond strength to dentin and/or enamel is below 10 to 15 MPa, and that has been confirmed by different testing facilities, this material is not appropriate when bond strength is an issue.

Mechanical Properties

The mechanical properties are of paramount importance, as posterior restorations have to withstand occlusal forces in the range of 50 to 150 N while food is chewed and even higher forces (300 to 500 N) in people with bruxism or gnashing. The best tests to characterize the mechanical stability of a composite resin are the flexural strength and fracture toughness tests. In the former, standardized bars—which are polymerized with curing lamps normally used in the practice, not with sophisticated curing furnaces that might enhance the conversion rate of the composite—are broken with a universal testing machine;[8] in the latter, the test describes the resistance of the material to not propagate cracks, which is conducted by creating an artificial crack in a bar that is then broken. To assess the influence of water, the test should be carried out after one day of storage in water and after three months of water storage of another set of specimens. A good composite resin should have a flexural strength of more than 100 MPa after three months in water and a fracture toughness of 1.5 MPa or more.[9] There is clinical evidence suggesting that, if the flexural strength is below 80 to 90 MPa, one can expect 20 to 30% fractures of posterior and Class IV restorations within two years.[10]

Expansion

All composite resins absorb water over time. This process is normally completed after three months so that a plateau is reached if specimens are put into water and measured at certain intervals. The expansion should be no more than 0.8%.[11] Otherwise, tooth cracks with pain and cusp fractures can occur.

Depth of Cure

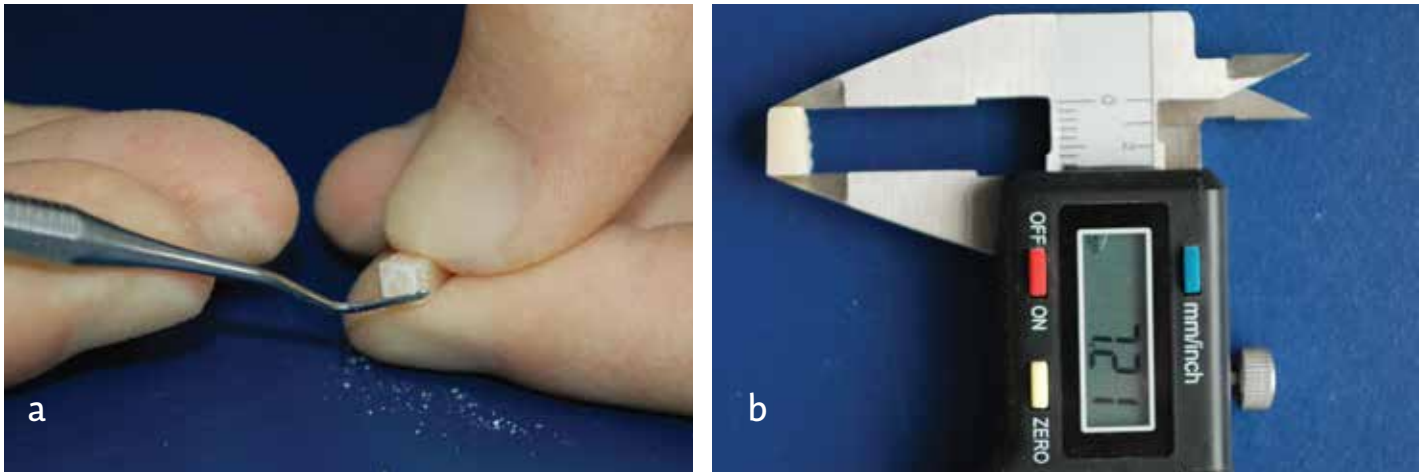
A composite should be cured not only at the surface but also at the most distant parts of the restorations. A critical site is the gingival bottom of the proximal portion of posterior restorations. Uncured or inadequately cured composites leach more monomers and are prone to degradation, which results in discoloration and, eventually, caries at the margin. An easy way to measure curing depth is to fabricate a cylinder-like composite specimen approximately 10-mm long x 4-mm diameter by placing the material in a mold (steel or plastic or a simple drinking straw) and cure it from the top.

After polymerization, the composite cylinder is removed from the mold, the uncured resin material is removed with a spatula, and the length of the specimen is measured. This value is divided by two, which results in a value that gives (approximately) the maximum curing depth.[8] Dentists can easily perform this test in their practices. A good composite should have a curing depth of 2 to 3 mm, and the so-called "bulk" materials should have a depth of at least 4 mm **(Figs 3a & 3b)**. A simple clinical sign for complete/incomplete curing derives from the initiator system. Many composite resins contain camphorquinone, a polymerization initiator with a yellow color. If there is still a yellowish color to the composite after polymerization, this is a sign of incomplete curing.

High-viscosity bulk-fill materials are preferred as they allow the placement of thick increments, thus making the placement of the composite less time-consuming and the curing safer. As polymerization lamps are also critical for an adequate curing they should have a light density of at least 800 mW/cm^2, which should be checked on a regular basis with radiometers.

Radiopacity

The radiopacity of a resin should be at least 200% aluminum, so that a restoration with the material can be differentiated between dental hard tissues in the x-ray **(Fig 4)**. A standardized specimen of the composite material is x-rayed together with



Figures 3a & 3b: Evaluation of curing depth of a composite resin. Cylindrical bars of approximately 10 mm length and 4 mm diameter are produced by means of a plastic mold and cured from the top. The uncured composed is scratched away with a spatula (a), the remaining composite bar is measured with a caliper (b), and the obtained value is divided by two, which gives the curing depth (in this case, 3.6 mm).

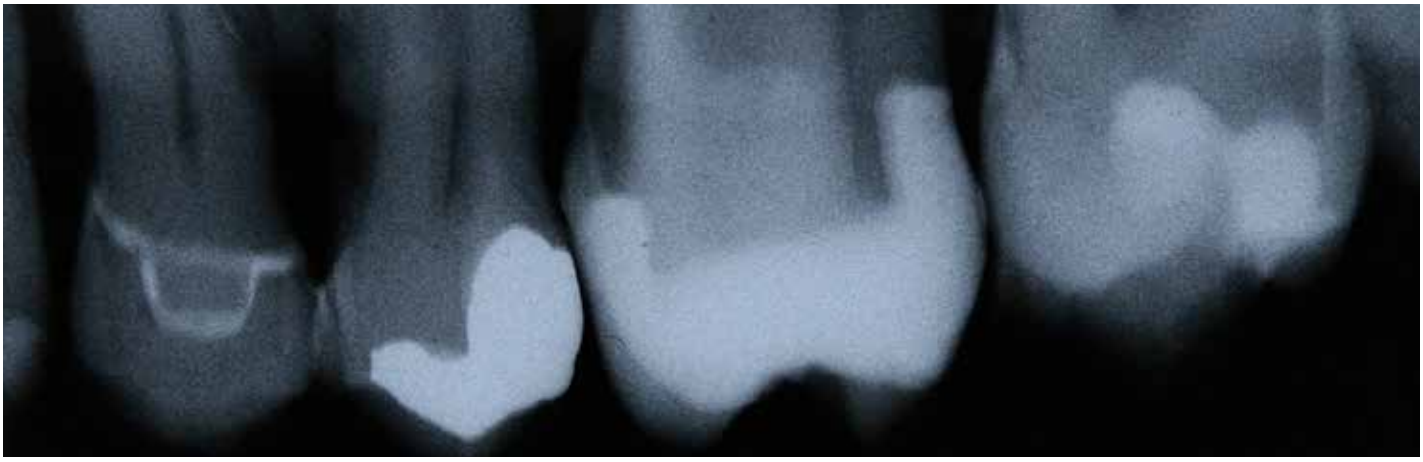
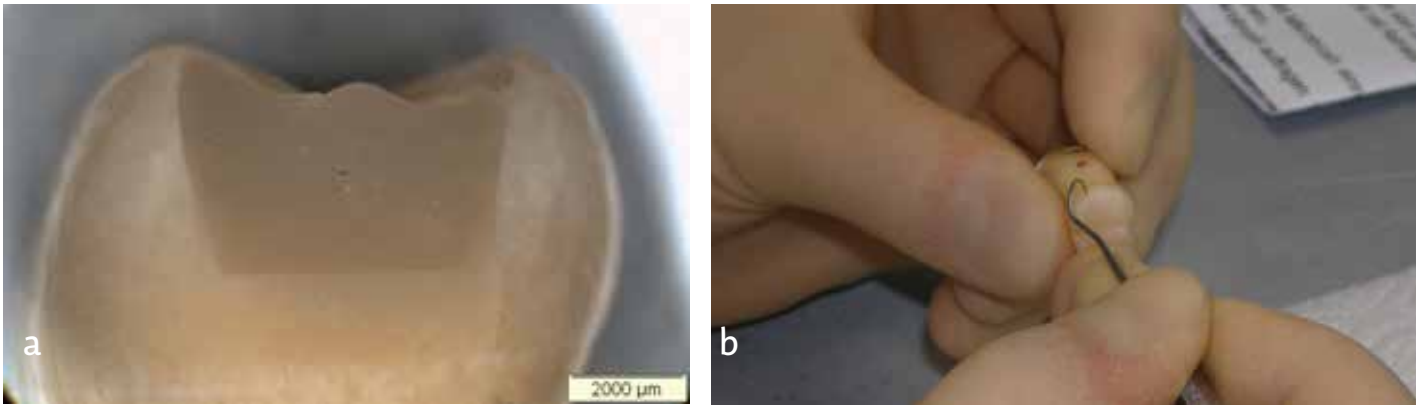


Figure 4: Two direct composite restorations that exhibit different radiopacities on the upper left quadrant (teeth #27 and #26). Note that the mesial restoration at #27 is barely distinguishable from the dental hard tissue. Tooth #25 has an amalgam restoration, and #24 has an adhesively luted glass ceramic inlay. *Radiograph courtesy of B. Zimmerli (Bern, Switzerland).*



Figures 5a & 5b: (a) Composite placed in bulk in an extracted molar tooth with a self-etch adhesive; (b) evaluation of margins with magnifying glasses and explorer.

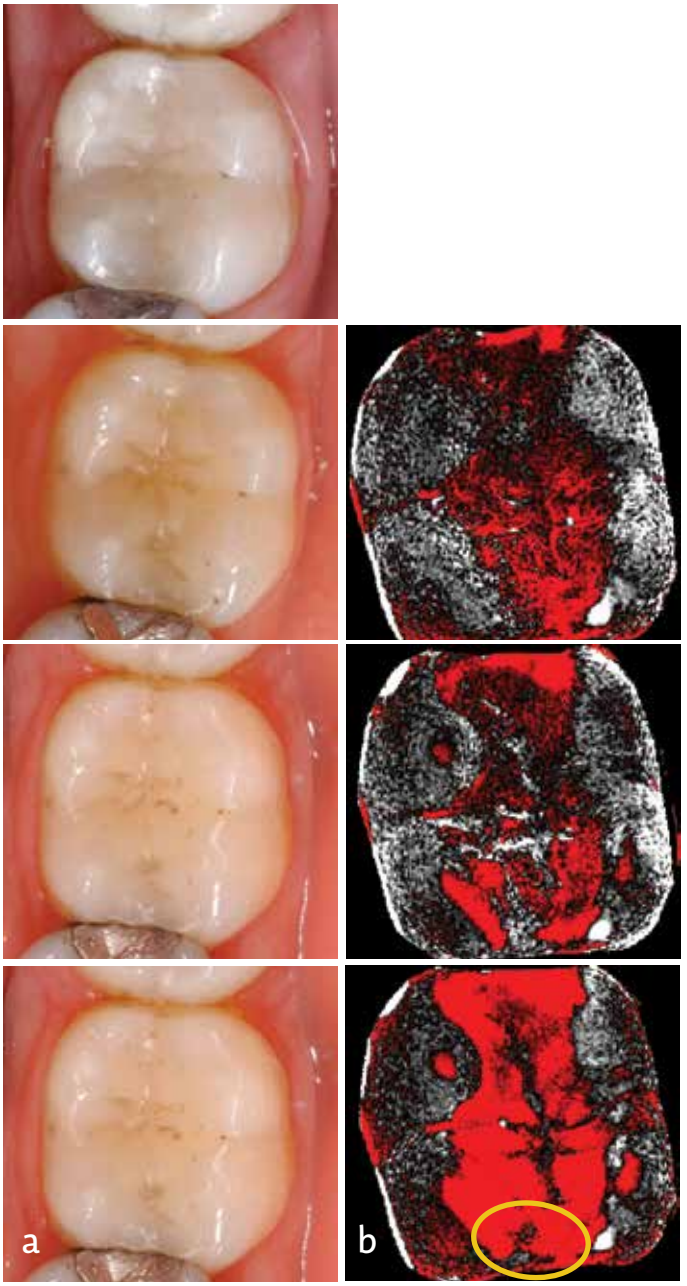
the aluminum standard. The optical density of the test material is then compared to the aluminum standard and must be greater than or equal to that of the standard.

Marginal Integrity

There is now plenty of evidence suggesting that the quality of the marginal integrity is neither related to caries at the margin nor to postoperative hypersensitivity.[6] A bad marginal integrity with gaps and marginal fractures is only related to the staining of those margins, which, however, is an esthetic problem in the long run. Therefore, microleakage tests with a dye are useless and do not have any clinical significance. As many practitioners continue to confound marginal staining with suspected caries (and the former has nothing to do with the latter), the reduction of the frequency of marginal staining also leads to a reduction of this confusion and, thus, to the risk of premature replacement or repair. The best way to reduce the staining on enamel is to apply an etch-and-rinse adhesive system. Self-etching systems are not yet capable of maintaining a durable bond to enamel.[12] The general practitioner can easily test a self-etch system by applying the material in a cavity that he or she drilled in an extracted molar tooth and evaluate the enamel margin with magnifying glasses and an explorer **(Figs 5a & 5b)**. A good adhesive system should produce more than an 80% regular enamel margin. By placing a restoration, the dentist can evaluate the handling characteristics and depth of cure at the same time.

Shrinkage

Shrinkage of resin is another parameter that has been overestimated until now. Shrinkage by volume is often regarded as the most significant shortcoming of contemporary composite resins, and dental manufacturers have long sought to reduce shrinkage.[10] Indeed, shrinkage could be reduced from approximately 4% to 2%. However, even a resin with 1% shrinkage did not perform better



Figures 6a & 6b: A Class II composite restoration, made of a composite resin, at different recall intervals: (a) clinical pictures (from top to bottom) at baseline, after 1 year, after 2 years, and after 5 years; (b) images showing negative differences resulting from superimposed laser scans (from top to bottom): after 1 year, after 2 years, and after 5 years. Red areas represent negative differences; a redder color means higher wear. The volumetric loss after 5 years was 1.9 mm^3, and the greatest vertical loss was 310 µm (see circle). Although scans detected wear, this is clinically almost imperceptible.

Clinical images courtesy of A. Peschke, Ivoclar Vivadent.

than one with 2% shrinkage, as clinical trials have shown.[13,14] Therefore, shrinkage is less important today and not an essential factor for material choice.[15]

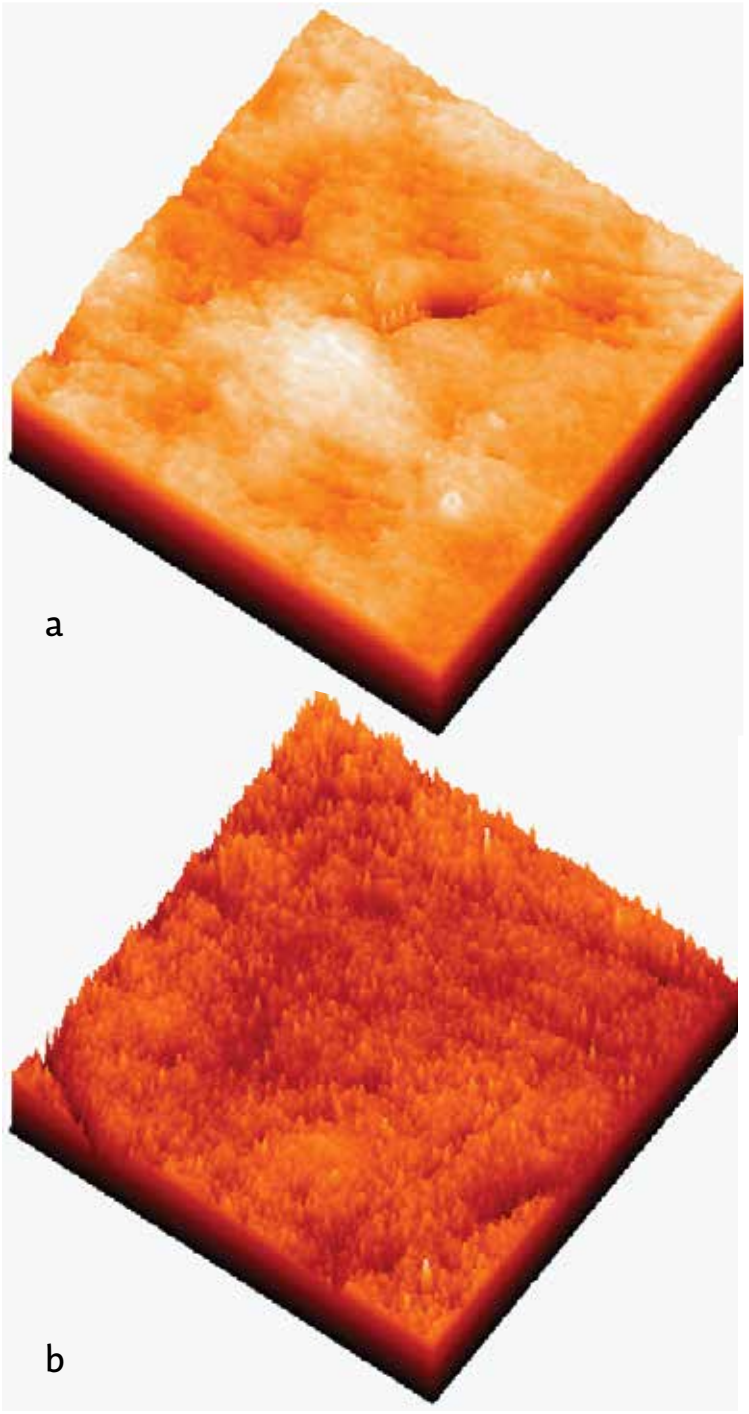
Wear

Every composite restoration shows wear over time, more in some patients than in others **(Figs 6a & 6b)**. Wear does not have a strong biological impact and is an esthetic issue in the first place.[16] Even excessive wear does not cause damage to the temporomandibular joint or periodontal tissue, and elongation of the antagonist rarely happens.

The wear of contemporary composite resins is much lower compared to composites that were used in the 1980s.[17] Today, the patient's influence is much greater than the influence of the material itself.[18] Therefore, the testing of composites that are based upon contemporary technology is less important and practitioners should not pay too much attention to the wear results of laboratory tests, especially because there are very weak correlations between the most popular wear tests and clinical wear, as a systematic review has recently shown.[18]

Polishablity

A good composite should be finely polished, as this decreases the risk of biofilm accumulation and increases the patient's comfort, being that rough surfaces can be detected by the tip of the tongue.[19] The practitioner can easily evaluate whether a composite can be efficiently polished by fabricating a flat specimen of composite, roughening it with a diamond bur, and polishing it with a polisher of choice. Preferably, the polisher contains diamond particles, as these are very efficient and produce a high gloss within a short period of time **(Figs 7a & 7b)**.[20] The gloss can be checked under a lamp. A more accurate method is to use a gloss meter. A material can be regarded as highly polishable if gloss values greater than 60 are obtained after 10 seconds of polishing.



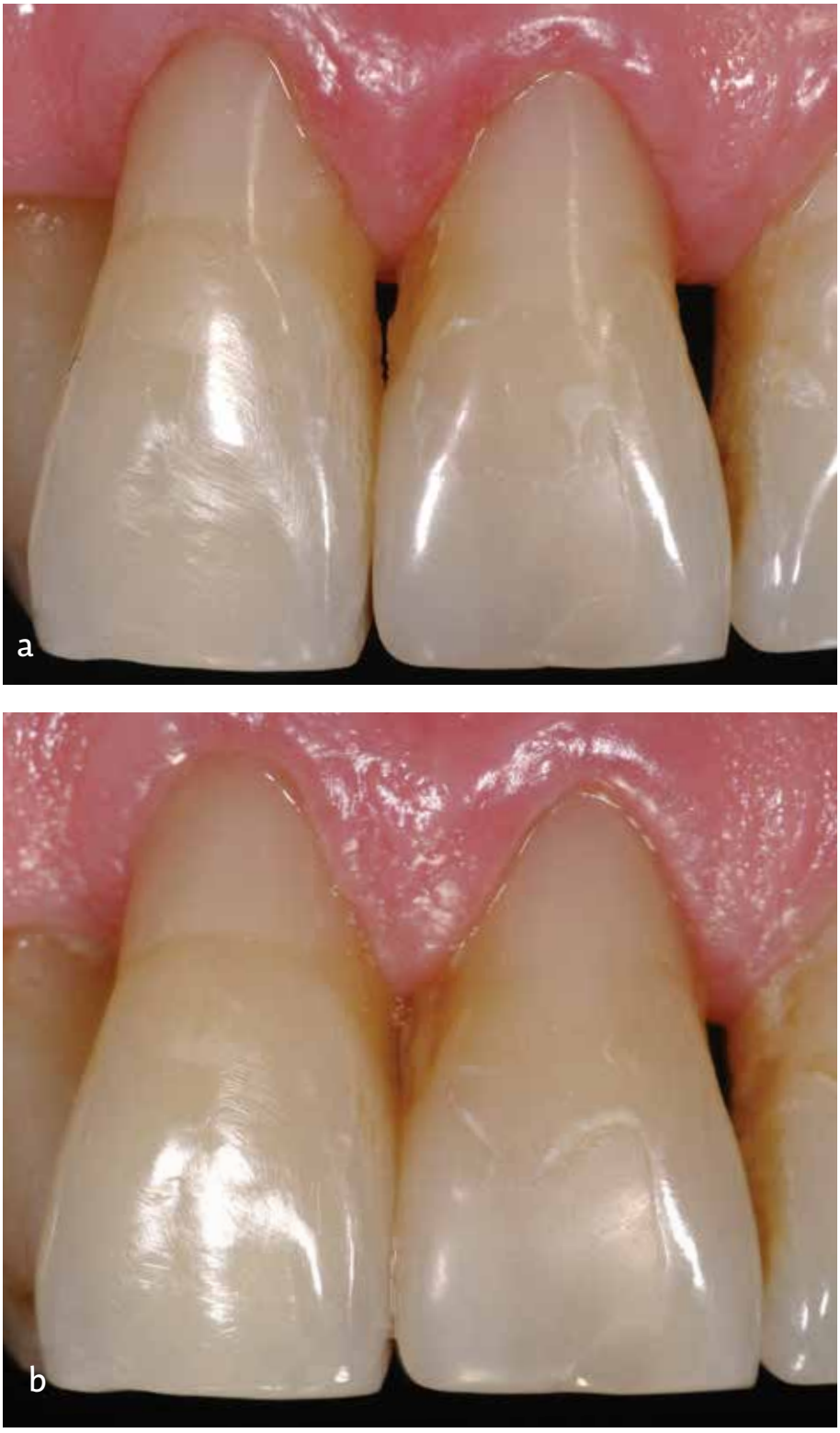
Figures 7a & 7b: Surface roughness after polishing two different composite materials for 30 seconds with a three-step polishing system. The mean roughness is 0.1µm for the first material (a) and 0.4µm for the second material (b).

Gloss Stability

Each composite will suffer some loss of gloss over time, which is especially visible in large anterior restorations, but mostly only if the surface is dry and not covered with saliva **(Fig 8a)**. There are some composites that are more stable than others. The primary reason for loss of gloss is abrasive toothpaste.[21] The monomer matrix of the composite is less resistant to the toothpaste than the filler particles and, therefore, wears more rapidly than the fillers do, thus exposing the fillers and making the surface less glossy **(Fig 8b)**. Gloss stability can be evaluated by submitting highly polished composite specimens to a toothbrush simulation device. The gloss values should not drop below 60 after 1 hour of tooth brushing, which corresponds to approximately 1.8 years of oral tooth brushing.[21]

Conclusions

Most contemporary composite resins from major manufacturers have a high standard of quality. The general practitioner should select a material based upon the following: depth of cure; mechanical strength; esthetic properties; and handling characteristics like polishability, stickiness, and consistency. Some of these parameters can easily be checked by dentists in their practices; other useful physical parameters are listed in **Table 2**. Some of these parameters are part of ISO standard #4049 on composite resins for posterior use. However, threshold values other than those established by ISO should be chosen to be on the safe side. Concerning adhesive systems, etch-and-rinse systems are still the material of choice, as they establish a predictable and durable bond to cut and uncut enamel, thus reducing the risk of gaps and marginal staining.



Figures 8a & 8b: Loss of surface gloss of a Class IV restoration on the central incisor: (a) after placement; and (b) after 2 years. *Clinical images courtesy of A. Peschke, Ivoclar Vivadent.*

Table 2: Useful Laboratory Tests for a Composite Resin Material.[22] ("Threshold value" indicates the recommended minimum or maximum value for composite materials.) *Test is part of ISO standard 4049. **Threshold values as defined by ISO standard.

Laboratory test	Threshold value for clinical suitability	Clinical importance
3-point bending test (MPa)*	≥ 100 (> 80**) (after water storage)	mechanical stability
Modulus of elasticity (MPa)	> 8,000	mechanical stability
Depth of cure (mm)*	> 2 (> 1.5**)	stability and integrity
Sensitivity to ambient light (sec)*	120 to 240	handling time
Expansion (%)	< 0.8 cusp fractures	cracked tooth syndrome
Solubility (µg/mm3)*	< 1 (< 7.5**)	chemical stability biocompatibility
Color stability*	no change	esthetics
Transparency (%)	< 15	esthetics
Radiopacity (%Al)*	≥ 200 (> 100**)	distinction between restoration and tooth/ caries

"Most contemporary composite resins from major manufacturers have a high standard of quality. The general practitioner should select a material based upon the following: depth of cure; mechanical strength; esthetic properties; and handling characteristics like polishability, stickiness, and consistency."

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Disclosure: Dr. Heintze works in Research & Development for Ivoclar Vivadent.

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EXPLORING the Factors and Aspects of

Composition, Applications, and Clinical Considerations

Federico G. Ferraris, DDS, CDT

Abstract

Clinicians today can choose from a large variety of resin-based materials for a composite restoration, based upon characteristics of the cavity, functional goals, esthetic expectations, and type of restoration. The ideal composite for each clinical situation is not easily determined, but a detailed knowledge of different characteristics of the individual resin-based materials can be critical in obtaining a particular esthetic or functional result. Direct composite restorations in posterior teeth have gained greater prominence in the past decades and are now considered the first choice of treatment. Thanks to materials with low shrinkage, possible side effects while treating cavities with unfavorable c-factors can be prevented. Another aspect that should be considered by the clinician is wear resistance, which is an important factor related to the gain of a morphological stability and long-term prognosis of the restoration. In addition, the improvement of polishing has been sought from companies that aim to offer high-performance products, especially in the restoration of anterior teeth. Indirect restorations today can also use composite materials, according to their ability to withstand occlusal loads and be used in adhesive cementations.

Key Words: composite materials, low-shrinkage materials, finishing and polishing, direct restorations, composite onlay

Composite Materials

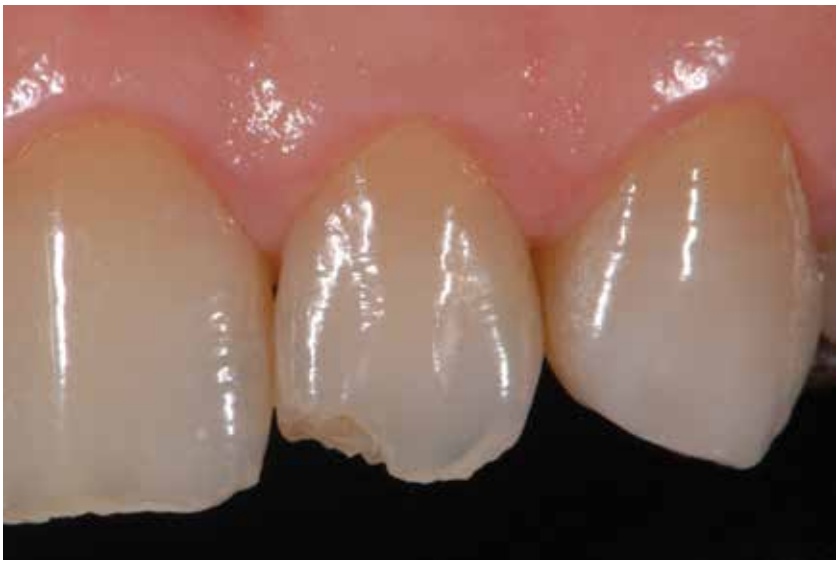

Figure 1: Initial case involving Black Class IV cavity of #3 after fracture.

Introduction

Resin-Based Materials

The wide variety of composite materials available today provides many opportunities but can also cause confusion. Users of these materials should be familiar with their characteristics and distinctions.[1-3]

According to classifications proposed by Ardu and colleagues,[4] resin-based materials can be divided into conventional, hybrid, and microfilled categories, depending upon the filler size and characteristics. Hybrid-defined composite materials can be further divided into coarse, fine, and micro classifications, which can be additionally divided into homogenous and inhomogeneous subclassifications. Additionally, these materials can be placed into four different groups, according to the matrix nature:

- methacrylates
- ormocers
- compomers
- silorane-based.

Methacrylates

The most well-known materials are the hybrid composites. This technology, based on methacrylates and different types of filler coupled with silanes, has been continuously improved. Some disadvantages, such as volumetric shrinkage, bacterial adhesion, and side effects due to monomer release, still remain, but the new technologies offer improved materials. To reduce these negative factors, manufacturers have worked on materials adapting the individual components. The fillers are made of quartz, ceramic, silica, and other oxides. When filler content is increased, polymerization shrinkage, water absorption, and the linear expansion coefficient are reduced. Furthermore, compressive and tensile strength, modulus of elasticity, and wear resistance are generally increased.[5]

Nanohybrid composites are the newest family and probably the most widespread on the market today. They are designed to provide superior esthetic and wear resistance as well as excellent polishing and handling. Their agglomerated nanoclusters, interspersed with micro-sized particles, give them very acceptable wear characteristics. Consequently, they are considered "universal" materials suitable for anterior and posterior teeth.

These composites can have different types of filler particles: prepolymerized, finely milled agglomerated nanoclusters; larger (submicron-sized) glass or silica particles in the range of 0.4 m; and individual nano-sized particles (0.05 m).

This family of materials has many desirable features regarding clinical application, as will be explained. Examples of these materials include the following:

- Filtek Supreme XTE and Filtek Z250 XT (3M ESPE; St. Paul, MN)
- IPS Empress Direct and Tetric Evo Ceram (Ivoclar Vivadent; Amherst, NY)
- Enamel Plus HRi (Micerium; Avegno (GE), Italy)
- Miris 2 and Synergy D6 (Coltène/Whaledent; Cuyahoga Falls, OH)
- Venus Diamond and Venus Pearl (Heraeus Kulzer; South Bend, IN)
- Herculite Ultra and Premise (Kerr; Orange, CA)
- G-aenial and Kalore (GC America; Alsip, IL)
- RefleXions XLS (Bisco; Schaumburg, IL)
- Esthet-X HD (Dentsply Caulk; Milford, DE)
- Estelite Sigma Quick (Tokuyama; Tokyo, Japan)
- Grandio (Voco America; Briarcliff Manor, NY)
- Clearfil Majesty (Kuraray; Houston, TX).

Ormocers

With organically modified ceramic materials (ormocers) (e.g., Admira, Voco America), the methacrylate has been partially replaced by an inorganic network. According to some studies, the biocompatibility was not improved in all cases.[6,7]

Compomers

Compomers aim to combine the positive properties of glass ionomers with composite technology (e.g., Dyract [Dentsply Caulk] and Compoglass [Ivoclar Vivadent). However, this goal has only partially succeeded, because the fluoride release is low. The fluoride release of compomers increases quickly initially (in the first 24 hours), but decreases quickly, too.[8-11] Compomers are most suitable for restorations in the deciduous dentition due to their low abrasion resistance.[12-14]

> **Another important point to consider is the esthetic behaviors of resin-based materials.**

Siloranes and Low-Shrinkage Resin-Based Materials

Manufacturers have addressed problems related to shrinkage of resin-based materials in different ways, including increasing molecular weight and developing materials with ring-shaped molecules. For example, silorane (siloxanes and oxirans) replaces the chain monomers in the composite matrix via ring-shaped molecules (e.g., Filtek Silorane LS). These materials are hydrophobic and need to be bonded to the dental hard tissue with a specific adhesive system. According to some studies,[15-17] silorane's low shrinkage leads to a lower contraction stress; furthermore, these restorations were shown to have both low water absorption and water solubility.[18] Silorane has also been shown to have good mechanical properties.[19,20] The clinical application of these materials is limited to the posterior teeth, however, because few low-translucent colors are available.[2]

Some research in the dental literature does not support the use of silorane-based materials. In one clinical study, the marginal quality of the silorane composite was shown to be somewhat inferior to that of a nanohybrid composite.[21] In another study, silorane did not produce lower contraction stress than other composites.[22]

As aforementioned, other monomers with increased molecular weight have been developed for composites with reduced shrinkage. The urethane monomer TCD-DI-HEA (bis-(acryloyloxymethyl)tricyclo (5.2.1.02,6) decane), found in Venus Diamond and Venus Pearl, has been shown to produce lower-curing contraction stress than other composites marketed as low-shrinking.[22] Other low-shrinkage materials are available, such as the modified urethane dimethacrylate (UDMA) resin from DuPont found in Kalore, which has a relatively high molecular weight compared to bisphenol a glycidyl methacrylate (bis-GMA) and traditional UDMA. Another strategy is represented by dimer acid monomers used in N'Durance (Septodont; Lancaster, PA), which are also of relatively high molecular weight and have been shown to have high conversion of carbon double bonds while undergoing lower polymerization shrinkage than bis-GMA-based systems.[23,24]

Clinical Considerations

Direct Anteriors

In anterior restorations, the material mainly chosen, in many cases, is composite resin. In the past, micro-particle composites were especially preferred for their good polishing, but they showed low resistance to surface wearing.

Considering the fairly favorable c-factor in anterior areas (Black Class III or IV cavities[25]) **(Fig 1)**; and knowing that addictive morphological modifications may need to be made, there is no strong clinical indication to use low-shrinkage materials. Therefore, it is more appropriate to focus on different materials.

In anterior restorations, the goal is mechanical and wear strength. Furthermore, from an adequate polished surface, nanohybrids and nanofilled materials are recommended today. In vitro scientific studies have shown that various nanohybrids materials yield an excellent surface quality[26,27] and have low wear, thanks to increased wear resistance.[28-30] The nanofilled materials also possess preferred mechanical properties,[31] a relatively low shrinkage rate, and high strength.[32] These types of materials provide excellent results concerning surface roughness.[33] Additionally, some technologies have been further developed in this family of materials to improve the maintenance of polishing, creating clusters with the nanoparticles that constitute the material (e.g., Filtek Supreme XTE).

Another important point to consider is the esthetic behaviors of resin-based materials. Considering the translucency and opacity of both flowable and paste composites (generally photo-curable), it is advisable to choose the proper materials to recreate the different areas of natural dentin and enamel. Some systems offer many composite masses with intermediate translucency, which are very similar to one another, although they are possibly deficient in translucency effects, intensives, and stains.

The criteria of correct layering are already well known.[34,35] Under normal conditions, the stratification of the composite provides in the most superficial area an enamel that has good translucency characteristics. This makes it possible to highlight the contrast between the dentin and the translucent effects placed under it in a natural manner **(Figs 2-5)**.

Another preferred feature, available in some products currently on the market, is to have a composite light refractive index similar to natural tooth tissues. Generally, resin-based materials have a lower refractive index; therefore, in equal thicknesses (composite and tooth), the optical behavior is different. Materials with a high refractive index (e.g., Enamel Plus HRi) provide an anatomical stratification, with equal thicknesses compared to dental tissues.

Lastly, in anterior composites a proper finishing is needed to emphasize the major and minor morphologies, including a multiple-step polishing using burs, polishers, discs, and brushes, which helps smooth out rough surfaces and achieve depth perception. It was demonstrated that the surface finished using multiple-step polishing systems

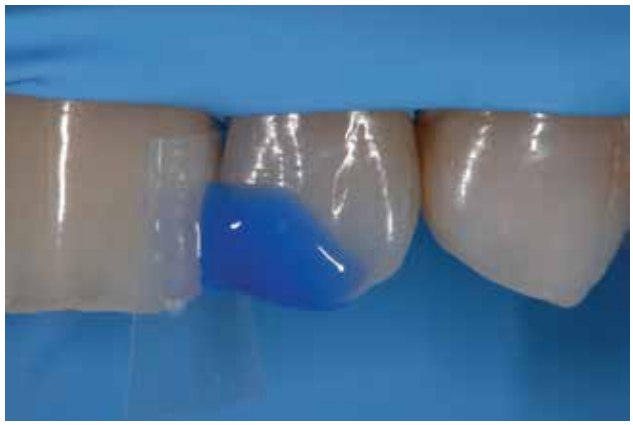

Figure 2: After gentle preparation, the isolation of the field and phosphoric etching are performed.

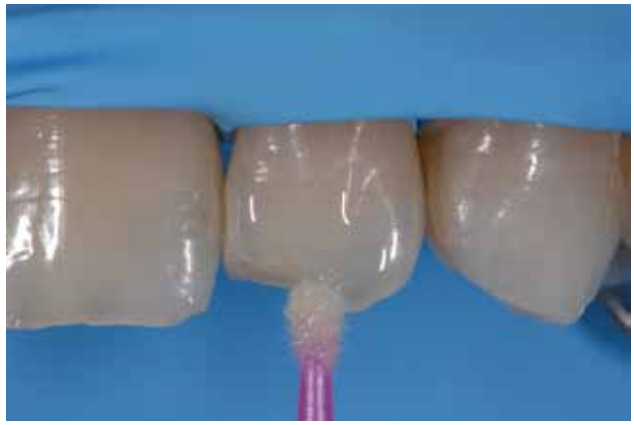

Figure 3: Adhesive procedures on hard tissues.

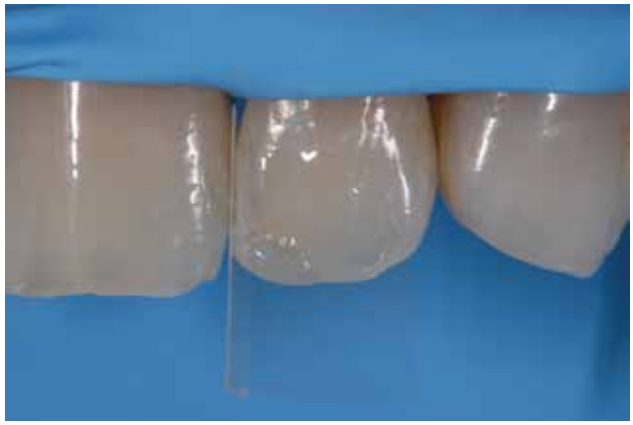

Figure 4: Palatal enamel is layered onto the dentin prior to applying effects and the final enamel covering.

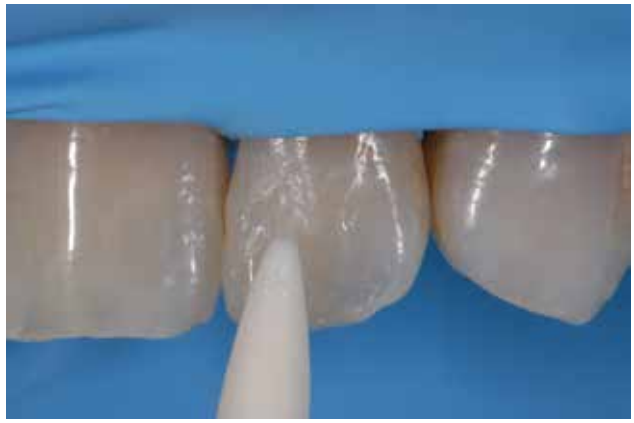

Figure 5: A layer of composite is applied using a special silicone tip.

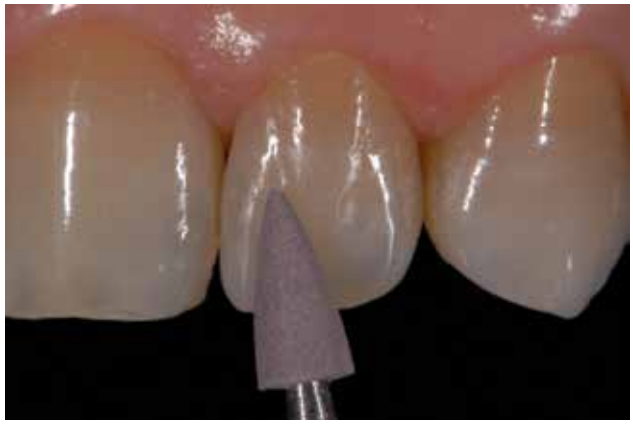

Figure 6: A medium-grit polisher is used during the finishing procedure.

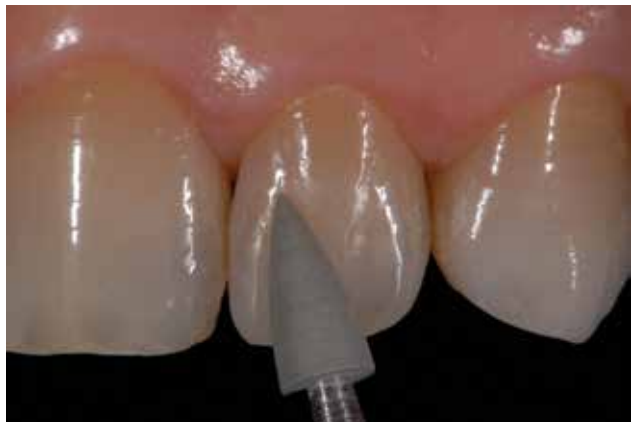

Figure 7: A fine-grit polisher is used during the finishing stage.

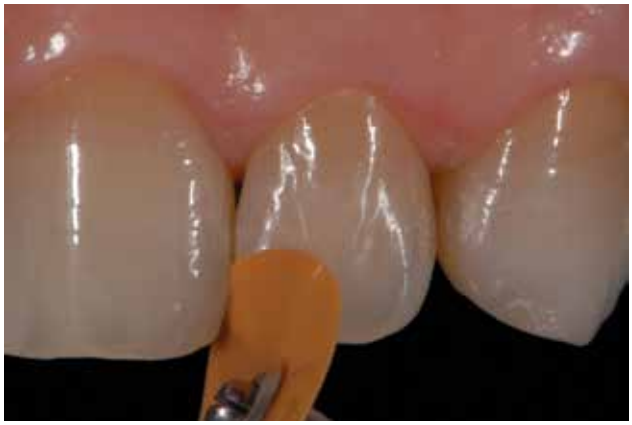

Figure 8: An aluminium oxide disc is employed during the finishing stage.

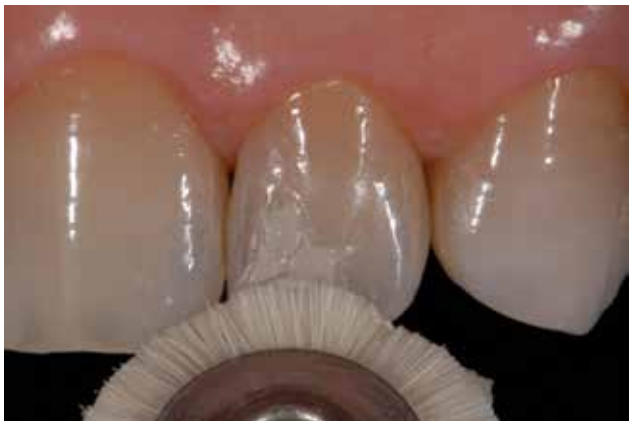

Figure 9: Diamond paste is applied with a brush during the polishing stage.

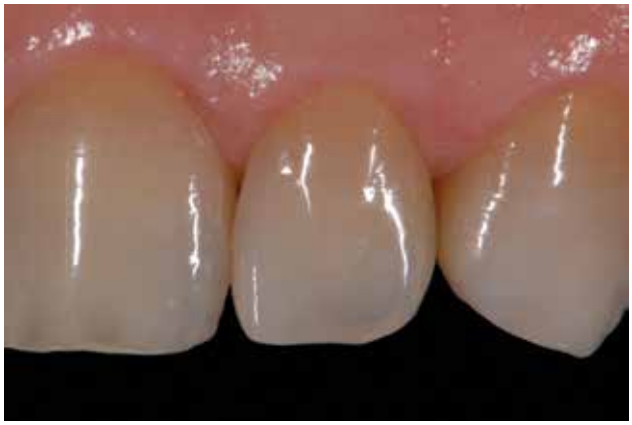

Figure 10: Final results one week after completion of the restoration.

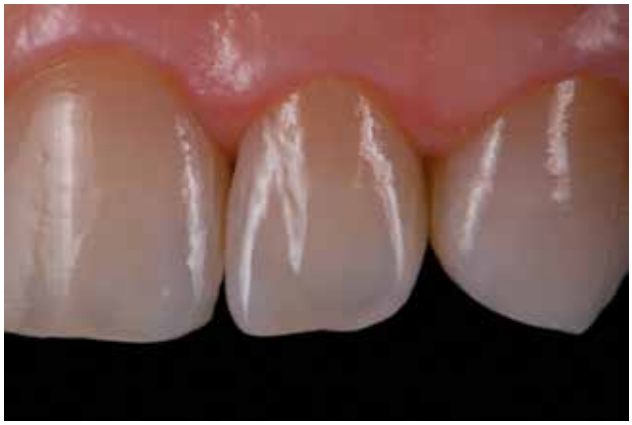

Figure 11: Final results shown via a different photographic technique that highlights certain morphologies.

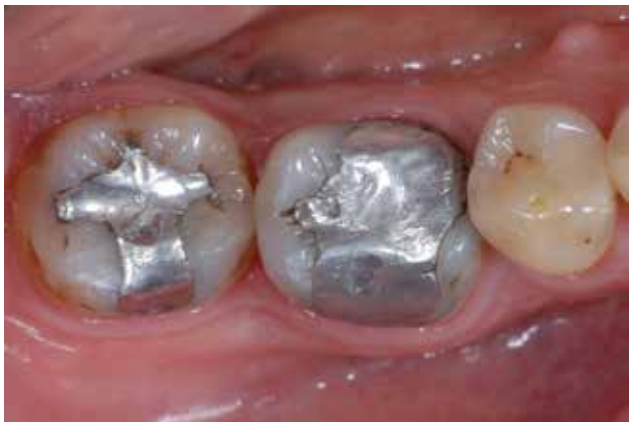

Figure 12: The initial case. Amalgam reconstructions on #6 and #7 and a composite filling on #5 will be replaced.

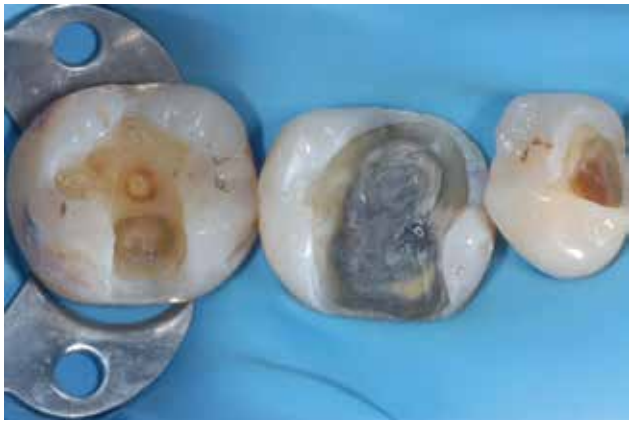

Figure 13: The old filling and secondary carious lesions are removed, and the cavity is prepared.

was superior to that obtained with one-step systems,[36] and three-step rubber polishers were more efficient than two-step and one-step polishing methods on nanoparticle and hybrid resin composites **(Figs 6-11)**.[37]

Flowable materials, which are usually less filled and less viscous compared to paste composites, often suffer from high shrinkage. These materials could best be used in Black Class I, II, or V cavities and in areas of cavitated enamel.[38]

Direct and Indirect Posteriors

As a posterior restorative, resin composite represents the primary choice today for most clinicians. In in vivo studies analyzing the prognosis of composite restorations, with 10 to 20 years follow-up, the annual failure rate was low: approximately 2%.[39-41] Gaengler and colleagues[39] described 10 years of follow-up of direct posterior composite with the following conclusions: "The early risk of failure is attributed to bulk fractures and partial loss of filling material. The longevity over 10 years is a maximum of 74.2%, and the very low secondary caries rate and the high percentage of correct anatomical form confirm the clinical safety of posterior composite restorations."

In clinical studies that have compared the follow-up of posterior restorations with amalgam and composite, the results are similar, although it can be assumed that some amalgams have a slightly greater longevity.[42-44]

Another study with 12 years of follow-up involving high caries-risk patients compared composite and amalgam restorations. Both materials showed higher failure rates, although in large cavities composite behaved better in patients with a lower caries risk.[45]

Posterior composite restorations can be made via a direct or indirect technique. It has been shown that, in a medium-sized cavity, indirect and direct composite restorations have revealed no differences in performance after many years.[46] The cavity should be analyzed carefully and a treatment evaluation should be performed to determine which restoration is preferred,[47]

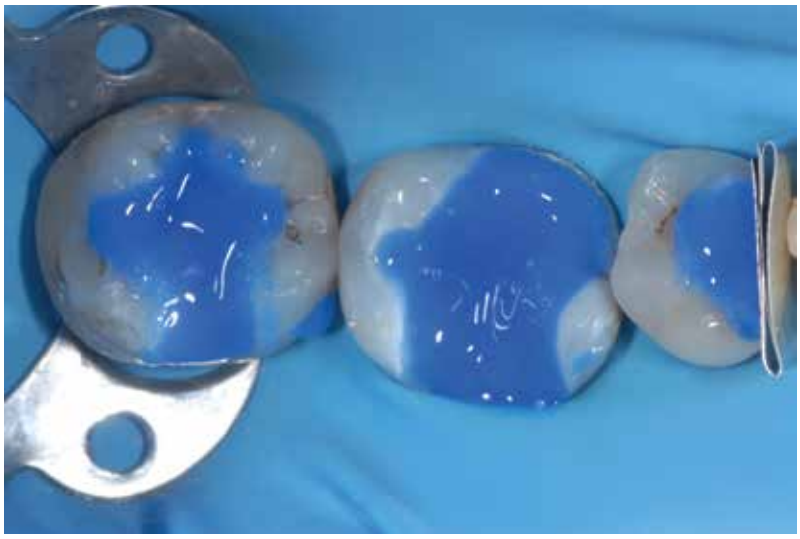

Figure 14: Etching phase during the adhesive procedure.

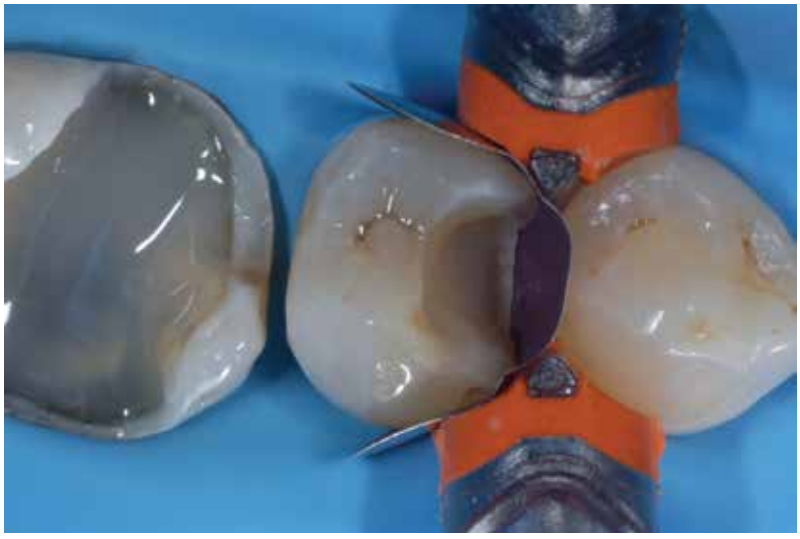

Figure 15: The matrix has been positioned for the buildup of the interproximal wall. Some flowable composite was placed on the dentin to support the cervical residual enamel.

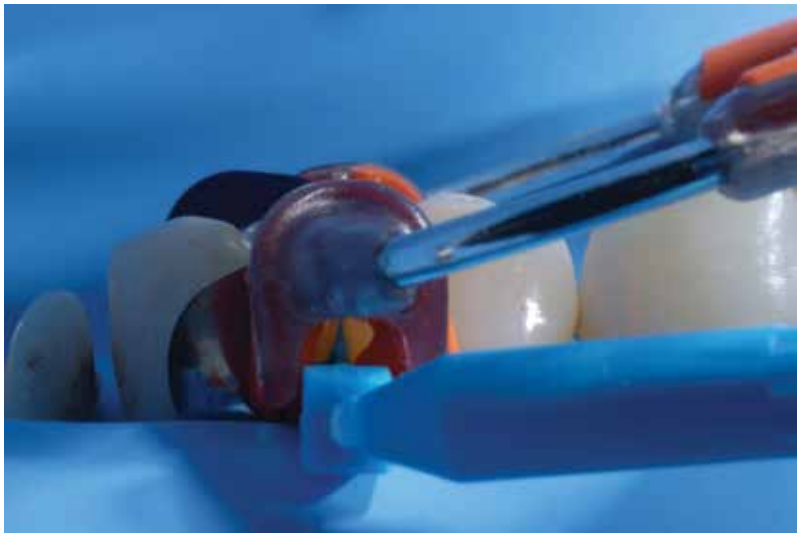

Figure 16: The matrix from a buccal point of view, demonstrating the relationship between the wedge, matrix, and ring.

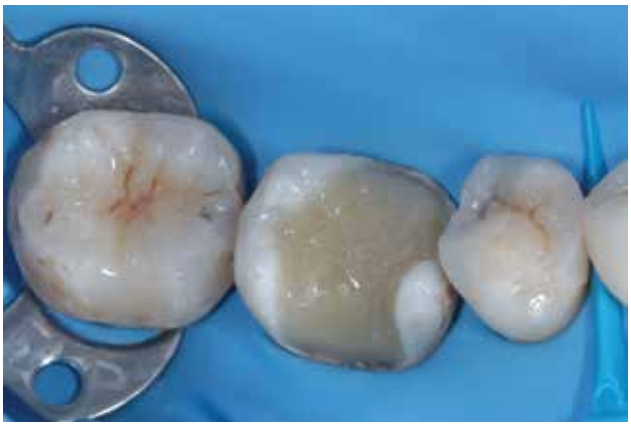

Figure 17: Completion of the layering of direct restorations. The composite buildup on #6 must now be finished.

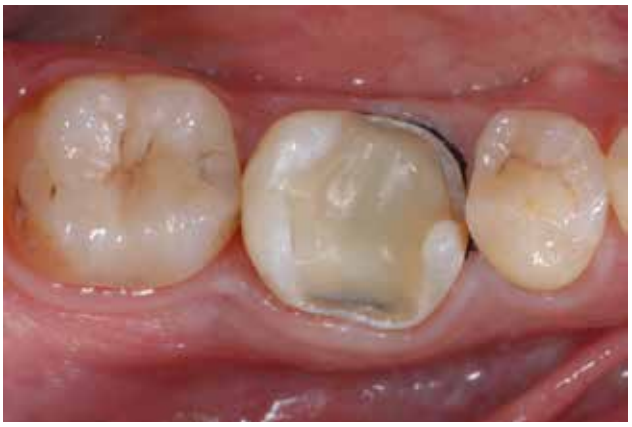

Figure 18: The cavity on #6 is prepared for the impression. Enamel margins are available on the full perimeter. A retraction cord is positioned to the closest margins to the gingiva.

Figure 19: Composite onlay before cementation.

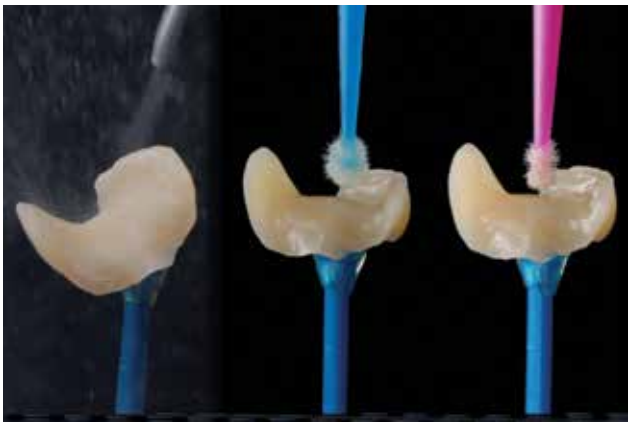

Figure 20: Adhesive treatments of composite onlays: sandblasting (left), silane (middle), and bonding (right).

Figure 21: Cavity cleaning under rubber dam, before the adhesive cementation.

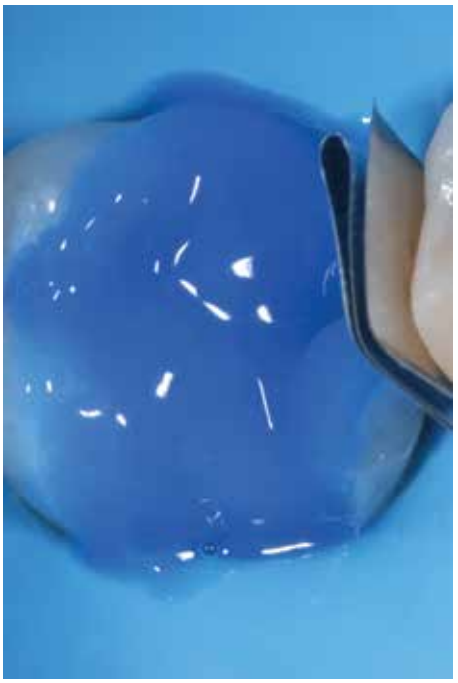

Figure 22: Cavity etching with phosphoric acid.

Figure 23: Cavity bonding.

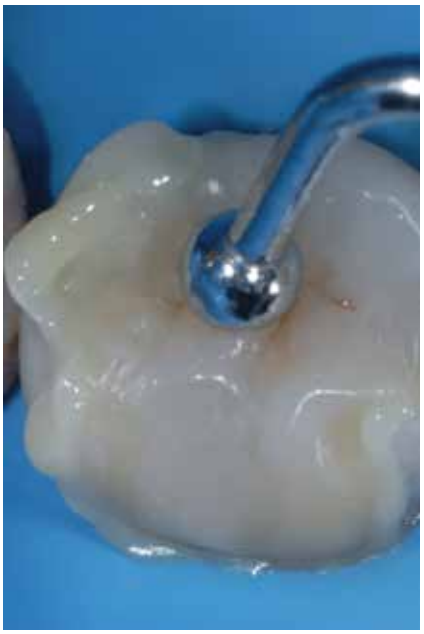

Figure 24: Excess cement must be removed during onlay cementation of the seating phase.

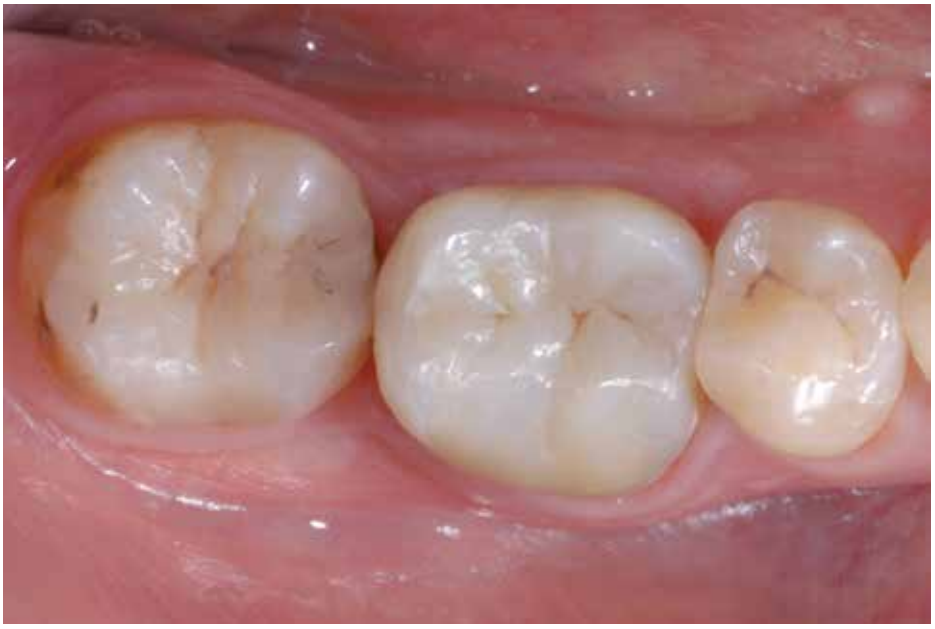

Figure 25: Final results after one week showing a direct composite restoration on #5 and #7 and an indirect onlay composite bonded on #6.

and qualitative and quantitative evaluations of the residual cavity structures and the need to rebuild one or more cusps should be thoroughly considered. However, it is possible that teeth can be reconstructed within the same quadrant using either a direct or indirect technique **(Figs 12-25)**.

Direct posterior restorations are more susceptible to shrinkage stress compared to indirect restorations; hence, it may be desirable to use a material with low shrinkage and a favorable elasticity modulus. Furthermore, to minimize these negative effects, it is recommended to use an appropriate layering technique followed by proper curing for each layer.

In Black Class II cavities, positioning a sectional matrix can help provide a correct point of contact and result in a good interproximal morphology **(Figs 15 & 16)**.

Composite resins are also indicated in indirect onlays **(Figs 17 & 18)**. Some in vitro studies have compared indirect onlays with ceramic restorations and found that fracture resistance, when applying a normal masticatory load, was similar for both materials. With masticatory overload, however, the composite gave better results in terms of resistance and distribution of stress on the root below. In addition, composite resins layered and milled with CAD/CAM technology showed higher fatigue resistance than porcelain.[48,49] Other desirable features of composite resins include better management of the morphology and less shrinkage of the material, which is polymerized out of the cavity **(Fig 19)**.

Indirect composite restorations can be cemented adhesively, thanks to pretreatments and proper procedures. Unlike cemented porcelain restorations, indirect composite restorations are sandblasted (using aluminium oxide or silica coating) and not treated with hydrofluoric acid.[50,51] The pre-treatment before the resin cement (that can be light-curable) can be represented by silane and hydrophobic resinous bonding **(Figs 20-25)**.

Summary

Composites have been shown to perform well in clinical situations. In the anterior region, they can be used to produce excellent esthetic results. Their response to stress also makes them suitable restorations in the posterior area, using either direct or indirect techniques. Nanohybrid materials are considered universally suitable for numerous clinical uses, flowable composites have specific indications, and low-shrinkage materials are recommended in particular clinical cases, especially in posterior cavities.

Proper polishing of composites, however, can represent a limitation compared to other esthetic materials, although it is not a major limitation. Lastly, some clinical studies[1] showed good outcomes with few clinical limitations, including marginal staining (a problem related more to adhesive systems than restorative materials), some discoloration, and edge chipping in high-stress situations.

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Clinical Performance of CAD/CAM-Generated Composite Inlays After 10 Years

Comparing the Longitudinal Performance of Composite and Porcelain

Dennis J. Fasbinder, DDS
Gisele F. Neiva, DDS, MS
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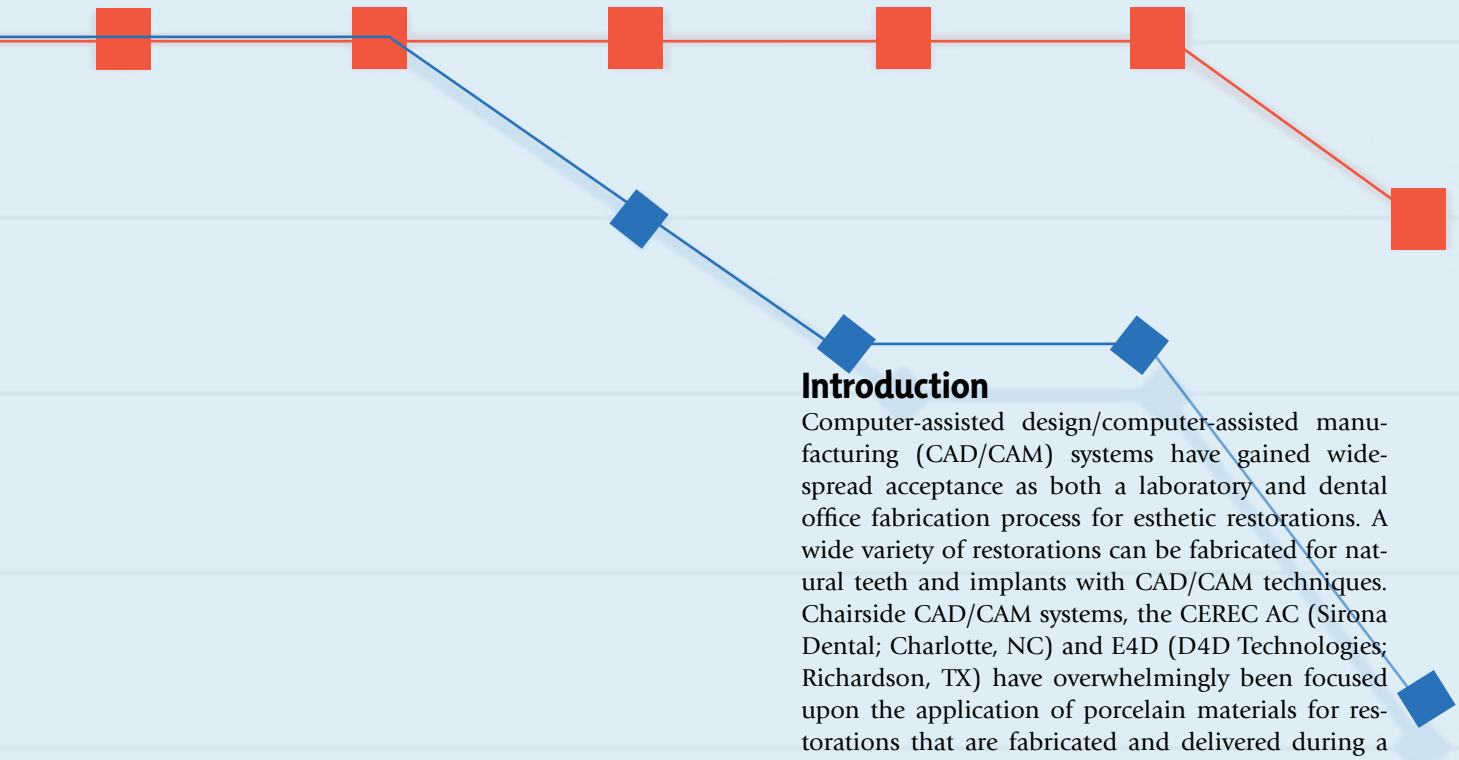
Donald R. Heys, DDS, MS

Abstract

A number of porcelain materials have demonstrated clinical reliability with a chairside placement CAD/CAM technique (e.g., CEREC). The purpose of this clinical study was to evaluate the longitudinal clinical performance of a composite resin material (Paradigm) compared to a porcelain material (Vita Mark II) for chairside CAD/CAM-generated adhesive inlays. The inlays were evaluated at six months, one year, two years, three years, six years, and 10 years. Composite resin CAD/CAM inlays performed equally as well as porcelain CAD/CAM inlays after 10 years of clinical service, with clinical advantages noted favoring composite inlays for fracture resistance and better color match to the tooth.

Key Words: CAD/CAM, digital dentistry, ceramics, composites, CEREC



Introduction

Computer-assisted design/computer-assisted manufacturing (CAD/CAM) systems have gained widespread acceptance as both a laboratory and dental office fabrication process for esthetic restorations. A wide variety of restorations can be fabricated for natural teeth and implants with CAD/CAM techniques. Chairside CAD/CAM systems, the CEREC AC (Sirona Dental; Charlotte, NC) and E4D (D4D Technologies; Richardson, TX) have overwhelmingly been focused upon the application of porcelain materials for restorations that are fabricated and delivered during a single dental appointment.

Porcelain options for use with the CEREC system include feldspathic porcelain (Vita Mark II [Vident; Brea, CA] and Sirona Blocs [Sirona Dental]); leucite-reinforced porcelain (IPS Empress CAD, Ivoclar Vivadent; Amherst, NY); and lithium disilicate porcelain (IPS e.max CAD, Ivoclar Vivadent).[1] A number of clinical studies have reported very good performance and longevity with a direct placement CAD/CAM technique utilizing blocks of porcelain material to fabricate the restorations.[2-5] An innovative composite resin material has also been available for use in fabricating CAD/CAM restorations. Paradigm MZ100 (3M ESPE; St. Paul, MN) is a bis-GMA/TEGDMA composite resin with filler composed of nanocrystalline zirconia in an amorphous silica µ matrix.[6] The inorganic filler loading is 85% by weight, with an average particle size of 0.6 µ, and is radiopaque. However, there are no corresponding longitudinal studies on CAD/CAM-generated composite inlays documenting its clinical usefulness.

This investigation is a longitudinal, randomized clinical trial to study the clinical performance of a composite material for CAD/CAM-generated adhesive inlays. The purpose of this study was to: (1) compare the longitudinal clinical performance of porcelain and composite CAD/CAM inlays after 10 years of clinical service; and (2) evaluate the postoperative sensitivity associated with the adhesive luting technique.

Learning Objectives:

CE CREDIT

After reading this article, the participant should be able to:

1. Know the treatment options for tooth-colored inlays using a chairside CAD/CAM system.
2. Understand the clinical longevity and performance of porcelain and composite chairside CAD/CAM inlays.
3. Be aware of the low failure rate of chairside CAD/CAM inlays and understand the difference in fracture resistance between composite and porcelain chairside CAD/CAM inlays.

> A wide variety of restorations can be fabricated for natural teeth and implants with CAD/CAM restorations.

Methods and Materials

A total of 43 patients participated in the study based upon their need for a restoration as described below. They were fully informed of the nature of the study and signed a written consent form, approved by the Institutional Review Board of the University of Michigan Health Sciences (Ann Arbor, MI) prior to being enrolled in the study. Each patient had at least one two-surface mesial-occlusal or distal-occlusal (MO or DO) or three-surface mesial-occlusal-distal (MOD) carious lesion or defective restoration to be restored on a maxillary or mandibular bicuspid or molar. Each lesion or defective restoration exhibited sufficient size to extend at least one-half the intercuspal width of the tooth. All restored teeth were in functional occlusion and had at least one adjacent proximal contact. All restored teeth tested vital and were asymptomatic at the beginning of treatment. No more than two restorations were placed per patient. Exclusion criteria included:

- devital teeth
- sensitive teeth
- teeth with prior endodontic treatment
- teeth with a history of direct or indirect pulp-capping procedures
- patients with significant untreated dental disease, including periodontitis and rampant caries.

Two clinicians, each with more than five years of experience using the CEREC technique, placed 40 composite resin inlays of Paradigm MZ100 and 40 porcelain inlays of Vita Mark II for a total of 80 inlays. The preoperative shade of the tooth to be restored was determined using a shade guide (Vita Classic and 3D Master) prior to starting the restorative treatment. Following injection of local anesthetic, rubber dam isolation was used for cavity preparation, optical imaging, and adhesive cementation for every restoration. The rubber dam was removed after the restoration was adhesively cemented and final occlusal adjustment and polishing were completed.

Inlay cavity preparation consisted of butt joint margins without bevels. All walls were tapered six to eight degrees from the pulpal floor to the cavosurface margin. No bases or liners were used in the study. The flare of the proximal boxes conformed to standard criteria for an inlay, with the proximal margins exposed for convenience in finishing. The floor of the proximal box was prepared sufficiently cervical to open the proximal contact and to remove existing caries or prior restorations. The amount of remaining enamel at the box cervical margin was consistent with usual clinical practice. Cervical box extension enabled proper isolation and ensured access for digital imaging. The manufacturer's instructions were strictly adhered to in the imaging, computer graphic design, and milling of the restorations. A CEREC 2 unit with operating system 1.21 was used to design the inlays. The extended machining option was used for milling all restorations.

Following computer graphic design of the inlay, the operator opened the envelope containing the random assignment of the prefabricated block to be used for the specific restoration. Randomization assignment was predetermined based upon a table of random numbers. Delaying the unveiling of the random assignment of restorative material to this point in the treatment process ensured that shade determination, cavity preparation, and computer graphic design were not biased by the choice of restorative material.

Forty inlays were milled from prefabricated porcelain blocks of Vita Mark II. After trial seating, the internal surfaces of the ceramic inlays were etched for 30 seconds with 9.5% hydrofluoric acid gel, rinsed for 20 seconds, and then air-dried with oil-free air. A pre-hydrolyzed silane coupling agent (RelyX Ceramic Primer, 3M ESPE) was applied to the etched restoration prior to cementation. Forty inlays were milled from prefabricated composite blocks of Paradigm MZ100. After trial seating, the internal surfaces were air-abraded with 50 µ aluminum oxide at 40 psi. A layer of Single Bond (3M ESPE) was applied to the internal surface of the inlay, air-thinned, and cured for 20 seconds. All cavity preparations were acid-etched for 30 seconds with 37% phosphoric acid and then rinsed for 20 seconds. The tooth was lightly dried with high-volume evacuation, and pooled water was blotted dry with cotton to ensure a moist surface and to avoid dehydration of the cavity preparation.

Single Bond was applied to all prepared tooth surfaces prior to seating the restoration, air-thinned, and cured for 10 seconds. A dual-cured resin cement, RelyX ARC, was used for all inlays and cured with a visible light-curing unit for 40 seconds from the facial, lingual, and occlusal directions for a total curing time of two minutes. A series of diamond finishing burs, rubber abrasive points and cups, finishing strips, and diamond polishing pastes were used to remove excess cement, adjust the occlusion, and complete final polishing.

Intraoral color photographs were taken at baseline to document the preoperative condition, cavity preparation, inlay try in, and postoperative conditions. A post-cementation quadrant impression was made of each test restoration in a polyvinyl siloxane (PVS) material, and casts were poured in an epoxy die material for indirect evaluation.

Data Collection

Patients were contacted by telephone once a week after the initial appointment to evaluate immediate postoperative sensitivity. The telephone interview was used as a follow-up procedure to minimize recall loss, as patients

were not required to return to the clinic. During the telephone interview a criterion-referenced rating was made of functional tooth sensitivity that factored in the following sensitivity criteria:

- No sensitivity is experienced at any time.
- Slight sensitivity is experienced occasionally, but the tooth is not uncomfortable.
- Moderate sensitivity is experienced intermittently, and the tooth is noticeably uncomfortable.
- Severe discomfort is noted routinely with cold or pressure stimulation.

The authors of this article did not participate in the baseline evaluations of the restorations they placed. For each recall examination, two independent evaluators performed the direct clinical evaluation using written criteria based upon modified U.S. Public Health Service (USPHS) criteria for the following:

- color match
- margin discoloration
- anatomic form
- margin finish
- margin adaptation
- surface finish
- cusp/tooth fracture
- caries
- restoration fracture
- proximal contact.

Modifications to the USPHS criteria were based upon those developed at the University of Michigan.[7] The modifications were added to allow for more subtle clinical distinctions to be made in an attempt to identify early performance trends in the restorations. **Table 1** shows the modified criteria. Disagreements in evaluations were discussed between the evaluators, and a consensus judgment was reached and recorded for every criteria. Quadrant PVS impressions and intraoral color photographs were made at the six-month, one-year, two-year, three-year, six-year, and 10-year recall visits **(Figs 1-7)**. Systat 13 software (Systat Software; Chicago, IL) was used for the statistical analysis.

Table 1: Modified Clinical Evaluation Criteria.

Margin Discoloration	Rating
No evidence of discoloration	Alpha
Surface stain along less than 50% of exposed margin	Bravo-1
Surface stain along greater than 50% of exposed margin	Bravo-2
Penetrating discoloration of exposed margin	Charlie
Margin Adaptation	
No visible evidence of crevice formation along cavosurface margin Explorer does not catch when drawn across the margin	Alpha-1
No visible evidence of crevice formation along cavosurface margin Margin is detectable along less than 50% of cavosurface margin	Alpha-2
No visible evidence of crevice formation along cavosurface margin Margin is detectable along more than 50% of cavosurface margin	Alpha-3
Evidence of crevice formation (penetrable) along less than 50% of the cavosurface margin; greater than 1 mm in depth	Bravo-1
Evidence of crevice formation (penetrable) along greater than 50% of the cavosurface margin; greater than 1 mm in depth	Bravo-2
Restoration is fractured, mobile, or missing in part or whole	Delta
Restoration Fracture	
No evidence of restoration fracture	Alpha
Evidence of restoration fracture confined to less than 50% of the occlusal isthmus width, pieces not mobile	Bravo
Evidence of restoration fracture extending more than 50% of the occlusal isthmus width, pieces not mobile	Charlie
Fracture of restoration with mobile pieces or restoration defect	Delta

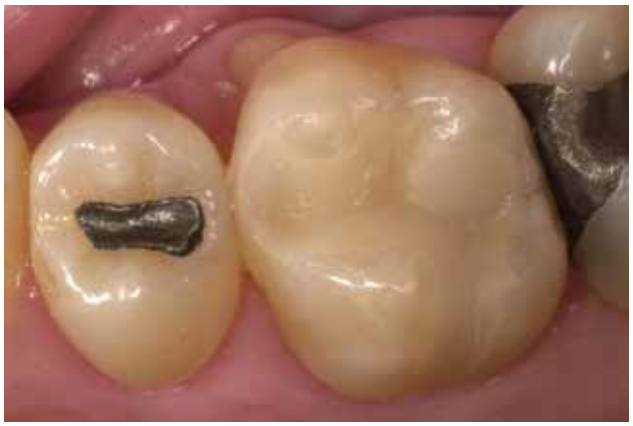


Figure 1: Paradigm MZ100 inlay #3 at baseline delivery.

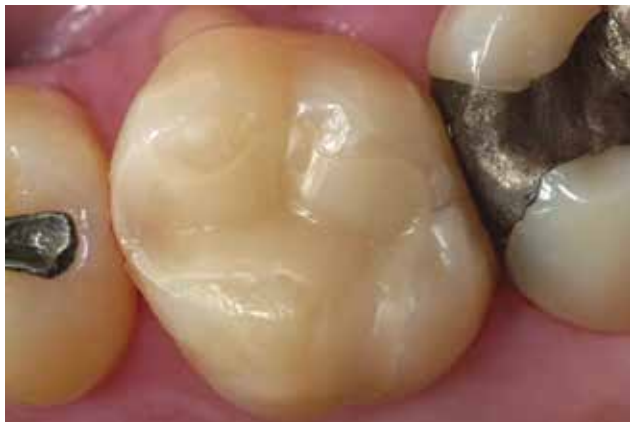


Figure 2: Paradigm MZ100 inlay #3 at the three-year recall.

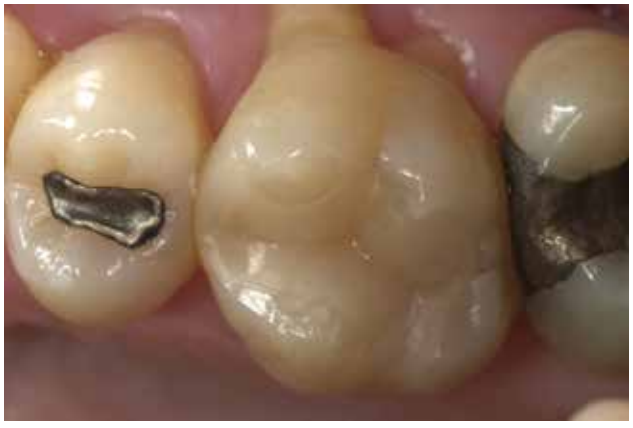


Figure 3: Paradigm MZ100 inlay #3 at the six-year recall.

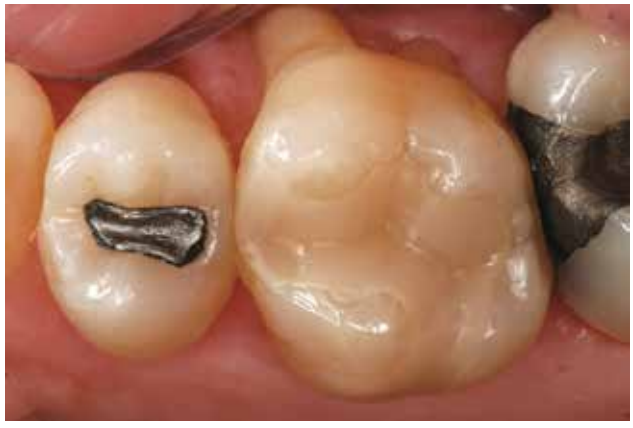


Figure 4: Paradigm MZ100 inlay #3 at the 10-year recall.

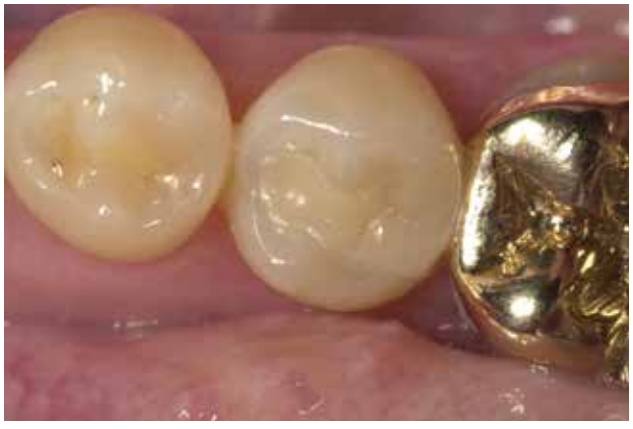


Figure 5: Vita Mark II inlay #20 at the three-year recall.

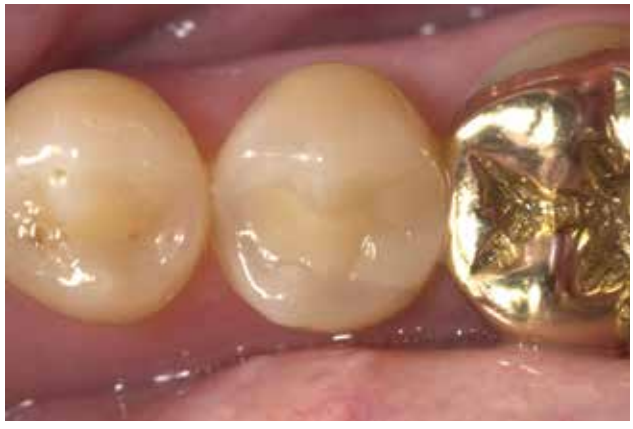


Figure 6: Vita Mark II inlay #20 at the six-year recall.

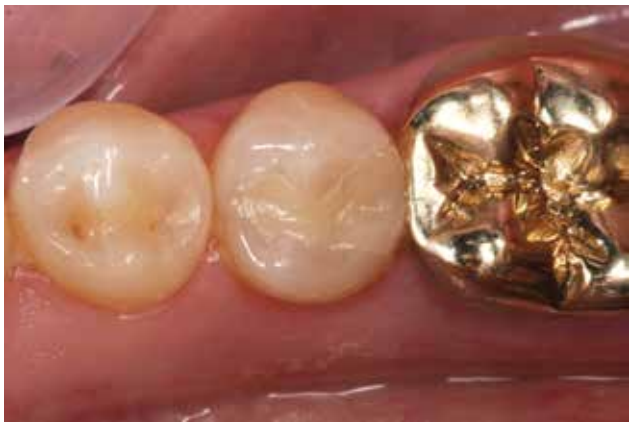


Figure 7: Vita Mark II inlay #20 at the 10-year recall.

Table 2: Number of Restorations by Type.

Baseline	Vita Mark II		Paradigm		
	Bicuspids	Molars	Bicuspids	Molars	Totals
Maxillary	15	7	12	10	44
Mandibular	8	10	8	10	36
Totals	23	17	20	20	80

> "All restored teeth tested vital and were asymptomatic at the beginning of treatment."

Results

A total of 80 inlays were placed in 43 patients, divided between 37 molars and 43 bicuspids. At the 10-year recall, 34 of 40 ceramic inlays and 36 of 40 composite inlays were available for evaluation for an overall recall rate of 88%. **Table 2** shows the number of restorations per arch, tooth type, and location.

Of the 80 inlays cemented with RelyX ARC, one inlay had slight sensitivity at one week. This slight sensitivity was resolved by the second week. There was no additional sensitivity reported in any of the inlays for either material through the 10-year recall.

Clinical Evaluation

The ratings for anatomic form, margin finish, surface finish, and recurrent caries for both groups remained essentially unchanged from baseline to 10 years, with all ratings in excess of 93% alpha **(Table 3)**.

Only one of the composite inlays and five of the porcelain inlays had evidence of restoration fracture by 10 years. Five teeth with composite inlays as well as two teeth with porcelain inlays had tooth or cusp fractures. One porcelain inlay was rated as having a fracture of the isthmus at baseline, probably due to excessive loading during cementation. Another porcelain inlay was rated as having a fracture of the occlusal isthmus at two years. Both inlays have remained asymptomatic and completely bonded through the 10-year recall evaluation. At six months, a porcelain inlay was rated as having a small fracture from the distal marginal ridge. The patient did not report food impaction in the affected proximal contact, so the inlay was maintained in the study. At 10 years, a larger piece of the restoration fractured, necessitating replacement of the porcelain inlay.

One porcelain inlay was fractured at three years and was replaced with a porcelain onlay **(Fig 8)**. One porcelain inlay on a bicuspid fractured at 10 years and was replaced by a ceramic crown. Two additional teeth with porcelain inlays had cuspal fractures, one at seven years and one at eight years, requiring an onlay and crown, respectively. One of the composite inlays on a bicuspid fractured at 10 years and was replaced with an onlay **(Fig 9)**. A second tooth restored with a composite inlay developed symptoms of incomplete tooth fracture at two years and was restored with an onlay. The Survival Analysis Graph illustrates the number of surviving restorations during the 10 years of the study **(Graph 1)**.

Direct evaluation of margin adaptation was conducted. Based upon original USPHS criteria as commonly used in clinical evaluations, the composite inlays had 86.2% alpha scores and porcelain inlays had 70% alpha scores at 10 years **(Figs 10 & 11)**. There was no significant difference in margin adaptation between the two materials at 10 years (Mann-Whitney U test, $p < 0.05$).[8,9] However, both showed a significant decrease in margin adaptation compared to baseline (Wilcoxon signed-rank test, $p < 0.05$).[8,9] In this study, based upon the more discriminating modified criteria, the porcelain inlays were rated 97.5% alpha-1 (undetectable with

Table 3: Percentage of Alpha Scores Paradigm and Vita Mark II Inlays.

Criteria	Baseline		6 months		1 year		2 years		3 years		6 years		10 years	
Inlay Type	P	VM	P	VM	P	VM	P	VM	P	VM	P	VM	P	VM
Inlays Recalled	40	40	37	38	35	37	34	33	37	34	36	32	31	34
Shade Match	100	85	97.3	57.9	97.1	64.9	91.1	57.6	86.5	58.8	86.1	56.2	90	64.7
Margin Discoloration	100	100	100	100	91.4	100	91.2	90.9	83.8	91.2	81.2	81.2	79.3	70.6
Anatomic Form	97.5	100	100	100	100	100	100	100	94.6	100	96.8	100	93.1	100
Margin Finish	97.5	85	83.8	89.5	88.6	94.6	97.1	100	91.9	100	100	100	100	100
Margin Adaptation	100	100	100	100	100	100	100	100	94.6	100	93.7	75	86.2	70
Surface Finish	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Cusp/Tooth Fracture	100	100	100	100	100	100	97.1	100	94.6	100	90.0	100	86.1	92.6
Caries	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Restoration Fracture	100	97.5	100	94.7	100	89.2	100	90.9	100	88.2	100	84.4	97.2	81.5
Sensitivity Now	100	97.5	100	100	100	100	100	100	100	100	100	100	100	100

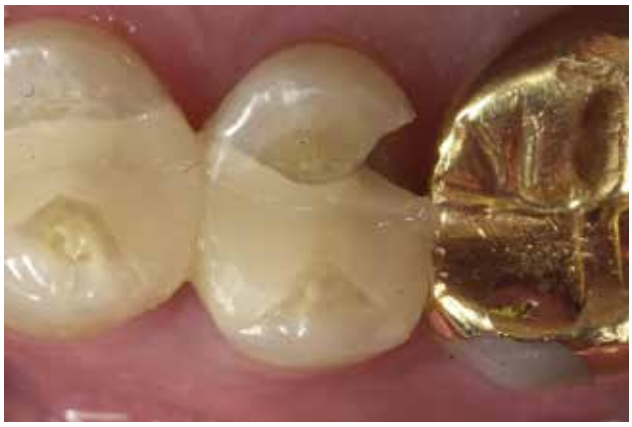


Figure 8: Fractured distal proximal box Vita Mark II inlay at three years.

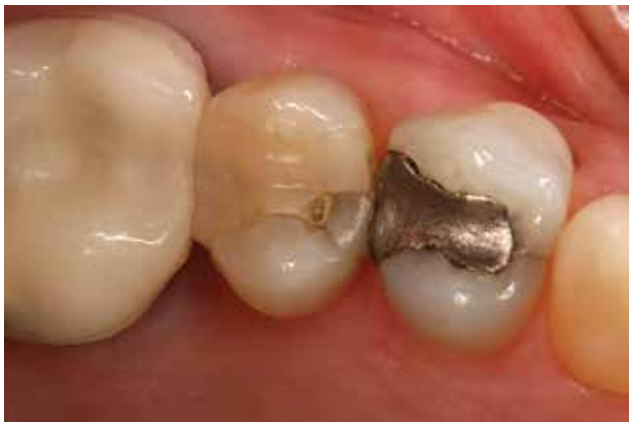
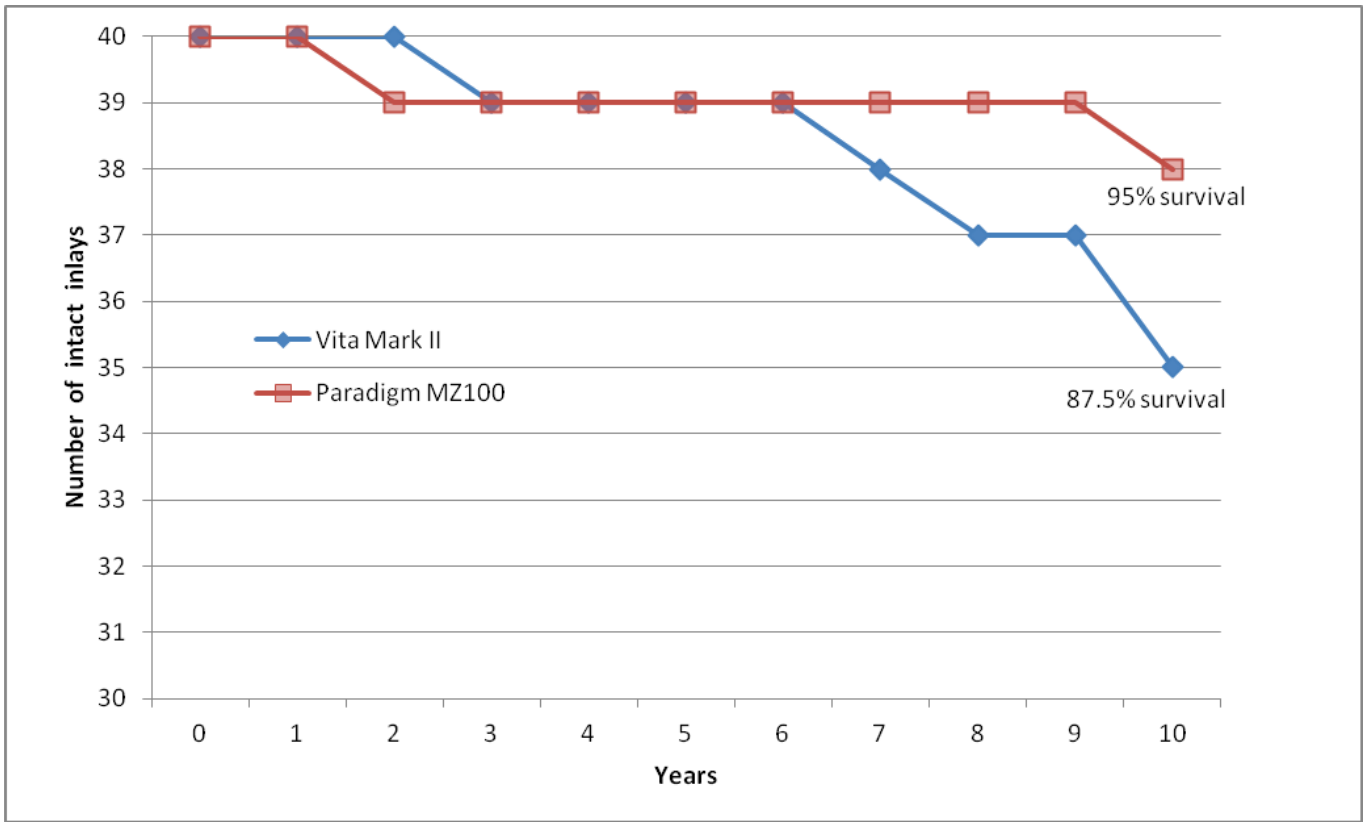


Figure 9: Fractured mesial proximal box Paradigm MZ100 inlay at 10 years.

Graph 1: Survival Analysis Graph Plotting the Number of Intact Inlays at Each Time Interval (Years).



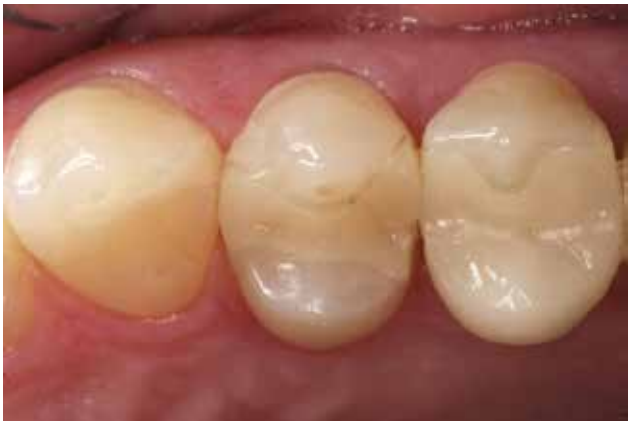


Figure 10: Vita Mark II inlay at 10 years, with evidence of marginal wear.

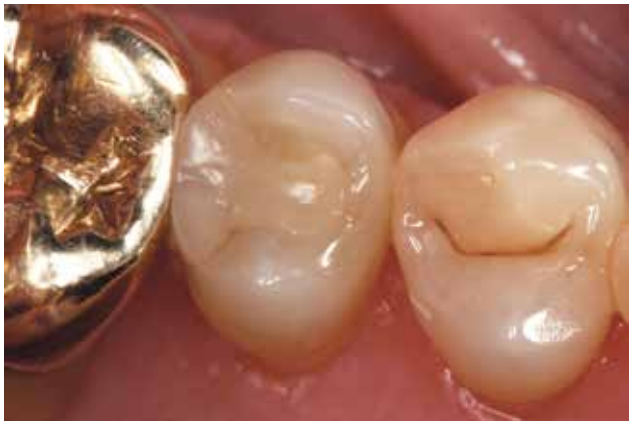


Figure 11: Paradigm MZ100 inlay at 10 years, with evidence of marginal wear.

an explorer) at baseline and 7.5% alpha-1 at 10 years. Composite resin inlays were rated 100% alpha-1 (undetectable with an explorer) at baseline and 20.7% alpha-1 at 10 years **(Table 3)**.

At baseline and six months, 100% of composite resin and porcelain inlays were rated alpha for lack of margin discoloration **(Table 3)**. There was no significant difference in margin discoloration between the two materials at 10 years (Mann-Whitney U test, $p < 0.05$)[8,9] with 79.3% of the composite resin inlays and 70.6% of the porcelain inlays rated alpha. However, both materials showed a significant increase in margin discoloration at 10 years compared to baseline (Wilcoxon signed-rank test, $p < 0.05$).[8,9]

At baseline, 100% of composite resin inlays and 85% of the porcelain inlays were rated alpha for color match **(Table 3)**. The composite resin inlays had a significantly better color match than the porcelain inlays at 10 years (chi-square test, $p < 0.05$).[8,9] The composite resin inlays had no significant difference in color match at any recall period compared to baseline (Wilcoxon signed-rank test, $p < 0.05$).[8,9] The porcelain inlays had a significant decrease in color match at six months compared to baseline; however, there was no significant difference noted between six months and 10 years (Wilcoxon signed-rank test, $p < 0.05$).[8,9]

Discussion

Postoperative sensitivity following adhesive restorative procedures is not uncommon. However, a very low rate of postoperative sensitivity has been reported on chairside CAD/CAM restorations. Sjögren and colleagues reported that 10 of 72 patients had postoperative sensitivity with Vita Mark I or II ceramic inlays.[10] However, Heymann and colleagues reported no postoperative sensitivity at any recall interval in their four-year clinical trial of CEREC ceramic inlays.[11] Fasbinder and colleagues reported that 13% of 92 Vita Mark II onlays were rated slightly sensitive at one week and 4% at two weeks.[12] All sensitivity was resolved within one month, and there was no postoperative sensitivity throughout the remainder of the three-year study.

A similar minimal amount of postoperative sensitivity was discovered in the present study. All sensitivity resolved by two weeks and was not a factor over the 10-year time period. There are several possible reasons for the lack of postoperative sensitivity. The use of rubber dam isolation for control of the operating field for all restorations throughout the preparation, design, and cementation steps ensured a clean, isolated tooth surface for adhesive bonding. The CAD/CAM technique may also play a role in minimizing postoperative sensitivity. The ability to deliver the porcelain and composite resin inlays in a single appointment prevented the potential for tooth contamination during the temporization phase. Immediate dentin sealing, such as is achieved during single-appointment restorations, has been linked to improved bond strength, fewer gap formations, decreased bacterial leakage, and reduced dentin sensitivity.[13] Also, the use of manufactured blocks of porcelain and composite resin minimized the influence of polymerization shrinkage since it was limited to the thickness of the resin cement.

The failure rate of chairside CAD/CAM restorations has been reported to be low. Hickel and Manhart reviewed clinical studies in the dental literature during the 1990s and reported annual failure rates of posterior restorations in stress-bearing areas as 0%-11.8% for composite inlays, 0%-7.5% for ceramic inlays, and 0%-4.4% for CAD/CAM ceramic restorations.[14] Martin and Jedynakiewicz reported a systematic review of clinical studies on intracoronal CEREC restorations[15] and reported a mean survival rate of 97.4% over a four-year period. Wittneben and colleagues reported a systematic review of CAD/CAM single-tooth restorations from 1985-2007.[16] An annual failure rate of 1.75% was reported over a mean exposure time of 7.9 years, resulting in an overall survival rate of 91.6% after five years. The most common failure reported by all the systematic reviews was fracture of the restoration or the tooth.

The results of this study also reflect low failure rates for chairside CAD/CAM inlays, with fracture of the inlay or supporting tooth being the primary reason for failure. Five of the 40 Vita Mark II inlays fractured and two teeth with porcelain inlays fractured over the 10 years of the study. Of note is that only one of the Paradigm inlays chipped or fractured during the study, with the fracture being identified at the 10-year recall. Five teeth fractured during the study that contained composite inlays, requiring the placement of onlays.

The porcelain and composite resin inlays had no significant changes in surface finish and anatomic form, which was consistent with other reported clinical studies.[10,11,17] Gladys and colleagues reported a three-year clinical evaluation on CAD/CAM ceramic inlays and composite inlays (P-50, 3M-ESPE).[18] The surface of 89% of the inlays was rated as smooth, and all restorations were rated clinically acceptable. Thordrup and colleagues reported a 10-year study comparing CEREC porcelain inlays to indirect and direct composite restorations as well as an indirect porcelain inlay.[19] They reported that the indirect composite inlays had a rougher surface texture, which they attributed to the larger filler particle size, compared to the direct composite and porcelain materials. There were localized rough areas on the remaining inlays attributed to wear at functional cusp locations. In the present study, both the Vita Mark II and Paradigm materials have demonstrated superior surface properties that maintained the surface finish and anatomy over time.

Color matching for CEREC restorations may be considered problematic, due to the monochromatic nature of the mill blocks. However, this was

Table 4: Percentage Scores for Margin Adaptation (modified USPHS criteria). Paradigm and Vita Mark II Inlays.

Criteria	Baseline		6 months		1 year		2 years		3 years		6 years		10 years	
Inlay Type	P	VM	P	VM	P	VM	P	VM	P	VM	P	VM	P	VM
Alpha-1	100	97.5	97.3	92.1	91.4	75.7	67.6	72.7	62.1	64.7	40.6	34.3	20.7	7.5
Alpha-2	-	2.5	2.7	7.9	8.6	24.3	32.4	27.3	32.4	35.3	43.7	40.6	58.6	62.5
Alpha-3	-	-	-	-	-	-	-	-	-	-	8.3	21.8	6.45	22.6
Bravo-1	-	-	-	-	-	-	-	-	-	-	6.2	3.1	9.7	7.4

not a significant limitation in achieving an acceptable color match, as evidenced by the baseline alpha scores for color match (100% alpha for the composite inlays, 85% alpha for the porcelain inlays). Tooth color match of the porcelain inlays decreased by the six-month recall, but then remained unchanged at the 10-year recall. The decrease in rating for color match was more a function of the darkening of the tooth color over time rather than a discoloration of the porcelain inlays. Color match was significantly better at 10 years with the composite resin inlays, as they appeared to reflect the surrounding tooth color to a better degree than the porcelain inlays.

These results are consistent with those reported by Sjögren and colleagues for a 10-year prospective evaluation of CAD/CAM porcelain inlays.[5] Mismatch in color increased from 16% at the five-year recall evaluation to 38% at the 10-year evaluation. Molin and Karlsson reported similar findings for a five-year clinical study of Empress (Ivoclar Vivadent), Mirage (Myron's Dental Laboratory; Kansas City, MO), and Vita Mark II inlays.[20] They reported that the mismatch in color increased from 15% at baseline to 50% at five years.

Margin adaptation is often discussed as a critical factor in the longevity of indirect restorations. Deterioration of the margin over time is attributed primarily to the loss of the luting material at the enamel-restoration interface due to functional wear. It has been suggested that, as margin gap size increases, this may lead to degradation of the adhesive bond, resulting in microleakage and recurrent caries. However, the consequences of these potential changes are not adequately documented in the long term. In this study, margins were detectable clinically for both materials as early as six months. There were no significant differences in the margin adaptation between the porcelain and composite resin inlays after 10 years. At the one-year recall, there was a significant difference in the margin adaptation, with the composite resin inlays having a greater percentage of nondetectable margins (91.4%) versus the porcelain inlays (75.7%).

This was consistent with a study by Gladys and colleagues in which they reported no significant difference in margin adaptation between Vita Mark I porcelain and P-50 composite resin inlays after three years, but noted margin detection at as early as six months.[18] The P-50 material had the best inlay-luting agent margin interface at three years. Pallesen and Qvist also reported an equivalent wear of the resin cement and the resin inlays over 11 years.[21] Composite resin fillings and inlays were evaluated with modified USPHS criteria that did not distinguish any significant margin wear. However, examination of the stone dies made at each recall interval revealed wear of the resin luting agent along the enamel occlusal margins in more than half of the models. This finding illustrates the inherent problem of detecting measurable amounts of margin wear during a clinical examination.

In this study, the modified USPHS criteria were refined to try and detect subtler margin changes **(Table 4)**. The modified criteria distinguished between margins that were nondetectable and those detectable in less than or greater than 50% of the occlusal margin. Evaluation of the alpha-1 (nondetectable) and alpha-2 (detectable at less than 50% of the margin) scores revealed a significant increase in margin detection for the porcelain inlays at the one-year recall and for the composite inlays at the two-year recall. By the three-year recall, there was no significant difference in margin detection between the composite and porcelain inlays. It seems logical that, early in the clinical life of the composite resin inlay, the inlay has a similar wear rate to the composite resin-luting agent, thus masking the initial wear of the inlay margin. It is not until sufficient wear at the margin occurs, exposing the enamel margin, that it can be detected similarly to that of the porcelain. Despite the detected margin wear, there was no secondary caries noted for either material over the 10 years. This would indicate that the margin wear is an occlusal surface phenomenon and was not accompanied by a breakdown in the adhesive bond to the tooth.

Conclusion

CAD/CAM-generated adhesive inlays performed well clinically, according to modified USPHS criteria after 10 years. Postoperative sensitivity was not a significant finding from baseline to 10 years for either Paradigm or Vita Mark II inlays when using a total etch process with dual-cured resin cement.

Initial color match for both materials was rated as very good and was maintained better by the composite resin inlays at 10 years ($p < 0.05$). Tooth color match of the porcelain inlays decreased by the six-month recall, but then remained unchanged at the 10-year recall ($p < 0.05$).

Margin adaptation was initially very good for both materials, with an increase in margin discontinuity due to apparent wear of the composite resin-luting agent.

In summary, the composite resin inlays performed equally as well as the porcelain inlays in all categories in a 10-year longitudinal, randomized clinical trial, with clinical advantages noted in fracture resistance and better color match to the tooth.

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(CE) Exercise No. jCD10

Dental Materials (Basic Science) AGD: Subject Code: 017

The 10 multiple-choice questions for this Continuing Education (CE) self-instruction exam are based on the article, "Clinical Performance of CAD/CAM-Generated Composite Inlays after 10 Years," by Drs. Dennis Fasbinder, Gisele Neiva, Joseph Dennison, and Donald Heys. This article appears on pages 134-145.

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1. In comparing the treatment of Paradigm composite material and Vita Mark II porcelain material just prior to cementation, only the Paradigm material would be treated by

a. trial-seating the inlay into the prepared tooth with water.
b. etching the internal surface for 30 seconds with hydrofluoric acid.
c. application of a pre-hydrolyzed silane coupling agent.
d. air-abrading the internal surfaces with 50 µm aluminum oxide.

2. In comparing the treatment of Paradigm composite material and Vita Mark II porcelain material just prior to cementation, only Vita Mark II material would be treated by

a. trial-seating the inlay into the prepared tooth using water.
b. etching the internal surface for 30 seconds with 9.5% hydrofluoric acid.
c. applying a layer of Single Bond to the internal surface.
d. air-thinning and curing the silane coupling agent for 20 seconds.

3. Bonding of the Paradigm composite material and Vita Mark II porcelain material into the tooth was different in that the Paradigm material requires

a. the cavity preparations to be etched for 30 seconds with 37% phosphoric acid and then rinsed for 20 seconds.
b. the tooth to be lightly dried with high-volume evacuation, and pooled water to be blotted dry with cotton.
c. nothing different, as the tooth was treated the same for both types of materials.
d. Single Bond to be applied to all prepared tooth surfaces prior to seating the restoration, air-thinned, and cured for 10 seconds.

4. The overall clinical performance of the two materials (Paradigm composite material and Vita Mark II porcelain material) demonstrated that

a. postoperative sensitivity was significantly greater for the Paradigm composite material.
b. color match was better for the Vita Mark II porcelain materials.
c. clinical advantages favored the Paradigm composite material for fracture resistance and color match.
d. fracture resistance was better for Vita Mark II porcelain materials.

5. Regarding margin adaptation between the two materials (Paradigm composite material and Vita Mark II porcelain material), at a 10-year reevaluation the following was noted:

a. There was no significant difference in margin adaptation between the two materials.
b. Only the Paradigm composite material showed a significant decrease in margin adaptation compared to baseline.
c. Only the Vita Mark II porcelain material showed a significant decrease in margin adaptation compared to baseline.
d. Based upon the more discriminating modified criteria, both materials were rated 97.5% alpha-1 (undetectable with an explorer) at reevaluation.

To see and take the complete exam, log onto www.aacd.com.

Standing Out in the Marketplace

Top Product Awards

Sabiha S. Bunek, DDS

Editor's Note: The information contained in this article does not imply endorsement from *jCD* or the AACD.

Introduction

Each year *The Dental Advisor* presents product awards to recognize quality products and equipment, taking into account clinical and evidence-based research to honor the best. To be considered for an award, products must receive an "excellent" rating by *The Dental Advisor*, as well as stand out from all others in the marketplace. With hundreds of products to review each year, our task to choose the winners is not easy. Our editorial board spends weeks debating, discussing, and voting on products that fit our criteria for innovation, quality and excellence in each category. In the end, only one product in each category is chosen for the Top Product Award, and the runner-up receives the Preferred Product Award. Congratulations to the winners, and many thanks to our editorial board and our 250 clinical consultants in the United States.

This issue of *jCD* focuses on dental materials and research. This column therefore will highlight a few products that have furthered our profession in the past year.

Featured Award Winners

Top Innovative Cement: Ceramir

What makes this cement unique? In the research world, there is a lot of buzz about Ceramir. This cement has properties that are very similar to dentin; and it encourages the buildup of nanocrystals and hydroxyapatite to integrate with the dentin and enamel. The Ceramir technology is natural and biocompatible, and not irritating to the pulp.

Product Reviews from *The Dental Advisor*

Ceramir Crown & Bridge ++++1/2 (Doxa Dental)

Ceramir Crown & Bridge is a permanent, radiopaque, bioceramic luting cement supplied in capsules. It is indicated for conventional cementation of metal, lithium disilicate-, alumina- and zirconia-based restorations. The cement is designed to be biocompatible and to resist acid and acid-producing bacteria. It requires no etching, priming, bonding, or conditioning.

Fifteen percent of consultants reported that Ceramir Crown & Bridge was better than their current crown and bridge cement and 60% reported that it was equivalent. Sixty percent would switch to Ceramir Crown & Bridge and 85% would recommend it. Ceramir Crown & Bridge was evaluated by 20 consultants in 314 uses. It received a 92% clinical rating.

Top Innovative Product: Ivoclean

What makes it unique? Contamination of indirect restorations with saliva or blood during try in is a common occurrence. Ivoclean was developed specifically to clean restorations before cementation. Contaminants such as blood and saliva can be completely removed. Colored indicator pastes or sprays, which tend to stain etched ceramic surfaces, also come off cleanly. Testing at *The Dental Advisor* Biomaterials Research Center confirmed that the use of Ivoclean was effective in maintaining or improving the bond strength of resin cement to zirconia and lithium disilicate after contamination of these surfaces with saliva.

Ivoclean ++++1/2 (Ivoclar Vivadent)

Ivoclean is a universal cleaning paste indicated for cleaning of prosthetic restoration surfaces that have been contaminated during intraoral try in. Ivoclean contains sodium hydroxide and is for extraoral use only. It is compatible with all dental restorative materials, including glass ceramics, zirconium oxide ceramics, aluminum oxide ceramics, precious metal alloys, base metal alloys, and lab-fabricated composite restorations.

Seventy-four percent of consultants found Ivoclean to be better than other methods of cleaning restorations after try in, while 22% found it to be equivalent. Eighty-two percent would switch to Ivoclean and 89% would recommend it to a colleague. Ivoclean was evaluated by 24 consultants in 484 uses. It received a 91% clinical rating.

Top Pulpal Protection: TheraCal LC

What makes it unique? TheraCal LC is provided in a simple syringe delivery unlike other products on the market. The material integrates well into the clinical procedure, handling much like a flowable composite. Consultants who evaluated the product were optimistic about the potential regenerative properties of TheraCal LC and found the short-term lack of sensitivity to be excellent. All consultants who evaluated TheraCal LC were currently using a traditional calcium hydroxide paste or glass ionomer liner.

The Dental Advisor is currently tracking long-term results of this material. Look for the results of this study later this year.

TheraCal LC +++++ (Bisco)

TheraCal LC is a light-cured, resin-modified calcium silicate material that performs as a barrier and protectant to the dental pulpal complex. It is indicated for direct and indirect pulp capping and as a protective base/liner under restorative materials including composite, amalgam, and cements. The formulation consists of tricalcium silicate particles in a hydrophilic monomer that stimulates hydroxyapatite and secondary dentin bridge formation through calcium release and an alkaline pH.

Ninety percent of consultants rated TheraCal LC as better than their current pulp capping and base/liner material and 5% rated it equivalent. Ninety percent would switch to TheraCal LC and 100% would recommend it to a colleague. TheraCal LC was evaluated by 20 consultants in 438 uses. It received a 96% clinical rating.

Scotchbond Universal Adhesive +++++
(3M ESPE)

Scotchbond Universal Adhesive is a single-component, light-curing adhesive that can be used in self-etch or total-etch procedures. It also contains MDP and silane, which allow it to prime metal, silica-based ceramic, and zirconia restorations. Addition of the optional dual-cure activator allows it to be used with dual- or self-cured composite materials and cements. Scotchbond Universal Adhesive is ethanol- and water-based and bonds to moist or dry tooth surfaces. It is indicated for use in all direct and indirect bonding procedures, including composite fillings; core buildups; and cementation of crowns, bridges, inlays, onlays, and veneers.

Fifty-eight percent of consultants reported that Scotchbond Universal Adhesive was better than their current adhesive, and 39% reported it was equivalent. Eighty-four percent would switch to Scotchbond Universal Adhesive, and 94% would recommend it. Scotchbond Universal Adhesive was evaluated by 31 consultants in 1500 uses. It received a 98% clinical rating.

Top Bonding Agent: Universal
What makes this adhesive unique? Scotchbond Universal Adhesive is an outstanding adhesive, offering more versatility than consultants have seen in other products. It can be used in total-etch or self-etch techniques. It has the ability to prime all substrates, including metal, silica-based ceramics, and zirconia. In addition, it can even be used with a dual- or self-cured composite and cements. It simplifies many procedures and reduces inventory. Having one product for self-etch and total-etch applications was significant for many consultants. Being able to bond to moist or dry teeth reduces the technique sensitivity that exists with many adhesives.

BeautiSealant ++++1/2 (Shofu Dental Corp.)

BeautiSealant is a fluoride-recharging pit and fissure sealant. It is BPA- and HEMA-free and incorporates Giomer technology. BeautiSealant is indicated for the preventive sealing of pits and fissures in the primary and secondary dentition. A self-etching primer is provided and eliminates the need for phosphoric acid etchant. The primer contains acidic monomers in an acetone/water solvent.

Seventy-four percent of consultants rated this product as better than other pit-and-fissure sealants they had used and 26% rated it equivalent. Ninety percent would switch to BeautiSealant and 84% would recommend it. BeautiSealant was evaluated by 19 consultants in more than 400 uses. It received a 94% clinical rating.

Top Pit and Fissure Sealant: BeautiSealant
Why is it unique? BeautiSealant utilizes a self-etching primer in place of phosphoric acid etch. By eliminating the etch and rinsing steps, clinicians can place sealants in less time, decreasing the chance of saliva contamination, thereby increasing the chances of retention.
A long-term study is underway, tracking retention over time. Look for results in a future issue of *The Dental Advisor.*

Top Anesthetic Accessory: OraVerse
Why is it unique? OraVerse is the first and only local anesthesia reversal agent. Not only is it helpful for the clinician, but it also was well received by patients and is a great marketing tool for a practice. Most of the patients responded that numbness wore off quickly (within an hour) and they tolerated OraVerse well.

OraVerse ++++1/2
(Septodont, Inc.)

OraVerse is a local anesthesia reversal agent that accelerates the return to normal sensation and function for patients after routine dental procedures. It is a formulation of phentolamine mesylate and is recommended for adults and children age six and older and weighing 33 lbs or more. OraVerse is administered by injection with a standard dental syringe in the same injection site as that used for the local anesthetic. OraVerse is used in a 1:1 ratio to local anesthetic.

OraVerse was used by 16 consultants in 128 cases. Seventy-five patients responded to surveys. Seventy-five percent of consultants would continue to use OraVerse in their practice and 94% would recommend it. OraVerse received a 93% clinical rating.

Summary

Unique to *The Dental Advisor*, our group considers a combination of clinical evaluation, long-term clinical data, and comprehensive laboratory testing and pulls it all together in an easy-to-understand format. To view the full list of top products and preferred products, please visit www.dentaladvisor.com and click on the icon on the homepage.

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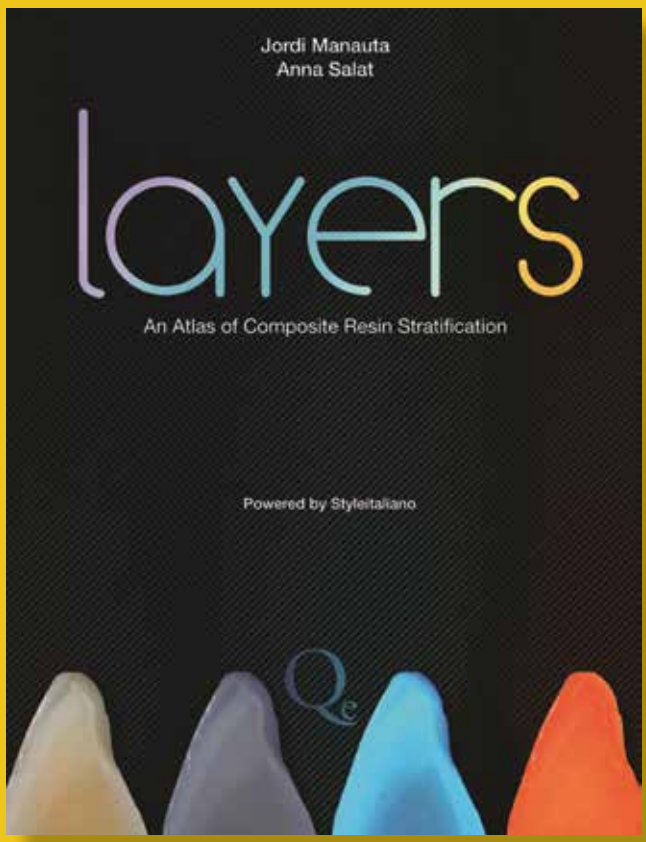
jCD Book Review

The *Journal of Cosmetic Dentistry's* Book Review is an opinion piece highlighting works that are currently available from publishers in the dental industry.

Title: *Layers: An Atlas of Composite Resin Stratification*
Authors: Dr. Jordi Manauta & Dr. Anna Salat
Publisher: Quintessence Publishing



Layers provides a detailed analysis of the layering system of composite resins. The text contains hundreds of step-by-step color photographs of the layering process needed to create lifelike polychromatic restorations. The subjects of color, and finishing and polishing a restoration are well documented. The book also describes how a restoration is layered with the correct composite from the very inner aspect to the outermost aspect. Posterior restorations, anatomy, and occlusion are detailed. Care is taken to show how to create surface characterizations as well as how to create realistic pathology. *Layers* should be read in its entirety, from cover to cover, to fully appreciate the concepts within. For example, the second chapter seemed a little confusing at first, but after reading the next two chapters, the information all made sense.

It would help if more clinical cases had been illustrated; it would have been nice to see concepts applied in a step-by-step clinical series of photographs. Some of the material is not very applicable to the everyday dentist. For example, the chapter on "Pathologic Phenomena" is interesting, but why would someone want to deliberately make a tooth look unesthetic? A point of disagreement with the authors is their claim that hybrid composite can polish better and hold its polish better than nanofills and microfills. It would have made more sense to simply say that with their technique, an extremely high polish can be obtained using any composite material (as evidenced by the photos in the book).

The question-and-answer section at the beginning of each chapter by world-renowned opinion leaders on the subject of composite resins is great. The photography and illustrations throughout are beautiful. Two excellent and informative chapters are those on "Color" and "Surface and Polishing." The custom shade guides detailed should prove to be very useful. The book is heavily influenced by the teaching, techniques, and materials derived from Dr. Didier Dietschi and Dr. Lorenzo Vanini. For dentists who use their systems and techniques (or would like to), *Layers* is a must-have resource!

A Special Gift to *jCD* Readers:

Take advantage of a special offer from Quintessence Publishing! As an AACD member, you can receive a 33-page preview of *Layers* and the chance to purchase the book for 25% off the regular price, a savings of more than $50! Simply enter promo code JCD2013 at checkout. To take advantage of this discount, visit: http://www.quintpub.com/jcd/

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Developed 15 years ago by dentists and MicroDental, Macstudio restorations are the leading choice for dentists who are committed to life-changing dentistry. Michael's story began with a comprehensive exam where Dr. Ebrahimian discovered a forward head posture, retrognathic jaw, deep overbite, and fractures. Dr. Ebrahimian consulted with Macstudio technicians and together they developed a full mouth case plan. By using a collaborative approach to smile design and modern cosmetic restorative techniques, the Macstudio team and Dr. Ebrahimian were able to restore the patient's desired aesthetic smile line. Upon his 7 month evaluation, Michael reported no symptoms and findings were within normal limits. Michael is very pleased with his new smile and comfortable bite.

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