In the 1964 version of this review, the late Dr Ralph Phillips wrote, “As the vistas of research extend forward and as the skills and technology involved in scientific investigation become more and more elegant, the task of keeping abreast of the increasing volume of literature is becoming one of heroic proportions.” Dr Phillips went on to explain that while the task of merely identifying pertinent scientific research was monumental, the process of evaluating that research and then synthesizing that information so that it might be useful for restorative dentists is even more daunting.

Identifying, evaluating, and synthesizing the dental scientific literature was clearly a difficult process in 1964. Fifty years later, those same tasks are almost insurmountable. Modern technology may have made identifying scientific research in various disciplines somewhat easier, but the problems of evaluating the quality of the science and its clinical relevance continues to be an enormous challenge.

This review is intended to assist practicing dentists in their efforts to keep abreast of new scientific findings and to practice evidence-based dentistry. Many dentists continue to make heroic efforts to practice evidence-based dentistry, and these efforts are a tribute to their passion and commitment to providing optimum dental care for their patients. This is in contrast to the current trend for widespread commercialization of the dental profession.

This review is conducted to keep the busy dentist abreast of the latest scientific information regarding the clinical practice of dentistry. Each of the authors, who are considered experts in their disciplines, was asked to peruse the scientific literature in their discipline published in 2013 and review the articles for important information that may affect treatment decisions. Comments on experimental methodology, statistical evaluation, and overall validity of the conclusions are included with many of the reviews. The reviews are not meant to be stand alone but are merely intended to inform the interested reader about what has been discovered in the past year. The readers are then invited to go to the source.

The analysis of the scientific literature published in 2013 is divided into 7 sections: cariology, periodontics, dental materials, occlusion and temporo-mandibular disorders (TMD), sleep-disordered breathing, prosthodontics, and implant dentistry.

DENTAL CARIES AND CARIOLOGY

In the past 10 to 15 years, written reports on dental caries have increased exponentially. This is because, in addition to a more traditional approach to the disease, biomolecular scientists have added to the better understanding of the complexity of this polymicrobial disease by using genetic research and
all the new microbiologic disciplines grouped under the term “-omics,” including genomics, proteomics, metagenomics, and metabolomics, as well as other new, emerging disciplines. The year 2013 followed previous trends, and many articles were published on dental caries, both on a purely biomolecular level and from a more clinically oriented point of view.

Published articles can be classified into 4 basic categories: (1) biofilm and biomolecular/genetic studies aiming to understand the disease better and to find possible new therapeutic strategies, including selective targeting and vaccines; (2) demographic/epidemiologic studies evaluating the distribution of caries among the population and the association between caries and other diseases; (3) articles on prevention, not only with the most commonly used fluoride, chlorhexidine (CHX) derivatives, and xylitol but also with probiotics, alternative medicine using plant extracts, and new restorative materials with antibiofilm properties; and (4) discussed treatment strategies, including remineralization processes and incomplete caries removal.

Biofilm and biomolecular/genetic studies

Ultimately, dental professionals deal with patients needing preventing strategies and treatment for dental caries. However, most of the new knowledge on dental caries has not come from dentists. Furthermore, most dentists do not have the appropriate professional background to fully comprehend the research by molecular scientists because so much has changed since traditional caries principles were taught in dental schools a few decades ago. The contemporary theories about caries and the numerous biomolecular and genetic tools currently available to study oral biofilms and the mechanisms behind biofilm formation are elegantly described in 2 reviews published in 2013. These articles are extremely useful in assisting dental professionals without a background in molecular biology to fully understand the actual progress of biomolecular research on dental caries. By reading these 2 articles, dentists can fully comprehend how biofilms form in the oral cavity, as well as the advantages, disadvantages, and potential of both traditional and new approaches to the study of oral pathogens.

The oral cavity, like other sites in the human body, is colonized by a variety of microbiota such as bacteria, which play the biggest role in quantity and diversity, as well as yeasts, mycoplasmas, archaea, and protozoa. These microbiota generally live in a natural balance called microbial homeostasis in harmonious relationship with the host. Several factors can alter this equilibrium, including altered salivary flow rates, medications, and alimentary habits. A genetic predisposition to dental caries has also been demonstrated within family members. Thus, dental caries is still the most common disease that affects humans, and it is also the most common childhood illness. Among this wide spectrum of microbiota, certain bacterial species, including Streptococcus mutans, live on the tooth surface and produce acids upon fermentation of dietary carbohydrates. Constant acid production ultimately drops the pH below the critical threshold of 5.5 and activates a shift in the enamel demineralization/remineralization equilibrium toward demineralization. This decrease in pH also promotes the growth of acid-tolerant and acid-generating species, which accelerate the demineralization process and the subsequent caries development.

This apparently simple process is actually the result of a complex interaction between the oral environment and oral pathogens. Microbiota need to adhere to the tooth surface to initiate a carious process, and to do this, they group in biofilms. Biofilms are organized communities of densely packed interactive microbial cells. All areas of the oral cavity are covered by the acquired pellicle, a layer of adsorbed molecules of bacterial and salivary origin. Pioneer species, like S mutans, attach to this thin film of molecules through a weak physicochemical interaction between charged molecules on the cell and the oral surfaces. This interaction becomes stable through strong chemical connections between adhesions on the bacterium and specific receptors in the acquired pellicle. These initial colonizers are mainly streptococci, and as they mature, they alter the environment and determine conditions favorable for colonization by more microorganisms. Secondary colonizers bond to receptors on these already attached bacteria (coadhesion), and progressively, the heterogeneity of the biofilm increases to form a multispecies population. The attached microorganisms synthesize a variety of extracellular polymers to organize a biofilm scaffold called the exopolysaccharide matrix that can retain and bind many molecules, including enzymes. Therefore, it is not only a supporting structure but a biologically active assembly. A critical review by Koo et al emphasized how glucosyltransferases produced by S mutans and responsible for producing the exopolysaccharide matrix are incorporated into the tooth pellicle and adsorbed by other bacteria, producing exopolysaccharide matrix in situ themselves. The bacteria act both in synergy and in competition among themselves. They combine their aggressive potential to metabolize complex host macromolecules, developing food chains where the metabolic by-product of one organism turns out to be a key nutrient for a different microbe. The gene expression between members of the same biofilm adapts according to the need of the community and no longer of the single bacterium. Simple peptides are used for signal modulation between gram-positive bacteria, while autoinducer 2 is used by most of the gram-negative species. Therefore, as these oral biofilms grow and consolidate, they acquire biologic properties that are greater than the sum of the individual species; this increases their resistance to both host defenses and antimicrobial
agents. For this reason, even if caries had been considered for years to be caused by the single pathogen, *S. mutans*, first described by Clarke in 1924, in some sort of association with lactobacilli, today it has a universally accepted polymicrobial etiology. This does not diminish the fundamental role that *S. mutans* plays in the etiology of dental caries. Bacteria living in a petri dish have no relation to what happens in nature. In fact, organisms living in petri dishes turn off a section of their genoma so that they can live in that environment. However, when bacteria live in a biofilm, they turn off that section of their genoma and turn on another section of their genoma so that they can live and prosper in a multibacterial environment.

The shift of research from studying free-floating microorganism in an aqueous environment to focusing on the complexity of biofilms has been a major advancement in understanding the etiology of dental caries. Bacteria living in a petri dish have no relation to what happens in nature. In fact, organisms living in petri dishes turn off a section of their genoma so that they can live in that environment. However, when bacteria live in a biofilm, they turn off that section of their genoma and turn on another section of their genoma so that they can live and prosper in a multibacterial environment. Moreover, although microbial culturing has provided considerable knowledge on the microorganisms associated with dental caries over the years, this technique is limited to few species, and many oral pathogens cannot be cultivated in laboratories. For these reasons, a new approach based on biomolecular techniques has developed in the last decade. Most of the laboratory analysis has focused on the identification of microorganisms based on the sequence analysis of the 16S ribosomal RNA genes that can be examined after nucleic acid extraction from bacterial samples. The 16S rRNA gene is a subunit of the ribosomal RNA used for phylogenetic studies, as it is highly conserved between different species of bacteria and archaea. It also contains hypervariable regions that can provide species-specific signature sequences useful for bacterial identification. This approach allowed the identification of approximately 600 predominant oral bacterial species. Expression and identification of 16S rRNA is performed by using polymerase chain reaction (PCR) followed by gel electrophoresis, real-time quantitative PCR (RT-qPCR), microarrays, RNA sequencing (RNA-seq), next-generation sequencing (NGS), metabolomics, and proteomics. By using semiquantitative PCR associated with gel electrophoresis, a preliminary qualitative screening of biofilm diversity can be obtained. Different types of bacteria are identified without quantification of how many bacteria of the different species are present. On the contrary, more accurate and quantitative screening can be achieved with RT-qPCR. Using RT-qPCR, Park et al were able to develop primers designed to selectively identify 42 different bacterial species that can play a fundamental role in epidemiologic studies among the most common pathogens in caries, endodontic lesions, and periodontal disease. 16S rRNA gene microarrays is a new high-throughput screening methodology able to characterize wide microbial communities because up to 300 species can be identified with the same chip during the same analysis. All these techniques can identify known bacterial species, and sequencing analysis with the traditional Sanger method, RNASeq technique, or NGS approach can identify new species. A molecular biologic study repeated with RNASeq the analysis on *S. mutans* transcriptome and identified the set of genes of the DNA that are actually transcribed—information that was previously provided with a microarray technique. Data from the previous study were confirmed; however, with this newly applied methodology, it was also possible to identify additional genes and transcripts that were differentially regulated in *S. mutans* in response to carbohydrate source or loss of the catabolite control protein A (CcpA). CcpA is the protein responsible for turning off nonessential catabolic functions while activating the pathways required for the utilization of preferred carbohydrates and other carbon sources. This proves once more that biofilms change their genetic expression in relation to the environment in which they live.

Selective targeting and vaccine

Because the process of biofilm formation is so complex, many different research groups around the world are trying to develop selective molecules that can interfere with this process and stop dental caries. Ding et al performed an in vitro experimental study on a small peptide, Bac8c, which is selectively active against *S. mutans*. Bac8c’s activity against biofilm formation was tested at different concentration levels, as was its cytotoxicity on human fibroblasts, as a first step for future tests on humans. The peculiarity of this in vitro study is that the experiment was performed not in a...
experimental studies were done on rats on the tooth surface. However, both produce the accumulation of Smu t a n s, some actinomyces, and a few lactobacilli. From RT-qPCR analysis, it was determined that biofilm accumulation was inhibited by the down-regulation of genes involved in biofilm formation. More specifically, those genes involved in the production of glucans, the molecules necessary for biofilm initial adhesion, were down-regulated by this peptide, and biofilm was inhibited. Moreover, via a still-unexplained mechanism, Bac8c also directly kills Smu t a n s, thus inhibiting biofilm formation. At a concentration of 128 μg/μL in 15 minutes, Bac8c killed all the Smu t a n s. Therefore, this small, inexpensive, and easy-to-produce peptide shows promising antimicrobial activity that needs to be investigated further. Similarly, Li et al27 developed a small antimicrobial peptide (D-Nal-Pac-S25) of just 9 amino acids that was able to inhibit biofilm formation of Smu t a n s in vitro by binding to the external membrane and provoking cellular lysis. Although these in vitro analyses have to be proven effective in vivo, they confirm that selective targeting is the research approach most likely to lead to effective complete caries inhibition in the near future, something once expected from an anticaries vaccine.

A few experimental studies28,29 and reviews30,31 have also been published on vaccines against caries. More specifically, multiple antigens of Smu t a n s have been considered as vaccine candidates, but all of them aim to inhibit the initial adhesion of Smu t a n s to the acquired pellicle. Both these studies were successful in producing specific antibodies able to stop or reduce the accumulation of Smu t a n s on the tooth surface. However, both experimental studies were done on rats and are still far from being used on humans.

Epidemiologic studies

Caries is still the most common human disease both in adults and children,10,11 and many articles on the epidemiology of this disease have been published. A neat distinction is made in the epidemiologic studies of caries in children, known as early childhood caries, and adults. Different geographic areas around the world have reported different incidences of early childhood caries in toddlers from Anatolia (17%), Brazil (26.8%), Australia (40%), Lithuania (50.6%), and Puerto Rico (62.6%).32 Sometimes extreme variability of early childhood caries exists even within the same geographic area: 18.1%, 33%, and 78.1% were the percentages reported from 3 different cities in Turkey. This can be explained by the fact that demographic, socioeconomic, and behavioral factors may strongly influence tooth decay. People with higher educational status experience comparatively more dental caries on molar surfaces and comparatively less dental caries on nonmolar surfaces than individuals with lower educational status, probably as a result of socioeconomic status and consequent dietary habits.33 As expected, toothbrushing frequency was also inversely correlated with caries frequency,34 and school programs for the diffusion of proper oral hygiene methodologies have proven highly effective in reducing caries in Scottish children.35 The relation between obesity and dental caries has been also investigated. In Chinese children, no correlation was found between being overweight or obese and having dental caries; surprisingly, consuming sugary drinks did not have a statistical effect on the incidence of caries. The parents’ oral status36 and mouth breathing were the only 2 direct correlations found with caries prevalence.37 These findings are in agreement with those of others.38-40 A systematic review on caries and obesity7 also found no correlation in the primary dentition but revealed a small overall association between obesity and level of caries in the permanent dentition. However, when analyzing the data by geographic and socioeconomic areas, industrialized countries, with their increased sugar consumption, demonstrated more caries development, while less industrialized countries, like China in the previous study, showed a lower incidence of tooth decay.37 These data are difficult to interpret because on the one hand, the higher the level of education, the higher the level of oral hygiene; but on the other hand, the higher the level of education, the higher the socioeconomic status and consequently the higher the consumption of sugary drinks and high-sugar-content foods in general. Therefore, it seems reasonable to conclude from all the epidemiologic studies that in highly developed, highly educated areas with a high socioeconomic status, the caries rate will drop.41,42 However, populations living in highly developed areas but with a lower socioeconomic status (for example, some ethnic minorities) have a high incidence of caries because they have access to foods and drinks with a high sugar content but little awareness of the risk of caries.43 In very poor countries where sugar consumption is limited, it is possible to find areas where the caries rate is low and areas where the caries rate is very high even if the socioeconomic status is poor.44,45 Finally, in a retrospective study, Baumgartner et al46 found that the incidence of proximal caries was lower in a young Swiss population undergoing fixed orthodontic treatment than in a control group that did not receive orthodontic treatment. This proves that orthodontic treatment per se does not increase the caries rate, as is often thought. Even if brackets favor plaque accumulation, the increased risk of tooth decay is somewhat compensated by the increased salivary flow and consequently the increased buffer capacity of saliva and by the increased level of oral hygiene and awareness of motivated patients and their families.
Prevention

Research into the prevention of dental caries, fluoride, CHX, sealants, probiotics, xylitol, and new restorative materials with antibacterial properties followed the lines of previous research without adding new knowledge of interest to clinicians. However, one article of great benefit to clinicians was published by the Council on Scientific Affairs of the American Dental Association. This article updated the criteria for using topical fluoride to prevent caries and gave specific recommendations based on the available scientific evidence as well as the opinions of experts in this field.47

Fluoride is still the most commonly used method for the prevention of dental caries and has proven effective in the form of varnishes,48 gels,49 mouth rinses,50 and toothpastes with high fluoride concentration51; low-fluoride-concentration toothpastes, shown to be effective in some investigations,52 have proven to be ineffective in other studies.53,54 The effectiveness of fluoride varnishes on both permanent and primary teeth was confirmed by a systematic review,55 although the quality of the evidence was assessed as moderate because it included mainly studies with a high risk of bias, with considerable heterogeneity. An original retrospective analysis by Dholam et al56 also found fluoride varnishes to be very effective in controlling caries rate and tooth sensitivity in patients with irradiated head and neck cancer.

CHX is still widely used as an antimicrobial agent. In a comparative study on a population of 7- to 8-year-olds, a commercially available chlorhexidine varnish (CHX-V) was found to be effective in reducing the S mutans score during a 3-month period, while a varnish did not show a significant antimicrobial effect.57 On the contrary, in a placebo-controlled, double-blind, randomized clinical trial on mother-child pairs enrolled when the child was 4.5 to 6.0 months old, Robertson et al58 reported that CHX-V was not effective in reducing the number of new carious surfaces at 12, 18, and 24 months of age but did significantly reduce the number of severe carious lesions. In addition, a systematic review concluded that CHX-V was effective in preventing root caries for patients requiring special care in the absence of regular professional tooth cleaning.59

Dental sealants have been extensively used since the 1960s to prevent dental caries in pits and fissures of mainly occlusal tooth surfaces. An extensive review60 analyzed 34 trials comparing sealants with other sealants or either resin based or glass-ionomer-based sealants with no sealants and concluded that the application of sealants is recommended to prevent or control caries. Sealing the occlusal surfaces of permanent molars in a young population reduces caries up to 48 months compared to no sealant; after longer follow-up, the quantity and quality of the evidence is reduced. The relative effectiveness of different types of sealants has yet to be established according to the available data61; composite resin based materials seem to have a better sealing potential62 while being more difficult to use because of the moisture control necessary with these materials.53

Probiotics have been used in medicine since people started eating fermented milk; however, their relation to health benefits captured attention only in 1907, when Metchnikoff reported that the bacteria in fermented milk were competing with microorganisms harmful to humans. Their role in dentistry, their form of delivery, and their mechanism of action are synthetically but effectively discussed by Chopra and Mathur.64 One article representative of this new field of research was published by Romani Vestman et al.65 In this rigorous randomized double-blind placebo-controlled study, they evaluated the effect of a probiotic (Lactobacillus reuteri) on the regrowth of S mutans after full mouth disinfection with professional cleaning, oral hygiene instruction, flossing, and xylitol (1% CHX and 1% Tymol) together with CHX (0.2%) rinse twice a day. Sixty-two participants from 18 to 38 years old were included. The test group was given a solution with the probiotic to slowly melt in the mouth twice a day. An identical rinsing solution (except for the presence of the probiotic) was given to the control group. Saliva samples were collected and analyzed at 1 and 6 weeks and 3 and 6 months. The saliva was checked for the presence of cultivable L reuteri and S mutans. Below a certain concentration of bacteria, it is not possible to cultivate L reuteri; therefore, a second analysis, besides the culture, was performed with PCR to test the presence of DNA from that microbiota. No statistically significant differences in S mutans levels were observed between the test and control groups after 1 and 6 weeks of intervention or during follow-up. However, at the 6-month follow-up, a tendency for a higher number of S mutans in the control group (P=.084) was observed. When the test group was divided with respect to whether DNA from L reuteri was detected in the saliva, the positive participants showed no statistically significant increase in S mutans levels compared to baseline after either 1 or 6 weeks. In contrast, in participants with no detected DNA from L reuteri, the levels of S mutans increased significantly (P<.05) during the intervention and at 3- and 6-month follow-up (P<.01). Although the sample size of 62 participants was not large, the results are relevant. The clinical impact of this type of research could be promising for prevention of dental caries, especially considering the ease of administration on a large scale through milk derivatives or additives to food and beverages in general, or even chewing gum.66 In a randomized placebo-controlled trial on 40 young volunteers, Teanpaisan and Piwat67 found a significant reduction in the number of S mutans after consuming probiotics (Lactobacillus paracasei).

Among the xylitol studies, one article reported on the data from a previous multicenter trial that resulted in only a 10% reduction of the caries rate and found that xylitol lozenges reduced the root caries rate by 40% compared to the placebo group.68
A large number of publications have been dedicated to the research of restorative materials with antimicrobial properties. However, an original study looking into bacterial activity must be mentioned first. Because saliva is able to degrade bisphenol A-glycidyl methacrylate (BisGMA) contained in composite resin and adhesives because it contains esterases, Streptococcus species, that also produce esterases may possibly also degrade composite resins and adhesives. Therefore, they hypothesized that in addition to acid production, cariogenic bacteria contain esterase activities that degrade dental composite resins and adhesives. The findings of this in vitro study support the hypothesis that S. mutans contain esterase activities at levels capable of hydrolytic-mediated degradation of polymerized dental composite resins and adhesives. The surprising information that bacteria can directly degrade restorative materials gives even more relevance to research on restorative materials containing components with antimicrobial properties.

Several chemical agents are used as antimicrobial agents: carolacton, quaternary ammonium monomer, 12-methacryloyloxydodecylpyridinium bromide (MDPB), and silver nanoparticles. Although many promising articles have been published on restorative materials and adhesives with antibacterial properties, most of them are in vitro studies still lacking clinical validation. A systematic review failed to find a single trial to support or disprove the effectiveness of antibacterial agents incorporated into fillings to prevent further tooth decay. Similarly, another review analyzed the mechanism of the antibiofilm effect of all the different dental materials and concluded that evidence-based data are still lacking; both short-term and long-term clinical studies are currently unavailable.

### Treatment strategies

If demineralization occurs, several options are available on how to approach the lesions. Remineralization is a treatment strategy still under investigation. One article adding an original approach to this relatively new treatment is that of Brunton et al.

In their clinical study, the authors evaluated in vivo the efficacy of a self-assembling peptide, P₁₁₋₄, previously described to be effective in remineralizing carieslike lesions under simulated intraoral conditions. This peptide differs from other tooth-regenerative infiltrative strategies in that it is a bioactive peptide synthesized from natural amino acids that is triggered to assemble into a 3-dimensional fibrillar scaffold under environmental conditions of pH and salt concentration. Assembly takes place within the lesion itself, and the scaffold can then act as a nucleator for hydroxyapatite, directly effecting tissue remineralization by regenerating the mineral itself. Although this study was a small, noncontrolled safety clinical trial, the treatment demonstrated beneficial results in respect of enamel regeneration. Further investigation into the optimum clinical delivery for the P₁₁₋₄ must be carried out, as well as into the effect of multiple applications on the same enamel surface when the first application resulted in incomplete repair.

Minimally invasive dentistry is no longer only a philosophical treatment approach but a well-documented, clinically effective treatment over a 5-year period that has also proven effective when treating small lesions at the margins of failing restorations. Following this clinical strategy, Luengas-Quintero et al. showedatraumatic restorative treatment restorations (discussed and described in an article by Holmgren et al.) to be clinically effective when high viscosity glass-ionomer cement was used in a young population with approximately one third of permanent teeth and two thirds of primary teeth over a 2-year period.

Although ART restorations have proven successful, incomplete caries removal per se is not necessarily always the best option. An excellent systematic review and metaanalysis of all the randomized controlled trials from 1967 to 2013 looking at the effect of incomplete caries removal on teeth was published. For years, dentists have removed carious dentin and enamel with hand and rotary instruments, thus risking exposure of the pulp in deep caries. This may no longer be necessary. Instead of attempting to remove all bacteria, it should be sufficient to reshift the ecologic and metabolic balance within the biofilm, thus promoting remineralization and arresting the caries lesions. The problem is that there is no agreement on how much carious dentin needs to be removed or left under the restorative material. Two techniques are described in the literature for removing only part of the caries: 1-step versus 2-step excavation. With the first technique, dentin is removed and the definitive restoration is placed immediately over the remaining layer of caries. With the second technique, caries is partially removed, but an interim restoration is placed for several months before the caries is completely removed. This review aimed to compare complete versus incomplete (performed in 1 or 2 steps) caries removal. Starting from about 400 references, the full text of 87 studies was investigated. Eventually, 10 articles were used for the metaanalysis, while some of the excluded articles were used to evaluate trends and clinically relevant information. Incomplete caries removal seems advantageous in deep lesions close to the pulp because it significantly reduced the risks of pulpal exposure and postoperative symptoms compared to complete excavation. Also, when performing this technique, according to the literature, the 1-step technique is better. How much caries should be left is still left to the clinical judgment of the clinician, and further studies should try to answer this question. What is relevant to clinicians, though, is that the complete removal of caries is no longer always a must, as was taught for many years in dental schools and assessed in dental licensing examinations.

### PERIODONTICS

The periodontology review for 2013 covers systemic diseases and their...
relationships to periodontal health, mucogingival procedures, and periodontal regenerative therapy. Further, the review discusses periimplantitis, etiologies, treatment, and results of treatment.

**Systemic diseases and their relationships to periodontal health**

**Diabetes**

Periodontal disease and diabetes mellitus are common chronic diseases worldwide. Epidemiologic and biologic evidence suggest periodontal disease may affect diabetes. The purpose of this systematic, nonexperimental, epidemiologic review was to explore the evidence for the effect of periodontal disease on the control, complications, and incidence of diabetes. Sources for the review were electronic bibliographic databases, supplemented by hand searches of recent and future issues of relevant journals. From 2246 citations identified and available abstracts screened, 114 full-text reports were assessed and 17 were included in the review. A small body of evidence supports significant adverse effects of periodontal disease on glycemic control, diabetes complications, and development of Type 2 (and possibly gestational) diabetes. Only a limited number of eligible studies were available, several of which had small sample sizes. Exposure and outcome parameters varied, and the generalizability of their results was limited. Current evidence suggests that periodontal disease adversely affects diabetes outcomes and that further longitudinal studies are warranted.

Diabetes and periodontitis are complex chronic diseases with an established bidirectional relationship. There is evidence that hyperglycemia in diabetes is associated with poor periodontal outcomes. The purpose of one review was to report the epidemiologic evidence from cross-sectional, prospective, and intervention studies for the impact of periodontal disease on the incidence, control, and complications of diabetes and to identify potential underpinning mechanisms. Over the last 20 years, evidence has emerged that severe periodontitis adversely affects glycemic control in individuals with diabetes and glycemia in individuals without diabetes. In individuals with diabetes, a direct and dose-dependent relationship exists between the severity of periodontitis and the complications of diabetes. Emerging evidence supports an increased risk for diabetes onset in patients with severe periodontitis. Type 2 diabetes is preceded by systemic inflammation, leading to reduced pancreatic β cell function, apoptosis, and insulin resistance. Increasing evidence supports elevated systemic inflammation resulting from the entry of periodontal organisms and their virulence factors into the circulation, providing biologic plausibility for the effects of periodontitis on diabetes. Advanced glycation end products (AGE)-receptor for AGEs (RAGE) interactions and oxidative-stress-mediated pathways provide plausible mechanistic links in the diabetes to periodontitis direction. Randomized controlled trials consistently demonstrate that mechanical periodontal therapy associates with approximately a 0.4% reduction in glycated hemoglobin at 3 months, a clinical impact equivalent to adding a second drug to a pharmacologic regimen for diabetes. Randomized controlled trials are needed with larger numbers of participants and longer-term follow-up, and if results are substantiated, adjunctive periodontal therapies subsequently need to be evaluated. No current evidence supports the adjunctive use of antimicrobial agents for the periodontal management of those with diabetes.

The purpose of the following study was to review the evidence for the molecular and cellular processes that may link periodontal disease and diabetes. The pathogenic roles of cytokines and metabolic molecules (such as glucose or lipids) are explored, and the role of periodontal bacteria is discussed. Database searches were performed using MeSH terms, keywords, and title words. Studies were evaluated and summarized in a narrative review. Periodontal microbiota appears unaltered by diabetes, and there is little evidence that it may influence glycemic control. Small-scale clinical studies and experiments in animal models suggest that IL-1β, TNF-α, IL-6, OPG, and RANKL may mediate periodontitis in diabetes. The AGE-RAGE axis is likely an important pathway of tissue destruction and impaired repair in diabetes-associated periodontitis. A role for locally activated proinflammatory factors in the periodontium, which subsequently affect diabetes, remains speculative.

Substantial information exists on potential mechanistic pathways that support a close association between diabetes and periodontitis, but longitudinal clinical studies with larger participant groups, integrated with studies of animal models and cells/tissues in vitro, are badly needed. Individuals with diabetes have higher extent and severity of periodontitis. A group of investigators studied the relationship between those needing periodontal surgery and subsequent Type 2 diabetes. This was a retrospective cohort study using data from the national health insurance system of Taiwan. The periodontitis cohort involved 22,299 patients, excluding those with diabetes already or diagnosed with diabetes within 1 year from baseline. Each study participant was randomly matched by age, sex, and index year with 1 individual from the general population without periodontitis. Cox proportional hazards regression analysis was used to estimate the influence of periodontitis on the risk of diabetes. The results demonstrated that the mean follow-up period was 5.47 ± 3.54 years. Overall, the subsequent incidence of Type 2 diabetes was 1.24-fold higher in the periodontitis cohort than in the control cohort. This is the largest nation-based study examining the risk of diabetes in Asian patients with periodontitis. Those periodontitis patients needing dental surgery had an increased risk of diabetes within 2 years than those periodontitis participants without dental surgery.

The aim of the following randomized controlled clinical trial was to evaluate the clinical effects of CHX
application in a full-mouth disinfection protocol in participants with poorly controlled Type 2 diabetes and generalized chronic periodontitis. Thirty-eight participants were randomly assigned to the full-mouth disinfection group (n=19): full-mouth scaling and root planing within 24 hours plus local application of CHX gel plus CHX rinses for 60 days. The control group (n=19) underwent full-mouth scaling and root planing within 24 hours plus local application of placebo gel plus placebo rinses for 60 days. The clinical parameters were glycated hemoglobin and fasting plasma glucose assessed at baseline and again at 3, 6, and 12 months after therapy. All clinical parameters improved significantly at 3, 6, and 12 months after therapy. The treatments did not differ with respect to clinical parameters, including the primary outcome variable (that is, changes in clinical attachment level in deep pockets), for up to 12 months after treatment.

The following study may offer new insights into the relationship of periodontal treatment and diabetes and alter treatment for patients with Type II diabetes. Chronic periodontitis, a destructive inflammatory disorder of the supporting structures of the teeth, is prevalent in patients with diabetes. Limited evidence suggests that periodontal therapy may improve glycemic control. The study purpose was to determine if nonsurgical periodontal treatment reduces levels of glycated hemoglobin (HbA1c) in persons with Type 2 diabetes and moderate to advanced chronic periodontitis. The Diabetes and Periodontal Therapy Trial was a 6-month, single-masked, multicenter, randomized clinical trial. Participants had Type 2 diabetes, were receiving stable doses of medications, had HbA1c levels between 7% and less than 9%, and had untreated chronic periodontitis. Five hundred fourteen participants were enrolled between November 2009 and March 2012 from diabetes and dental clinics and communities affiliated with 5 academic medical centers. The treatment group (n=257) received scaling and root planing plus CHX oral rinse at baseline and supportive periodontal therapy at 3 and 6 months. The control group (n=257) received no treatment for 6 months. Treatment outcomes were different in change of HbA1c level from baseline between groups at 6 months. Secondary outcomes included changes in probing pocket depths, clinical attachment loss, bleeding on probing (BOP), gingival index, fasting glucose level, and Homeostasis Model Assessment (HOMA2) score. Enrollment was stopped early because of futility. At 6 months, mean HbA1c levels in the periodontal therapy group increased 0.17% (SD, 1.0) compared to 0.11% (SD, 1.0) in the control group, with no significant difference between groups based on a linear regression model adjusting for clinical site (mean difference -0.05%, 95% confidence interval [CI] -0.23 to 0.12; P= .55). Periodontal measures improved in the treatment group compared to the control group at 6 months, with adjusted between-group differences of 0.28 mm (95% CI 0.18 to 0.37) for probing depth, 0.25 mm (95% CI 0.14 to 0.36) for clinical attachment loss, 13.1% (95% CI 8.1 to 18.1) for BOP, and 0.27 (95% CI 0.17 to 0.37) for gingival index (P<.001 for all). The authors concluded that nonsurgical periodontal therapy did not improve glycemic control in patients with Type 2 diabetes and moderate to advanced chronic periodontitis. These findings do not support the use of nonsurgical periodontal treatment in patients with diabetes for the purpose of lowering levels of HbA1c.

Atherosclerosis

This systematic review studied the strength of observations whether treatment of periodontitis improves the atherosclerotic profile. The literature was searched in Medline, PubMed, Cochrane Central, and Embase, based on controlled periodontal intervention trials, including a nonintervention group. Data were extracted and meta-analyses were performed. From 3928 screened studies, 25 trials met the eligibility criteria. These trials enrolled 1748 periodontitis patients. Seven trials enrolled periodontitis patients that were otherwise healthy, and 18 trials recruited periodontal patients with various comorbidities such as cardiovascular disease (CVD) or diabetes. None of the trials used hard clinical end points of CVD. However, improvement of endothelial function has been consistently reported. Importantly, periodontitis patients with comorbidity benefitted most from periodontal therapy. This systematic review and metaanalysis demonstrate that periodontal treatment improves endothelial function and reduces biomarkers of atherosclerotic disease, especially in those who already have CVD and/or diabetes.

The following consensus report succinctly describes the current thinking related to the association between periodontitis and atherosclerotic cardiovascular disease. This consensus report is concerned with the association between periodontitis and atherosclerotic cardiovascular disease (ACVD). Periodontitis is a chronic multifactorial inflammatory disease caused by microorganisms and characterized by progressive destruction of the tooth-supporting apparatus leading to tooth loss; as such, it is a major public health issue. This report examined biologic plausibility, epidemiology, and early results from intervention trials. Periodontitis leads to the entry of bacteria into the bloodstream. The bacteria activate the host inflammatory response by multiple mechanisms. The host immune response favors atheroma formation, maturation, and exacerbation. In longitudinal studies assessing incident cardiovascular events, statistically significant excess risk for ACVD was reported in individuals with periodontitis. This was independent of established cardiovascular risk factors. The amount of the adjusted excess risk
varies by type of cardiovascular outcome and across populations by age and sex. Given the high prevalence of periodontitis, even low to moderate excess risk is important from a public health perspective. There is moderate evidence that periodontal treatment reduces systemic inflammation as evidenced by reduction in C-reactive protein and improvement of both clinical and surrogate measures of endothelial function but has no effect on lipid profiles, thus supporting specificity. Limited evidence shows improvements in coagulation, biomarkers of endothelial cell activation, arterial blood pressure, and subclinical atherosclerosis after periodontal therapy. The available evidence is consistent and speaks for a contributory role of periodontitis to ACVD. No periodontal intervention studies are available on primary ACVD prevention, and only 1 feasibility study on secondary ACVD prevention exists. It was concluded that there is consistent and strong epidemiologic evidence that periodontitis increases the risk of future cardiovascular disease, but although in vitro, animal, and clinical studies do support the interaction and biologic mechanism, intervention trials to date are not adequate to draw further conclusions. Well-designed intervention trials on the effect of periodontal treatment on the prevention of ACVD with defined clinical outcomes are needed.

The concept of focal infection or systemic disease arising from infection of the teeth was generally accepted until the mid-20th century, when it was dismissed because of lack of evidence. Subsequently, a largely silo approach was taken by the dental and medical professions. Over the past 20 years, however, a plethora of epidemiologic, mechanistic, and treatment studies have highlighted that this silo approach to oral and systemic diseases can no longer be sustained. Although a number of systemic diseases have been linked to oral diseases, the weight of evidence from numerous studies conducted over this period, together with several systematic reviews and metaanalyses, supports an association between periodontitis and cardiovascular disease, and between periodontitis and diabetes. The association has also been supported by a number of biologically plausible mechanisms, including direct infection, systemic inflammation, and molecular mimicry. Treatment studies have shown that periodontal treatment may have a small but significant systemic effect both on endothelial function and on glycemic control. Despite this, however, there is no direct evidence that periodontal treatment affects either cardiovascular or diabetic events. Nevertheless, over the past 20 years, we have learned that the mouth is an integral part of the body and that the medical and dental professions need to work more closely together in the provision of overall health care for all patients.

**Periodontal regeneration**

Restoration of the damaged periodontium has been a goal of periodontal therapy for many years. This year, articles will be reviewed that have added to the evidence base relating to this important aspect of periodontal therapy. Marginal pedicle periosteum has been used as a rigid membrane in guided tissue regeneration for osseous defects. The present research aimed to study the effect of providing space with an alloplastic graft material in reducing the bone defect area (BDA) of 2-wall defects. Twenty interproximal intrabony 2-wall defects in healthy nonsmoking patients with chronic periodontitis were randomly divided into control (Group 1, periosteum alone) and experimental (Group 2, periosteum with alloplastic graft material) groups. Measurements of probing depth (PD), clinical attachment level (CAL), and radiographic BDA were done at the baseline and 6-month postoperative evaluations. The 6-month postoperative assessment showed clinical and radiographic improvements with PD reduction, CAL gain, and changes in BDA in both groups, which was statistically significant compared to baseline (P<.05). However, BDA reduction was statistically greater in Group 2 compared to Group 1 at the 6-month follow-up (P=.009). Within the limitations of this study, it can be concluded that space provision with an alloplastic graft material increases the regenerative potential of marginal pedicle periosteum as a guided tissue regeneration membrane and results in increased defect fill.

Alveolar ridge preservation is important when dental implants are being considered and in obtaining optimal prosthetic and esthetic results. The purpose of the following study was to investigate and compare outcomes after alveolar ridge preservation (ARP) in the posterior maxilla and mandible. Twenty-four patients (54 ±3 years) with a single posterior tooth extraction were included. ARP was performed with freeze-dried bone allograft and collagen membrane. Clinical parameters were recorded at extraction and reentry. Collected bone cores were analyzed by microcomputed tomography, histomorphometry, and immunohistochemistry. In both the maxilla and mandible, ARP prevented ridge height loss, but ridge width was significantly reduced by approximately 2.5 mm. Healing time, initial clinical attachment loss, and the amount of keratinized tissue (KT) at the extraction site were identified as determinants of ridge height outcome. Buccal plate thickness and tooth root length were identified as determinants of ridge width outcome. In addition, initial ridge width was positively correlated with ridge width loss. Microcomputed tomography revealed greater mineralization per unit volume in new bone compared to existing bone in the mandible (P<.001). Distributions of residual graft, new cellular bone, and immature tissue were similar in both jaws. Within the limitations of this study, the results indicate that in different anatomic locations different factors may determine ARP outcomes. Further studies are needed to better understand the determinants of ARP outcomes.

Another study was designed to determine whether exclusion of the gingival connective tissue (CT) and periosteum...
with contained stem cells has a positive or negative effect on periodontal regeneration by comparing the use of a novel modified perforated collagen membrane with a traditional cell occlusive barrier membrane. Twenty nonsmoking participants with severe chronic periodontitis were included in the study. Single deep intrabony defects from each of the participants were randomly divided into 2 groups as follows: occlusive bovine collagen membranes (OM control group, 10 sites) and modified perforated bovine collagen membranes (MPM test group, 10 sites). The plaque index (PI), gingival index, PD, CAL, defect base level, and crestal bone level were measured at baseline and were reassessed at 6 and 9 months after therapy to evaluate the quantitative changes in the defect. At the 6- and 9-month observation periods, the MPM-treated sites showed a statistically significant improvement in PD reduction and CAL gain compared to the OM control group. Defect base level was significantly reduced with no significant difference between the 2 groups at the 6- and 9-month observation periods. Crestal bone level was significantly higher in the MPM group compared to that of the OM group at both observation periods. The postoperative differences between the 2 groups were 2 mm at 6 months and 1.7 mm at 9 months, in favor of the MPM-treated sites. This study demonstrated enhanced clinical outcomes with novel MPMs compared to OMs in the guided tissue regeneration procedures. These results may be affected by the penetration of gingival CT contained stem cells and periosteal cells and their differentiation into components of the attachment apparatus.

The objectives of another study were to compare differences in histologic and clinical healing after tooth extraction and ridge preservation with 2 different xenograft treatment protocols. Forty-four participants with a nonmolar tooth that required extraction and planned implant placement were randomly allocated into 2 ridge preservation protocol groups. Protocol 1 used a xenograft material consisting of 90% anorganic bovine bone in combination with 10% porcine collagen fibers combined with a resorbable bilayer membrane composed of non-cross-linked porcine Types I and III collagen. Protocol 2 used a xenograft sponge composed of 70% cross-linked Type I bovine collagen coated with a layer of non-sintered hydroxyapatite mineral on its surface combined with a resorbable membrane composed of Type I porcine collagen cross-linked by natural ribose glycation. After 21 weeks of healing, clinical measurements were repeated, and a core biopsy was obtained and prepared for histologic evaluation of the percentages of vital bone, residual graft, and CT/other. Similar percentages of CT/other were detected between the protocols, with no significant difference between groups (P = .763). A significantly greater percentage of vital bone was detected in specimens in protocol 2 (P < .001). Protocol 1 presented with a mean of 32.83% vital bone, 13.44% residual graft material, and 53.73% CT. Protocol 2 presented with a mean of 47.03% vital bone, no detectable residual graft material, and 52.97% CT/other. Clinically, no significant differences in dimensional changes were evident between the ridge preservation protocols.

A large body of evidence based on cells and animal models demonstrates the effectiveness of growth factors in periodontal regeneration. However, few studies compare the efficacy of growth factors in human periodontal regeneration compared to other techniques and procedures. Therefore, the aim of this study was to perform a systematic review of human studies using growth factors for periodontal regeneration and to compare the efficacy of these growth factors with other accepted techniques for periodontal regeneration. An electronic and manual search based on agreed search phrases between the primary investigator and a secondary investigator was performed to identify the use of growth factors in periodontics for the literature review. The articles that were identified by this systematic review were analyzed in detail, including their inclusion and exclusion criteria, outcome measures determination and analysis, risk of bias, adverse events, and conclusions or inference of the efficacy of growth factors to the general population. Five articles fulfilled the inclusion criteria. Two articles were identified that had sufficiently similar study design that a metaanalysis of their outcomes was possible. Most of the reported outcomes from the selected articles were descriptive. The articles demonstrated periodontal regeneration at least comparable to their respective positive controls, with only a couple of articles demonstrating significantly greater outcomes compared to their respective positive controls. Histologic evidence demonstrated greater periodontal regeneration with growth factors compared to other regenerative techniques and an increased healing and bone maturation rate compared to other regenerative and bone augmentation techniques in these human studies. Within the limits of this systematic review, the use of recombinant human platelet-derived growth factor (rhPDGF) BB led to a greater gain in clinical attachment, approximately 1 mm compared to an osteoconductive control, β-tricalcium phosphate (β-TCP). The use of rhPDGF-BB led to a greater percentage bone fill of approximately 40% compared to the osteoconductive control, β-TCP. Last, the use of rhPDGF-BB led to an increased rate of bone growth, approximately 2 mm compared to the osteoconductive control, β-TCP.

The use of collagen membrane with xenograft and rhPDGF in guided bone regeneration is debatable. The aim of this microcomputed tomographic experiment was to assess the efficacy of using PDGF and xenograft (with or without collagen membrane) for guided bone regeneration around immediate implants with dehiscence defects. Ten Beagle dogs underwent atraumatic bilateral second and fourth premolar extractions from both arches. A standardized dehiscence defect (6 x 3 mm) was created on the buccal bone, and immediate implants were placed in distal sockets in each site.
Animals were randomly divided into 3 groups: Group 1, xenograft with rhPDGF was placed and covered with collagen membrane; Group 2, xenograft with rhPDGF was placed over the defects; and Group 3, four immediate implants associated with dehiscence (controls). After 16 weeks, the animals were killed and jaw segments were assessed with micro-computed tomography for buccal bone thickness, buccal bone volume, vertical bone height, and bone-to-implant contact. Buccal bone thickness was higher in Group 2 (xenograft with rhPDGF) mm than Group 1 (xenograft with rhPDGF) (P<.001) and Group 3 (controls) (P<.05). Buccal bone volume was higher in Group 2 than Group 1 (P<.05) and Group 3 (P<.001). Vertical bone height was higher in Group 2 than Group 3 (P<.001). Vertical bone height was higher in Group 1 than Group 3 (P<.05). Bone-to-implant contact was higher in Group 2 than Group 1 (P<.05) and Group 3 (P<.01). Guided bone regeneration around immediate implants with dehiscence defects using PDGF and xenograft alone resulted in higher buccal bone thickness, buccal bone volume, vertical bone height, and bone-to-implant contact than in combination with collagen membranes (controls).

The purpose of the following study was to evaluate the 10-year results after treatment of intrabony defects treated with a enamel matrix protein derivative (EMD) combined with either a natural bone mineral (NBM) or β-TCP. Twenty-two participants with advanced chronic periodontitis and displaying 22 deep intrabony defects were randomly treated with a combination of either EMD+NBM or EMD+β-TCP. Clinical evaluations were performed at baseline and at 1 and 10 years. The following parameters were evaluated: PI, BOP, PD, gingival recession (GR), and CAL. The primary outcome variable was CAL. The defects treated with EMD+NBM demonstrated a mean CAL change from 8.9 ±1.5 mm to 5.3 ±0.9 mm (P<.001) at 1 year and to 5.8 ±1.1 mm (P<.001) at 10 years. The sites treated with EMD+β-TCP showed a mean CAL change from 9.1 ±1.6 mm to 5.4 ±1.1 mm (P<.001) at 1 year and 6.1 ±1.4 mm (P<.001) at 10 years. At 10 years, 2 defects in the EMD+NBM group had lost 2 mm, whereas 2 other defects had lost 1 mm of the CAL gained at 1 year. In the EMD+β-TCP Group 3 defects had lost 2 mm, whereas 2 other defects had lost 1 mm of the CAL gained at 1 year. Compared with baseline, at 10 years, a CAL gain of ≥3 mm was measured in 64% (7 of 11) of the defects in the EMD+NBM group and in 82% (9 of 11) of the defects in the EMD+β-TCP group. No statistically significant differences were found between the 1- and 10-year values in either of the 2 groups. Between the treatment groups, no statistically significant differences in any of the investigated parameters were observed at 1 and 10 years. Within their limitations, the present findings indicate that the clinical improvements obtained with regenerative surgery using EMD+NBM or EMD+β-TCP can be maintained over a period of 10 years.

The purpose of another study was to evaluate the efficacy of a modified minimally invasive surgical technique (M-MIST) with the local delivery of rhPDGF-BB gel in the treatment of intrabony defects. Twenty-four healthy participants were included in the present double-blind randomized controlled study. The test group was treated with M-MIST and rhPDGF-BB and the control group with M-MIST alone. The mean PD, CAL and GR, cementoenamel junction (CEJ) to base of the defect, defect depth, and CEJ to the alveolar crest at baseline to 6 months postoperatively in both groups were statistically significant. The intergroup comparison for gain in attachment level, PD reduction, and change in gingival margin position linear bone growth, percentage bone fill, residual defect depth (residual defect depth), and the change in alveolar crest position revealed no statistically significant differences. The gain in CAL and linear bone growth was 3 ±0.89 mm and 1.89 ±0.6 in the test group and 2.64 ±0.67 mm and 1.85 ±1.18 mm in the control group, respectively, and did not show statistical significance. An important conclusion of the study was that the improvement in both groups could be attributed to the novel surgical technique rather than to the addition of rhPDGF-BB.

The application of a synthetic BMP-6 polypeptide in a rat periodontal fenestration defect model enhanced periodontal wound healing/regeneration, including new bone and cementum formation. The purpose of this study was to translate the relevance of these initial observations into a discriminating large animal model. Critical-size (4 to 5 mm) supraalveolar periodontal defects were created at the second and third mandibular premolar teeth in 11 Beagle dogs. Experimental sites received BMP-6 at 0.25, 1.0, and 2.0 mg/mL soak-loaded onto an absorbable collagen sponge (ACS) carrier or ACS alone (control); each condition was repeated in 4 jaw quadrants. The animals were euthanized at 8 weeks when block biopsy specimens were collected and processed for histologic/histometric analysis. BMP-6 at 0.25, 1.0, and 2.0 mg/mL soak-loaded onto the ACS yielded significantly enhanced new bone (0.99 ±0.07 versus 0.23 ±0.13 mm/BMP-6 at 0.25 mg/ml) and cementum (2.45 ±0.54 versus 0.73 ±0.15 mm/BMP-6 at 0.25 mg/ml) formation, including a functionally oriented periodontal ligament compared to the control (P<.05). A significant inverse linear association between the BMP-6 dose and new bone (β=−0.21 ±0.09 mm, P=.016) and cementum height (β=−0.34 ±0.15 mm, P=.023) was observed. Minimal root resorption was observed without significant differences between groups. Ankylosis was not observed for any of the experimental groups. Surgical application of BMP-6/ACS onto critical-size supraalveolar defects enhanced periodontal wound healing/regeneration, in particular cementogenesis, including a functionally oriented periodontal ligament; the low BMP-6 concentration (0.25 mg/mL) apparently provided the most effective dose.

Another study compared the effects of enamel matrix derivative (EMD)
associated with a hydroxyapatite and β-tricalcium phosphate (HA/β-TCP) implant to EMD alone and to open-flap debridement when surgically treating 1- to 2-wall intrabony defects.106 Thirty-four participants exhibiting ≥3 intrasosseous defects in different quadrants were each treated with open-flap debridement, EMD, or EMD+HA/β-TCP in each defect. A complete clinical and radiographic examination was performed at baseline and at 12 and 24 months. Pretherapy and posttherapy clinical parameters (PD, CAL, and GR) and radiographic parameters (defect bone level and radiographic bone gain) for the different treatments were compared. After 12 and 24 months, almost all the clinical and radiographic parameters showed significant changes from baseline within each group (P<.001). Differences in PD, CAL, and defect bone level scores were also seen among the 3 groups at the 12- and 24-month visits (P<.001). Data support the hypothesis that the adjunct of an HA/β-TCP composite implant with EMD may improve the clinical and radiographic outcomes of the surgical treatment of unfavorable intrabony defects.

**Soft tissue augmentation**

Long-term studies on single implants are scarce and focus merely on clinical response parameters, complications, and bone remodeling.107 The objective of this retrospective case series was to assess alterations in soft tissue levels and esthetics over a 16- to 22-year period in periodontally healthy patients. Patients who had received a single turned implant in the anterior maxilla/mandible at the Dental Specialist Clinic in Malmo between 1987 and 1993 were invited for a reexamination on the basis of a number of inclusion criteria. Both neighboring teeth had to be present at reexamination, and baseline clinical photographs (within the first year of function) had to be available for soft tissue evaluation. These photographs were superimposed onto final clinical photographs to assess longitudinal soft tissue alterations. Twenty-one participants (9 women; mean age 23, range 16 to 41) treated with 24 single implants met the criteria for soft tissue evaluation. Perimplant soft tissue levels (papillae, midfacial level) remained stable over a 16- to 22-year observation period (P>0.372). However, neighboring teeth demonstrated midfacial recession and eruption pointing to a major distortion with the implant crown (>1 mm) in 5 (21%) of 24 and 10 (42%) of 24 of the participants, respectively. Baseline esthetics was considered poor (mean Pink Esthetic Score 7.42, mean White Esthetic Score 5.43), yet a significant time effect could not be demonstrated (P>0.52). Implant and tooth bone loss was low (mean 0.6 mm and 0.4 mm, respectively) over a 16- to 22-year period. This limited case series demonstrated stable perimplant soft tissue levels and esthetics in the long term after single implant treatment in periodontally healthy patients. However, midfacial recession and eruption may be expected at neighboring teeth.

In another study, the effectiveness of enamel matrix derivative (EMD) associated with a simplified papilla preservation flap (SPPF) technique was compared to SSPF alone when supraalveolar-type defects were treated surgically.108 Of the 54 initially selected participants, 50 presented with horizontal bone loss around ≥4 adjacent teeth and were treated with an SSPF technique; 25 participants also received EMD (test group), and 25 participants underwent flap surgery alone (control group). A complete clinical and radiographic examination was performed at baseline and 12 months after treatment. Pretherapy and posttherapy PD, CAL, GR, and radiographic bone level were compared. After 12 months, PD, CAL, and GR in both groups showed significant differences from baseline (P<.001). No differences in bone level scores were observed within the groups at the 12-month examination. After 1 year, the test group showed significantly (P<0.001) greater PD reduction (3.4 ±0.7 mm) and CAL gain (2.8 ±0.8 mm) and a smaller GR increase (0.6 ±0.4 mm) compared to the control group (PD, 2.2 ±0.8 mm; CAL, 1.0 ±0.6 mm; GR, 1.2 ±0.7 mm). Bone level changes did not significantly differ between the experimental groups. The results of this study suggest that combining EMD and SSPF in the treatment of suprabony defects may lead to a greater clinical improvement than SSPF alone.

A newly developed collagen matrix of porcine origin may represent an alternative to palatal connective tissue grafts (CTG) for the treatment of single Miller Class I and II GR when it is used in conjunction with a coronally advanced flap (CAF).109 At present, to what extent collagen matrix may represent a valuable alternative to CTG in the treatment of Miller Class I and II multiple adjacent gingival recessions (MAGR) remains unknown. The aim of this study was to compare the clinical outcomes after treating Miller Class I and II MAGR with the modified coronally advanced tunnel technique (MCAT) in conjunction with either collagen matrix or CTG. Twenty-two participants with a total of 156 Miller Class I and II GR were included in this study. Recessions were randomly treated according to a split-mouth design by means of MCAT+collagen matrix (test) or MCAT+CTG (control). The following measurements were recorded at baseline (before surgery) and at 12 months: GR depth, probing pocket depth (PD), CAL, KT width, GR width, and gingival thickness (GT). GT was measured 3 mm apical to the gingival margin. Patient acceptance was recorded by using a visual analog scale. The primary outcome variable was complete root coverage (CRC); secondary outcomes were mean root coverage, change in KT width, GT, patient acceptance, and duration of surgery. Healing was uneventful in both groups. No adverse reactions at any of the sites were observed. At 12 months, both treatments resulted in statistically significant improvements of CRC, mean root coverage, KT width, and GT compared to baseline (P<0.05). CRC was found at 42% of test sites and at 85% of control sites (P<0.05). The duration of surgery...
and patient morbidity was statistically significantly lower in the test group than in the control group (P < .05). The present findings indicate that the use of collagen matrix may represent an alternative to CTG in reducing surgical time and patient morbidity but yielded lower CRC than CTG in the treatment of Miller Class I and II MAGR when used in conjunction with MCAT.

GR defects can be treated by various methods, including acellular dermal matrices (ADM) or CAF.110 The aim of this histomorphometric experiment was to compare the efficacy of ADM and CAF for treating GR defects in dogs. In 8 Beagles, a critical-size labial GR defect was surgically induced on bilateral maxillary canines under general anesthesia. Test sites received ADM and CAF, and control sites underwent CAF treatment alone. The PI, bleeding index, and gingival index were measured at 4 weeks (baseline), 8 weeks, and 16 weeks. The width of keratinized gingiva was determined at baseline and at 16 weeks. The depth of recession and width of GR below the CEJ was also determined. After 4 months, the animals were killed, and jaw blocks were histomorphometrically assessed for tissue thickness and distance from the stent to the gingival margin and to the CEJ. At 4-, 8-, and 16-week intervals, no significant difference was found in the bleeding index, gingival index, and PI at the test and control sites. At 16 weeks, the thickness of keratinized gingiva was significantly higher at the control sites than at the test sites (P < .01). No difference was found in the midfacial recession depth and recession width at the test and control sites at baseline and before euthanasia (16 weeks). Histomorphometrically, there was no significant difference in tissue thicknesses and distances from the stent to the gingival margin and CEJ in the test and control sites. ADM might yield similar results to CAF alone and could decrease the amount of keratinized gingiva.

One of the success factors in periodontal plastic surgery is the synergistic relationship between the involved tissues and vascular supply. Gingiva is a unique functional unit with a specific vascular configuration and contains the supracrestal portion naturally created to survive over avascular root surfaces.111 The aim of this randomized controlled trial was to clinically evaluate the treatment of localized GR by using gingival unit grafts (palatal tissue involving marginal gingiva and papillae) compared to conventional palatal grafts. Seventeen participants with Class I to II recession defects on mandibular anterior teeth were included and randomly assigned into 1 of 2 groups. Recessions were treated with gingival unit grafts in Group 1 (n = 8) and with palatal grafts in Group 2 (n = 9). Clinical parameters, including vertical recession, PD, KT, and attachment level, were recorded at baseline and 8 months after surgery. Both treatments produced significant clinical improvements within the groups. Inter-group comparison revealed significantly higher vertical recession reduction, attachment, and KT gain in Group 1 than in Group 2; mean percentages of the defect coverage were 91.62% ± 9.74% for Group 1 and 68.97% ± 13.67% for Group 2 (P < .05). The healing of the gingival unit donor site was uneventful. Within its limits, this study demonstrates the possibility of treating buccal recessions with gingival unit grafts as an alternative to using gingival donor graft of site-specific vascular configuration, with better defect coverage as well as clinical and esthetic improvements.

Numerous surgical approaches for the treatment of single GR defects are documented in the literature.112 The aim of this 5-year split-mouth-design randomized clinical trial was to evaluate the effectiveness of CAF alone versus CAF with CTG in the treatment of single Miller Class I and II GR defects. Thirty-seven participants with 114 bilateral single Miller Class I and II GR defects were treated with CAF on one side of the mouth and CAF+CTG on the other side. Clinical measurements (GR length [REC], keratinized tissue width [KT], CRC, and percentage of root coverage [PRC]) were evaluated before surgery and after 6, 12, 24, and 60 months. A significant reduction of REC and an increase of KT was noted after surgery in both groups. CAF+CTG showed significantly better results for all evaluated clinical parameters in all observed follow-up periods. Miller Class I defects showed better results in terms of REC, CRC, and PRC, whereas Miller Class II showed better results in KT, both in favor of CAF+CTG. Miller Class I defects showed better results than Miller Class II GR defects regardless of the surgical procedure used. Both surgical procedures were effective in the treatment of single Miller Class I and II GR defects. The CAF+CTG procedure provided better long-term outcomes (60 months postoperatively) than CAF alone. Long-term stability of the gingival margin is less predictable for Miller Class II GR defects than those of Class I.

The purpose of another study was to evaluate the clinical outcomes of the use of a xenogeneic collagen matrix in combination with a CAF in the treatment of localized recession defects.113 In a multicenter single-blinded randomized controlled split-mouth trial, 90 recessions (Miller Class I, II) in 45 participants received either CAF with collagen matrix or CAF alone. At 6 months, root coverage (primary outcome) was 75.29% for test and 72.66% for control defects (P = .169), with 36% of test and 31% of control defects exhibiting complete coverage. The increase in the mean width of KT was higher in test defects (1.97 to 2.90 mm) than in control defects (2.00 to 2.57 mm) (P = .036). Likewise, test sites had more gain in GT (0.59 mm) than control sites (0.34 mm) (P = .003). Larger (≥ 3 mm) recessions (n = 35 participants) treated with collagen matrix showed higher root coverage (72.03% versus 66.16%, P = .043) and more gain in KT and GT. CAF with collagen matrix was not superior with regard to root coverage but enhanced GT and the width of KT compared to CAF alone. For the coverage of larger defects, CAF with collagen matrix was more effective.
Root exposure due to GR can cause cervical dentin hypersensitivity (CDH), which is characterized by tooth pain. The aim of this study was to evaluate the effect of surgical defect coverage on CDH and quality of life in patients with GR. Twenty-five GRs in maxillary canines and premolars were treated with coronally positioned flaps plus CTG. GR dimensions, the amount of keratinized gingiva, and the CAL were evaluated. CDH was assessed by thermal and evaporative stimuli. Quality of life was assessed by use of the Oral Health Impact Profile-14 (OHIP-14) questionnaire. All parameters were evaluated at baseline and after 3 months. A statistically significant reduction in CDH (P < .001), significant reduction in the impact of oral health on quality of life (P < .001), and significant changes in periodontal parameters were observed after 3 months. A mean defect coverage of 67.90% was achieved, with full coverage, in 11 individuals. The percentage defect coverage showed no correlation with air-blast-stimulated CDH (P = .256) or cold stimulus (P = .563). The OHIP-14 physical disability dimension was correlated with the amount of KT (P = .010) and also with defect coverage (P = .035). Surgical defect coverage may reduce CDH and improve patient quality of life by augmenting keratinized gingiva and the effect on physical disability, irrespective of the amount of defect coverage.

The aim of another randomized clinical trial was to introduce 3D digital measuring methods for evaluating the outcomes after surgical root coverage (RC) and to assess the clinical performance of the tunnel technique with subepithelial CTG (TUN) versus CAF with enamel matrix derivative in the treatment of shallow, localized GR defects. Twenty-four participants contributed a total of 47 Miller Class I or II recessions for scientific evaluation. Clinical outcomes were evaluated at 6 and 12 months. Precise study models gained at baseline and follow-up examinations were optically scanned and virtually superimposed to digitally evaluate the clinical outcome measures, including the percentage of RC and CRC. Patient-centered outcomes were evaluated with questionnaires. Final esthetic outcomes were assessed by using the root coverage esthetic score. At 12 months, RC was 98.4% for TUN-treated and 71.8% for CAF-treated defects (P = .0004). CRC was observed in 78.6% (TUN) and 21.4% (CAF) of the cases (P = .0070). Results for patient-centered outcomes were equivalent for both groups, but evaluation of the final esthetic outcomes with the RES revealed a significant difference (9.06 versus 6.92, P = .0034) in favor of TUN. TUN resulted in significantly better clinical outcomes compared to CAF. The new measuring method provided high accuracy and unforeseen precision in the evaluation of treatment outcomes after surgical RC.

### Ridge preservation

Previous studies of ridge preservation showed a loss of approximately 18% or 1.5 mm of crestal ridge width in spite of treatment. The primary aim of this randomized controlled masked clinical trial was to compare a socket graft with the same treatment plus a buccal overlay graft, both with a polylactide membrane to determine whether the loss of ridge width can be prevented by using an overlay graft. Twelve participants who served as positive controls received an intrasocket mineralized cancellous allograft (socket group), and 12 participants received the same socket graft procedure plus a buccal overlay cancellous xenograft (overlay group). Horizontal ridge dimensions were measured with a digital caliper, and vertical ridge changes were measured from a stent. Before implant placement at 4 months, a trephine core centered outcomes were equivalent for both groups, but evaluation of the final esthetic outcomes with the RES revealed a significant difference (9.06 versus 6.92, P = .0034) in favor of TUN. TUN resulted in significantly better clinical outcomes compared to CAF. The new measuring method provided high accuracy and unforeseen precision in the evaluation of treatment outcomes after surgical RC.

### Periimplantitis

The microbial differences between periimplantitis and periodontitis in the same participants were examined by using 16S rRNA gene clone library analysis and real-time PCR. Subgingival plaque samples were taken from the deepest pockets of periimplantitis and periodontitis sites in 6 participants. The prevalence of bacteria was analyzed with a 16S rRNA gene clone library and real-time PCR. A total of 333 different taxa were identified from 799 sequenced clones; 231 (69%) were uncultivated phylotypes, of which 75 were novel. The numbers of bacterial taxa identified at the sites of periimplantitis and periodontitis were 192 and 148 respectively. The microbial composition of periimplantitis was more diverse compared to that of periodontitis. Fusobacterium species and Streptococcus species were predominant in both periimplantitis and periodontitis, while bacteria such as Parvimonas micra were only detected in periimplantitis. The prevalence of periodontopathic bacteria was not high, while quantitative evaluation revealed that in most cases, prevalence was higher at periimplantitis sites than at periodontitis sites. The biofilm in periimplantitis showed a more complex microbial composition compared to periodontitis. Common periodontopathic bacteria showed low prevalence, and several bacteria were identified as candidate pathogens in periimplantitis.

This systematic review was requested by the Task Force of the American Academy of Periodontology as a follow-up study of the 2013 report, with the
aim of investigating the efficacy of different surgical approaches to treat periimplantitis. A search of 4 electronic databases from January 1990 until May 2013 was performed. Studies included were human clinical trials published in English that applied surgeries for treating periimplantitis. Parameters evaluated included reduction in PD, gain in CAL, reduction in BOP, and mucosal recession. The weighted mean and the 95% CI of the studied parameters were estimated with the random effect model. A total of 1306 studies were identified after reviewing titles, abstracts, and full texts, and 21 articles, 12 of which were case series, were finally included. Four treatment groups were identified: access flap and debridement, surgical resection, application of bone grafting materials, and guided bone regeneration. The mean initial PD ranged from 4.8 to 8.8 mm, with initial BOP ranging from 19.7% to 100%. Short-term follow-ups (3 to 63 months) revealed that the available surgical procedures yielded a weighted mean PD reduction of 2.04 (Group 2) to 3.16 mm (Group 4), or 33.4% to 48.2% of the initial PD. The weighted mean radiographic bone fill was 2.1 mm for Groups 3 and 4. Within the limitation of this systematic review, the application of grafting materials and barrier membranes resulted in greater PD reduction and radiographic bone fill, but high-quality comparative studies are lacking to support this statement. The results might be used to project treatment outcomes after surgical management of periimplantitis.

Information on the microbiota in periimplantitis is limited. One group hypothesized that neither sex nor a history of periodontitis/smoking or the microbiota at implants differ by implant status. Baseline microbiologic samples collected at one implant in each of 166 participants with periimplantitis and from 47 individuals with a healthy implant were collected and analyzed by DNA-DNA checkerboard hybridization (78 species). Clinical and radiographic data defined implant status. Nineteen bacterial species were found at higher counts from implants with periimplantitis, including Aggregatibacter actinomycetemcomitans, Campylobacter gracilis, Campylobacter rectus, Campylobacter, Helicobacter pylori, Haemophilus inﬂuenzae, Porphyromonas gingivalis, Staphylococcus aureus, Staphylococcus anaerobius, Streptococcus intermedius, Streptococcus mitis, Tanneraella forsythia, Treponema denticola, and Treponema socranskii (P<.001). Receiver operating characteristic curve analysis identiﬁed T forsythia, P gingivalis, T socranskii, S aureus, S anaerobius, S intermedius, and S mitis in periimplantitis, comprising 30% of the total microbiota. When adjusted for sex (not signiﬁcant [NS]), smoking status (NS), older age (P=.003), periodontitis history (P<.001), and T forsythia (likelihood ratio 3.6, 95% conﬁdence interval 1.4, 9.1, P=.007) were associated with periimplantitis. A cluster of bacteria including T forsythia and S aureus were associated with periimplantitis.

Another study in a Belgian population aimed to evaluate the frequency of mucositis and periimplantitis in patients with implants with at least 5 years of function. Another outcome was to access implant/patient characteristics as possible risk indicators for periimplantitis. One hundred three participants (38 men, 65 women) with a total of 266 implants were examined. Implants had been inserted in university hospitals as well as in private clinics, and the mean time of implants in function was 8.5 years (±3.2). The average participants’ age within the population was 62 years (±13.4). General health information was recorded as well as habits regarding smoking, maintenance visits, and oral hygiene. Full mouth clinical parameters (plaque index, BOP, pocket probing depth [PPD]) were assessed and radiographs made to determine the periodontal status and implant diagnosis. The prevalence of mucositis and periimplantitis at the patient level was 31% and 37%. They were 38% and 23% at the implant level. Participants older than 65 years (odds ratio [OR] 1.39) and those with active periodontitis (OR 1.98) were prone to periimplantitis. The association was stronger for hepatitis (OR 2.92) and totally edentulous patients (OR 5.56). Finally, at the implant level, a significant correlation was found in the multilevel analyses between rough surfaces, overdentures, and periimplantitis. After 8.5 years, an important proportion (±60%) of implants presented biologic complications. Furthermore, a positive correlation was shown between age, periodontitis, absence of teeth, rough surfaces, and periimplantitis. Consequently, patients with such characteristics should be informed before implant placement and frequently recalled afterward for maintenance visits.

The objective of the following study was to compare the clinical, microbiologic, and host-derived effects in the nonsurgical treatment of initial periimplantitis with either adjunctive local drug delivery or adjunctive photodynamic therapy (PDT) after 12 months. Forty participants with initial periimplantitis, that is, PPD of 4 to 6 mm with BOP and radiographic bone loss ≤2 mm, were randomly assigned to 2 treatment groups. All implants were mechanically debrided with titanium curettes and with a glycine-based powder air-polishing system. Implants in the test group (n=20) received adjunctive PDT, whereas minocycline microspheres were locally delivered into the periimplant pockets of control implants (n=20). At sites with residual BOP, treatment was repeated after 3, 6, 9, and 12 months. The primary outcome variable was the change in the number of periimplant sites with BOP. Secondary outcome variables included changes in PPD, CAL, mucosal recession, and in the bacterial counts and crevicular fluid levels of host-derived biomarkers. After 12 months, the number of BOP-positive sites decreased statistically signiﬁcantly (P<.05) from baseline in both groups. A statistically significant (P<.05) decrease in PPD from baseline was observed at adjunctive PDT treated sites up to 9 months (4.19 ±0.55 mm to 3.89 ±0.68 mm).
and up to 12 months at local drug delivery-treated sites (4.39 ±0.77 mm to 3.83 ±0.85 mm). Counts of P. gingivalis and T. forsythia decreased statistically significantly (P<.05) from baseline to 6 months in the PDT and to 12 months in the adjunctive local drug delivery group, respectively. Crevicular fluid levels of IL-1β decreased statistically significantly (P<.05) from baseline to 12 months in both groups. No statistically significant differences (P>.05) were observed between groups after 12 months with respect to clinical, microbiologic, and host-derived parameters. Nonsurgical mechanical debridement with adjunctive PDT was equally effective in the reduction of mucosal inflammation as with the adjunctive delivery of minocycline microspheres up to 12 months. Adjunctive PDT may represent an alternative approach to local drug delivery in the nonsurgical treatment of initial periimplantitis.

The objective of this randomized double-blind placebo-controlled trial was to study the effect of implant surface decontamination with CHX/cetylpyridinium chloride (CPC) on microbiologic and clinical parameters. Participants with implants diagnosed with periimplantitis (that is, PPD ≥5 mm with concomitant BOP and ≥2 mm of marginal bone loss or exposure of ≥1 implant thread) were treated by means of a combined approach with a deproteinized bovine bone mineral and a collagen membrane in the intrabony and an implantoplasty in the suprabony component of the periimplant lesion. The soft tissues were apically repositioned to allow for nonsubmerged healing. Clinical and radiographic parameters were evaluated at baseline and 12 months after treatment. Eleven participants with 12 implants were treated and completed the 12-month follow-up. No implant was lost, yielding a 100% survival rate. At baseline, the mean PPD was 8.1 ±1.8 mm and the mean CAL 9.17 ±2.5 mm. After 1 year, a mean PPD of 4.0 ±1.3 mm and a mean CAL of 6.7 ±2.5 mm were assessed. The differences between the baseline and the follow-up examinations were statistically significant (P=.001). The mucosal recession increased from 1.8 ±1.5 mm at baseline to 3.0 ±1.8 mm at the 12-month follow-up (P=.003). The mean percentage of sites positive for BOP around the selected implants decreased from 19.7 ±40.1 at baseline to 6.1 ±24.0 after 12 months (P=.032). The radiographic marginal bone level decreased from 8.0 ±3.7 mm at baseline to 5.2 ±2.2 mm at the 12-month follow-up (P=.000001). The radiographic fill of the intrabony component of the defect amounted to 93.3 ±13.0%. Within the limits of this study, a combined regenerative and resective approach for the treatment of periimplant defects yielded positive outcomes in terms of PPD reduction and radiographic defect fill after 12 months.

Little is known about the cost minimization and cost effectiveness involved in maintaining teeth and implants for patients treated for periodontal disease. A retrospective study was carried out encompassing all patients who had initial periodontal treatment followed by implant placement and maintenance therapy in a specialist practice in Norway. The neighboring tooth and the contralateral tooth were used as controls. The number of disease-free years and the extra cost over and above maintenance treatment for both teeth and implants were recorded. The sample consisted of 43 patients with an average age of 67.4 years. The patients had 847 teeth at the initial examination and received 119 implants. Two implants were removed 13 and 22 years after insertion. The prevalence of periimplantitis was 53.5% at the patient level and 31.1% at the implant level. The prevalence of periodontitis was 53.4% at the patient level and 7.6% at the tooth level. The mean number of disease-free years for implants was 8.66; for a neighboring tooth 9.08; and for contralateral teeth 9.93. These mean values were not statistically significantly different from each other. The extra cost of maintaining the implants was about 5 times higher for implants than for teeth. The number of disease-free years was the same for neighboring teeth, contralateral teeth, and implants. However, because of the high prevalence of periimplantitis, the cost of maintaining implants was much higher than the cost of maintaining teeth.

**DENTAL MATERIALS**

**Restoration repair**

The series of articles published in 2012 relating to the teaching of restoration repair in dental schools
continued in 2013, with an additional article describing the teaching practices in Japan.125 Nineteen of 29 schools responded to the survey, and 18 of those schools included teaching the repair of direct composite resin restorations. The one school not teaching the technique did not give reasons. Those that did teach repair listed clinical experience, existing evidence, and information from case reports as the top reasons. Thirteen of the 18 schools taught repair in both didactic and clinical instruction, while 4 reported didactic instruction only and 4 also reported providing only ad hoc clinical experience. The most commonly taught technique was acid etching, followed by a bonding agent and a flowable composite resin. The most common expectation for longevity of a repair was 3 to 5 years. A review article followed a bonding agent and a flowable composite resin. The most common expectation for longevity of a repair was 3 to 5 years. A review article investigated multiple aspects of restoration repair in 106 studies of composite resin repair, 42 studies of amalgam repair, and 51 studies of cast and ceramic restoration repairs.126 The overall conclusion was that repair of all types of restorations appeared to improve quality and longevity, but that the huge variation in study designs and outcomes prevented solid evidence-based recommendations.

A fifth-year continuation of a previously reported study looking at minimally invasive repairs of restoration defects compared the sealing of margins with a dental sealant to total replacement or no treatment.127 After 5 years, 36 of the original 90 restorations were unavailable for evaluation. For the sealant repairs, improvements from baseline were still apparent in margin adaptation, margin staining, and roughness were noted, with no significant changes in sensitivity or secondary caries. When comparing groups, no significant differences were noted in any of the clinical parameters between the repaired and replaced restorations. These results showed that sealing defective margins had similar 5-year results to restoration replacement for Class I and Class II amalgam and composite resin restorations.

The same team of investigators published a similar study looking at the 5-year results of repaired or refurbished Class I and Class II amalgam restorations.128 Margin repairs were done with mechanical preparation and new amalgam; refurbishing was done by polishing and finishing the existing restoration. These 2 methods were compared to complete restoration replacement and no treatment. At 5 years, 108 restorations in 45 patients were available for evaluation. The repaired restorations showed control of secondary caries, but margin adaptation continued to decline, indicating that repairs may not have addressed the underlying problems that led to the initial margin failure. The median survival time of both the repaired and refurbished restorations increased without any detrimental increase in secondary caries, tooth fracture, restoration failure, or pulpal injuries. The investigators noted that sealant repairs of defective amalgam margins, as reported in the previous study, may perform better than repairing the margins with new amalgam; sealing is also a far less invasive technique.

The overall weight of evidence supports the notion that restoration repair using minimally invasive methods can extend restoration life without adding significant risk of failure and in most cases can be as effective as total restoration replacement. Repair techniques are now taught at most dental schools, but other impediments, such as the lack of appropriate procedure codes for repair procedures, may be slowing adoption.

**Adhesives**

The sheer volume of literature related to the laboratory evaluation of dental adhesive systems is mind-boggling, so it was good to read one article in January 2013 that put into context the clinical relevance of these tests.129 This review pointed out that many of the laboratory tests in the literature are poorly validated and few actually correlate with clinical performance. The author concluded that microtensile methods of bond testing tend to correlate with clinical retention of cervical restorations, but only when results from multiple studies are pooled as part of a metaanalysis; any microtensile study taken alone cannot be considered predictive. There was also “some evidence” that marginal adaptation correlates with cervical restoration retention and also with marginal staining in Class II restorations. The author further concluded that microleakage testing with dye penetration does not correlate with any clinical parameter; however, this methodology continues to be useful for achieving degree and tenure publication requirements.

Several of the clinical adhesive studies published in 2013 focused on hydroxyethylmethacrylate (HEMA)-free systems. One investigator published 2 articles on 5- and 6-year prospective evaluations of these systems.130,131 The 5-year prospective study compared 2 such systems, one being a 1-step (G-Bond; GC America Inc) and the second a 3-step etch-and-rinse system (experimental); the study also included a HEMA-containing control group (XP Bond; Dentsply Caulk). A total of 169 nonretentive cervical restorations were followed on 67 participants, and, at 5 years, 159 restorations were available for recall. The results at 5 years showed that the HEMA-free restorations had higher retention (83.8%) than the HEMA-containing restorations (72.9%) with no significant difference between the 1-step and 3-step HEMA-free systems. The 6-year study was also a prospective evaluation of Class II restorations comparing a 1-step HEMA-free adhesive (G-Bond) to a 2-step HEMA containing control (FL-Bond; Shofu Dental Corp). At 6 years, 111 restorations were available for evaluation and again the failure rate
was greater for the HEMA-containing system (8.5% versus 17.7%). Most failures were due to restorative material fracture and tooth fracture.

A third study evaluated the 3-year performance of the HEMA-free G-Bond to the HEMA-containing Clearfil Tri-S Bond (Kuraray America Inc) in 175 noncarious cervical lesions. At 3 years, the retention rate was 93.8% for the Clearfil product and 98.8% for the G-Bond, with no statistical difference between these 2 products. This study, one hopes, will continue to track these restorations to see whether the HEMA-containing system demonstrates the higher failure rates after longer service, as noted in the first 2 studies. A comparison of these studies emphasizes the importance of having longer-term clinical evaluation and also shows that these products have come a long way since the days when Dr Jim Summit described the early adhesive studies thus: “On a quiet night in San Antonio, you can hear the restorations as they hit the floor.”

One 4-year study compared 2 self-etching adhesives with different pH values in nonretentive cervical lesions. Sixty-six restorations (33 with iBond [Heraeus Kulzer] and 33 with Clearfil SE) had 4 failures in each material, with no difference between the 2 products. A second 4-year study compared a selfetch (iBond Gluma; Heraeus Kulzer) to an etch-and-rinse (Tri-S Bond [Kuraray America Inc]) in 175 noncarious cervical lesions. This study also included a parallel laboratory comparison of microleakage and adhesion of these same adhesives. Both the laboratory microleakage and loss of clinical marginal integrity were noted as being greater with the self-etching iBond product, but no differences were observed in restoration retention.

Several additional studies on adhesives were published in 2013 describing the short-term clinical evaluation of adhesive systems. Two had 24-month results, 1 had 18-month results, 1 had 12-month results, and 1 went as far as reporting 6-month results. With the clinical expectations we have for today’s adhesive products, short-term clinical studies add little of value, other than to the author’s publication record, and the specific references for these studies will not be given in this review.

One interesting article compared the influence of rubber dam isolation on adhesive performance. One hundred forty noncarious cervical lesions were restored with either Adper Single Bond 2 (etch-and-rinse) (3M ESPE) or Adper SE Plus (selfetch) (3M ESPE), and both materials were split into groups placed with or without rubber dam isolation. The results demonstrated no difference between materials or isolation techniques, but the reader should also take into account that these are only the 12-month results and so only pertain to early failures. Another article on rubber dam that was not related to adhesives looked at the impact of rubber dam on patient stress and treatment time in children and adolescents. For this study, sealants were placed with and without rubber dam, and patient stress was measured by skin resistance, breath rate, and subjective participant assessment of pain. All 3 measures of stress were lower when rubber dam was used, and treatment time was reduced by 12.4%.

**Sealants and infiltration**

Several studies of pit and fissure sealant performance of moderate length were done in 2013. Three of these studies the influence of adhesives placed before resin-based sealants. A 48-month trial looked at 244 sealants placed on the permanent molars and premolars of young adults ages 18 to 21 years. Grandio Seal (Voco America Inc) sealant was placed with either Solo-bond M (2-step etch-and-rinse) (Voco America Inc) or Futurabond NR (1-step self-etch) (Voco America Inc) adhesive, but no control group of sealant placed without adhesive was included in the design. After 48 months, the retention rate for Solo-bond M was 71.9% and that of Futurabond NR was 8.7%, clearly demonstrating the inferior performance of the self-etch system. What was missing, unfortunately, was a comparison to sealant placed without any adhesive, as the Solo-bond retention rate was similar to reported values of sealant placed on etched surfaces without adhesives.

A second study compared sealants placed with and without bonding systems. This study compared 4 groups, Optibond FL adhesive (Kerr Corp), Optibond Solo Plus adhesive (Kerr Corp) Prompt-L-Pop adhesive (3M ESPE), and etch-and-rinse without adhesive. Retention rates after 3 years were approximately 81% for Optibond FL, 74% for Optibond Solo Plus, 48% for Prompt-L-Pop, and 67% for etch-and-rinse without an adhesive. Unfortunately, this study was complicated by its breaking out results separately on molars and premolars, which reduced the statistical power of comparisons, although the self-etch systems appeared to fare more poorly.

A larger and simpler school-based study used a split-mouth design to compare sealants placed with Scotchbond Multi-Purpose Plus (3M ESPE) with those placed with only etch-and-rinse. Sealant retention and caries were evaluated after 5 years, and no difference was found in sealant retention, new caries, or caries prevented between sealants placed with or without the adhesive system. No studies have yet reported the cost effectiveness of using an adhesive before placing resin-based sealants. Thus far, the necessity of applying an adhesive before a pit and fissure sealant resin has yet to be proven from either a clinical performance or a cost-effectiveness perspective.

Two well-designed school-based studies looked at some unique factors related to sealant performance. The first was a split-mouth randomized trial that compared permanent first molars, where one received a resin-based sealant and the other no treatment. This study also evaluated the effect of caries risk, as measured by active caries, visible plaque, and microbial burden. This report was the first
1-year follow-up of 253 children, and at this point molars receiving sealants were at less risk of developing new caries than control teeth (OR 0.21, 95% CI 0.14, 0.49). Only active caries at baseline was predictive of new caries, regardless of sealant placement (OR 3.11, 95% CI 1.27, 7.62).

A second school-based sealant study looked at the local in vivo fluoride release from 3 different sealants.\textsuperscript{141} Interproximal fluid samples were collected at 3 points up to 21 days adjacent to teeth sealed with glass ionomer cement, a fluoride releasing resin sealant, and a non-fluoride-releasing resin control group. An impressive total of 2640 children completed the trial. At 2 days, both the glass ionomer and fluoride-releasing resin sealants demonstrated significantly higher interproximal fluid fluoride levels. By 7 days, interproximal fluid adjacent to the glass ionomer averaged 2.54 ppm compared to 0.85 ppm for the fluoride-releasing resin and 0.53 ppm for the control sealant. After 21 days, results still showed the glass ionomer to be significantly higher in fluid fluoride. This study confirmed the ability of glass ionomer sealants to achieve a sustained fluoride release in fluids adjacent to sealed teeth.

Two studies of glass ionomer sealants looked at retention rates and caries inhibition. The first compared GC Fuji VII glass ionomer (GC America Inc) with an ormocer-based resin Admira Seal (Voco America Inc) in a split-mouth design on the first molars of 50 children.\textsuperscript{142} After 24 months, retention rates were similar for both materials (>80%), but the presence of caries was significantly different at 16% for the glass ionomer and 32% for the resin-based sealant.

The second study compared glass ionomer sealant with fluoride varnish in a similar split-mouth design.\textsuperscript{143} In this study, the teeth were newly erupted, and the children were grouped as those with and without caries experience. After 18 months, 28 of 299 teeth presented new caries, with sealed teeth having slightly more caries (n=15) than teeth with fluoride varnish (n=13). Most of these teeth (70%) were from children with prior caries. The retention rate for the glass ionomer sealants was 70%. The 11% caries rate for glass ionomer sealant after 18 months is relatively consistent with the 16% reported in the prior study after 24 months, but the interesting aspect was that similar results were achieved with periodic placement of fluoride varnish.

One study coming out of the Practitioners Engaged in Applied Research and Learning network reported on the use of sealants for treating hypersensitive cervical lesions.\textsuperscript{144} This study compared treatment of hypersensitive lesions with either a potassium nitrate dentifrice, a resin-based composite restoration, or placement of a sealant. All 3 treatments significantly reduced sensitivity, but the restoration and sealants resulted in a significantly higher and more immediate reduction. The degree of reduction was similar between the sealant and restoration, providing the opportunity for a less invasive option for sealing these sensitive areas.

Another article compared sealants placed with acid etching with those placed after laser etching.\textsuperscript{145} At the end of 24 months, retention rates were all above 80%, with absolutely no statistical difference between the 30-second etch-and-rinse method and the 30-minute laser etching method.

**Composite resin**

The biggest news in composite resins for 2013 was the awarding of 6 new grants from the National Institute of Dental and Craniofacial Research for the development of the next generation of dental composite resins.\textsuperscript{146} The first year’s funding is set at $2.8 million as the start of a 5-year funding cycle on these projects, which have the overall goals of developing an improved matrix resin and more than doubling the expected service life of composite resin restorations. Although these are laudable goals, these same objectives have been driving composite resin and adhesive research for nearly 5 decades.

Three articles are worth noting that looked at the safety of composite resins. The first was a clinical evaluation of DNA damage to gingival epithelial cells collected adjacent to composite resin restorations.\textsuperscript{147} The cells were collected up to 180 days after restoration placement, and although some cellular DNA damage was noted, the authors concluded that a significant repair process was also present and that the observed damage could not be considered biologically relevant.

The second article described an animal study of the reproductive toxicity of BisGMA in mice.\textsuperscript{148} A range of doses covering 3 orders of magnitude was administered, and a battery of physiological and reproductive parameters were followed for both parent and offspring mice. No observed effects were noted up to the highest dose level, which was equivalent to at least a 280- to 2000-fold increase over the maximum estimated human exposure to BisGMA from dental restorations. The same authors published a nearly identical study looking at the reproductive toxicity of the commonly used diluent monomer triethylene glycol dimethacrylate (TEGDMA).\textsuperscript{149} Again, the results were no observed effects at doses up to 3000-fold the maximum estimated for human exposure from dental materials.

Similar to adhesives, composite resin restorations have achieved a level of predictability where longer-term studies are becoming more common in the literature and are a requirement for properly comparing and assessing performance. Fortunately, there were several examples of such studies in the 2013 literature. A 6-year prospective randomized trial compared a nano-hybrid (Exite/Tetric EvoCeram; Ivoclar Vivadent Inc) and conventional hybrid (Exite/Tetric Ceram; Ivoclar Vivadent Inc) in pairs of Class II restoration in 52 participants.\textsuperscript{150} Fifty participants were available for recall, and the overall success rate was 88.1%, with no differences between the materials. The main reasons for failure were secondary caries and restoration fracture (57.1% combined), and the majority of recurrent...
lesions (63%) were found in patients at high risk for caries.

Two longer retrospective studies were published, the first comparing longevity of glass ionomer with composite resin in Class V restorations. In cervical restorations (564 total) were evaluated by means of a record review of 131 recall patients at a university clinic up to 23 years after placement. Kaplan-Meier survival analyses indicated median survival times of composite resin restorations to be 10.4 ±0.7 years (median ± standard error) and for glass ionomers 11.5 ±1.1 years. Restorations on anterior teeth survived approximately 3 years longer than those on posterior teeth, and a difference in survival between the 2 materials was only evident in anterior teeth, where composite resins fared better. One interesting note was that the survival estimates for restorations placed by residents were significantly below those placed by dental students or professors. No differences were found in secondary caries or postoperative sensitivity between the 2 materials, but composite resin proved superior in retention, marginal discoloration, and marginal adaptation.

This same team of investigators did a similar retrospective study of stress bearing amalgam and composite resin restorations. In this study, 269 Class I and Class II amalgam and composite resin restorations were tracked up to 18 years. The median survival times for amalgam restorations was 8.7 years and for composite resin restorations 5.0 years. For amalgam, Class I restorations had a median survival of 10.0 years versus 6.9 years for Class II. Composite resin Class I and Class II survival times were not statistically different at 3.3 or 5.4 years. Many different parameters were analyzed with respect to survival, and some of the most significant were patient age, with the highest risk being in the 20- to 30-year and 50- to 60-year age bands, tooth type, with molars at 2.45 times the risk of premolars, pulparly involved teeth being at 8.7 times the risk of noninvolved, and again an interesting situation where in this case restorations placed by dental students were at much lower risk of failure than those placed by residents or professors.

Two shorter studies were published of silorane-based composite resin restorations, limited in time by the shorter market availability of these products. The first looked at Class I posterior restorations and compared the Filtek Silorane composite resin (3M ESPE) with a traditional nanocomposite CeramX Duo (Dentsply Caulk) in 100 randomly assigned paired restorations. At 24 months, no secondary caries or postoperative sensitivity was found with either material, and only a slight downward shift to a few Bravo scores for both materials was found.

A second double-blind randomized trial similarly compared a silorane-based (Filtek P90; 3M ESPE) composite resin with a methacrylate-based (Filtek P60; 3M ESPE) system in Class II restorations. Eighty-eight restorations were evaluated after 18 months, with no differences in survival rates (>90%), but some degradation was noted in marginal integrity, marginal discoloration, and surface texture for the silorane-based product. The methacrylate-based product exhibited some degradation in marginal degradation and surface texture also. It will be interesting to see how these systems continue to perform when longer-term data are available.

One large study reported the 8-year follow-up of restorations placed on permanent teeth in children who were part of the public health service in Denmark. This study tracked the performance of more than 4000 posterior composite resin restorations placed by 115 dentists. The cumulative survival rate at 8 years was 84%, with secondary caries being the most frequent cause of failure (57%). Material failure was present in only 6% of failures, and 10% of restorations reported some form of postoperative sensitivity. Of the more than 500 restorations that were repaired or replaced, the most common reason was primary caries in a nonfilled surface.

A related study investigated the risk factors influencing failures of composite resin restorations. In this study, 306 posterior composite resin restorations were retrospectively assessed for 10 to 18 years, and the results were related to caries risk and occlusal stress, as measured by bruxism damage. In total, 30% of restorations failed, with secondary caries as the main reason for failure in caries-risk patients and material failure as the main reason in occlusal stress patients. Other factors with a significant impact on failure were tooth type, with posterior teeth having higher failures and pulp vitality with nonvital teeth exhibiting higher failures. The overall message continues to be that caries risk is a significant factor for composite resin restoration success and that restorations do not interrupt the natural course of the disease. If we want longer-lasting and more predictable restorations, we need to eliminate the underlying disease risks.

Several studies published in 2013 looked at specific clinical applications of resin-based materials. The first was a 7-year prospective split-mouth randomized trial that evaluated the direct composite resin restoration of worn anterior mandibular dentition. The results from 107 restorations in 15 adults showed an overall restoration survival of 85%, with 53% of patients retaining all of their restoration. Marginal breakdown was the most frequent complication, but most patients were satisfied with the outcomes, and the investigators thought that the restorations required an acceptable level of maintenance.

Another trial evaluated the 5-year clinical performance of posterior composite resin restorations replacing 1 or more cusps. Survival rates were 86.6% when counting restorations with complete and repairable failures and 87.2% when counting only complete failures. The mode of failure was considered by the authors to be predominantly adhesive in nature, although it was difficult to establish how this was determined. Unfortunately, wear was not reported as part of this study.
A study of the wear of composite resin posterior crowns with and without fiber reinforcement was done by comparing them with metal ceramic crowns. After 3 years of clinical service, no difference was observed between the fiber and nonfiber composite resins, but both exhibited greater wear than the metal ceramic crowns. This amount of composite resin wear, however, was still considered as clinically acceptable by the authors.

Last, a 5-year follow-up report was published on diastema closures done with 176 direct composite resin restorations. Over the 5-year period, 30 restorations required some level of repair, with none being completely lost, and the clinical quality was rated as good or excellent for more than 90% of the restorations. These results provide support for this minimally invasive technique.

Overall, it appears that the clinical performance of composite resins continues to evolve but that the underlying issue of recurrent caries is still the primary nemesis, and this factor is controlled by risk. Until we adequately address the underlying risks for disease, we cannot expect the materials to overcome this barrier.

**Amalgam**

The biggest news related to amalgam in 2013 was the U.S. Department of State signing the Minamata Convention on Mercury on November 6. The convention was developed through 4 years of international negotiations by 147 governments to limit mercury emissions to the environment. It put in place measures to limit emissions from industrial sources such as coal burning and chlor-alkali production, and it also directly addressed limiting the use of mercury-added products such as dental amalgam. Nine specific measures were stated in the document that relate to the phasing out of dental amalgam, of which any member country shall adopt 2 or more. These measures range from setting national caries prevention targets to adopting best management practices for amalgam waste. Several of these measures have already been adopted in the United States, thus assuring that we remain in compliance with the convention.

One study related to the exposure of dental students during training in amalgam removal measured mercury vapor levels generated while using water spray and suction, suction only, and no water spray or suction. Vapor levels were measured in ambient air with the Jerome Mercury Analyzer, and results showed that the mean concentrations were 8 µg/m³ with water spray and suction, 141 µg/m³ with suction only, and 214 µg/m³ when neither suction nor water spray were used. The Canadian authors noted that the levels generated using water spray and suction never exceeded the Alberta Occupational Health and Safety threshold value of 25 µg/m³ for constant exposure over an 8-hour period.

A second Canadian study assessed the urinary mercury concentrations of 5416 individuals aged 6 to 79 and stratified results by sex, age, and number of amalgam surfaces. Overall mean concentrations ranged from 0.12 µg/L to 0.31 µg/L, which was well below the lowest level associated with adverse effects of 7.0 µg/L. Women had generally slightly higher concentrations than men, but they were still below the values considered to pose any risk to health.

Another mercury study looked at the prenatal exposure of children as part of the Seychelles Child Development and Nutrition Study. In this study, the neurodevelopment of 5-year-old children was assessed with a battery of tests, and the results were correlated with the maternal amalgam status of their mothers, as measured by both amalgam surfaces and occlusal contact points. Exposure to methylmercury and other covariates related to neurodevelopment was taken into account as part of the analysis. The maternal amalgam status averaged 7 surfaces and 11 contact points across the 236 mothers. Neither the number of surfaces nor the number of occlusal contact points could be associated with any of the neurologic outcomes of the offspring children, thus again not supporting a relationship between prenatal exposure to elemental mercury from maternal dental amalgam and neurologic development in children. A second study with more questionable results looked at the neurobehavioral effects of mercury and their possible association with genetic polymorphisms of metallothionein. The study was described as an attempt to study the effects of mercury from amalgam exposure, but all measures and associations were made to urinary mercury, and no attempt was made to control for or identify actual or potential sources. Results were also suspect in that few independent main effects or interactions were present in girls. In boys, however, while there were no independent main effects from the 2 genetic variants, a significant interaction was reported between the two when associated with several neurobehavioral measures. The authors did point out that these findings did not support an association between dental amalgam and any adverse neurobehavioral outcome.

One study sought to determine whether stable isotopes of mercury could be used to distinguish between exposure to methylmercury and amalgam-derived elemental mercury. It was hypothesized that methylmercury from fish could be demethylated in the body and excreted as inorganic mercury in urine. Thus, urinary mercury would not reflect only amalgam exposure, but rather exposure to both amalgam and dietary methylmercury. Using isotopes they were able to determine that greater than 70% of urinary mercury from individuals with less than 10 amalgams was derived from the ingestion of methylmercury in fish. These results confirm that total urinary concentrations can overestimate exposure from dental amalgam for individuals consuming fish.

In an interesting play on the adage popularized by Mark Twain, “There are lies, damned lies, and statistics,” an
additional statistical assessment was published of the data emanating from the Casa Pia children’s dental amalgam trial. The parent study assessment of kidney function found no association between kidney function and exposure to dental amalgam. The authors of this present assessment claimed to use “a different and more sensitive statistical model” that now revealed a significant dose-dependent relationship between exposure to mercury from dental amalgam and 1 marker of possible kidney integrity. This further confirms that for every PhD, there exists an equal but opposite PhD.

People in Sweden who believe that they are experiencing adverse reactions to dental materials are eligible for subsidized replacement of those materials. A study reported changes in quality of life and symptoms in patients who had amalgam restorations replaced as part of this replacement policy. A total of 280 of 515 people who had applied for subsidies responded to a survey to see if restoration replacement had improved their symptoms and health-related quality of life to the levels of the general population. The results showed that the study participants’ quality of life was still significantly lower than that of the general Swedish population and that the most common remaining symptoms were musculoskeletal pain, sleep disturbance, and fatigue.

A second study from Sweden evaluated the patient-perceived oral health and reception from dental personnel by patients reporting problems with dental filling materials. A total of 9813 persons responded to a questionnaire; about 10% (868) reported problems from dental filling materials. Not surprisingly, this group perceived their general and oral health as being worse than that of others, and they also felt less well treated by dental personnel. No consistent socioeconomic or lifestyle characteristic, however, could be associated with those experiencing problems with dental materials.

One case report was published of an orofacial granulomatosis related to dental amalgam fillings. All signs and symptoms of the lesion completely resolved after replacing the amalgams with composite resin, highlighting that reactions, although rare, can occur in dental materials and that delayed patch testing for patients with orofacial granulomatosis should include dental materials.

A study compared the brain mercury levels in 10 cadavers with amalgam fillings to 22 that were amalgam-free. The average brain mercury concentration of the amalgam group was 0.97 ±0.83 μg/g, while the amalgam-free group had an average concentration of 1.06 ±0.57 μg/g, thus showing no correlation between the presence of amalgam and brain mercury levels.

The National Practice-Based Research Network published a 24-month evaluation of amalgam and resin-based restorations, but few conclusions could be made at this early time other than failures were more prone in restorations with multiple surfaces. This trial included 6218 restorations placed by 226 practitioners, so, one hopes, time will provide more definitive and predictive outcomes.

Another larger study of amalgam and composite resin restorations placed in military clinics looked at the frequency of replacement over about 3 years. A total of 485 composite and 565 amalgam restorations were followed, with a total replacement rate of 5.7%. No difference between the 2 materials was found, but both the number of surfaces and caries risk status were significant factors for replacement.

Another comparison of amalgam and composite resin compared pulpal response with the 2 materials placed in premolars scheduled for orthodontic extraction. At Day 1, there was no histologic difference in pulpal response; however, by Day 7, the inflammatory response was statistically greater in teeth restored with composite resin. This study failed to look at response after 30 days when inflammation is generally resolved and pulpal repair becomes more evident.

The overall assessment of the safety and performance of amalgam continues to support it as a viable treatment for direct restorations. Although overall use continues to decline, the material still provides a safe, cost-effective, durable, and predictable option.

**Endodontic materials**

With the variety of endodontic materials available today, determining whether something new is necessarily better can be difficult. One review article published in 2013 attempted to compare the sealing ability of newer obturation materials. Both in vitro and in vivo studies were reviewed, only to find that, again, few in vitro models of sealing ability correlated with clinical success, likely because of the interaction of the many factors that influence endodontic success. As is also often the case, the authors concluded that classic filling materials have withstood the test of time and that insufficient evidence is available for newer materials to prove superiority.

The treatment of primary tooth pulpotomies was the subject of 3 articles assessing the use of mineral trioxide aggregate (MTA). The first surveyed 39 pediatric residency programs to see what techniques were most commonly taught. Results indicated a small decrease in the teaching of formocresol 1:5 dilution; however, 82% of residency programs were still teaching this technique. The teaching of both ferric sulfate and MTA techniques increased, with about 25% of programs teaching MTA; however, the added cost of this material was a concern. The overall results indicated no major shift away from the use of formocresol over the last 5 years.

A second study compared MTA to Portland cement and calcium hydroxide as pulpotomy agents in primary teeth. Treated teeth were followed for 24 months, with histology done after exfoliation, and the results showed 100% success with MTA and Portland cement, while calcium hydroxide was associated with some residual canal necrosis. The results were equivalent between MTA and Portland cement.
other than the fact that 68,000 teeth could be treated with a single 94-pound bag of Portland cement.

A third study compared MTA with diluted formocresol in primary molars. 172 Two hundred fifty-two primary molars were followed up for 42 months with radiographs, and no significant differences were found in clinical survival between the 2 materials; however, radiographic findings were 5.1 times more likely in teeth treated with formocresol than in those treated with MTA.

Similar studies were also published comparing materials used for partial pulpotomies on permanent teeth. One randomized trial compared calcium hydroxide with MTA for direct pulp capping of caries exposed young permanent molars. 179 Eighty-four teeth were assigned to either Dycal (Dentsply Caulk) or ProRoot MTA (Dentsply Tulsa Dental Specialties) and followed by means of radiographs and clinical symptoms for 2 years. Three teeth in total had unfavorable outcomes, with no difference in survival between the 2 materials. These failed teeth, however, were in exposures larger than 5 mm. 2

A second randomized controlled trial compared the performance of MTA (ProRoot MTA) with a bioceramic paste (iRoot BP; Veriodent). 180 Twenty-four sound premolars scheduled for orthodontic extraction received direct pulp capping and were observed histologically 6 weeks after treatment. No difference in inflammation or dentin bridge formation was found between the 2 materials, and the only noted difference was in a lower incidence of cold sensitivity reported for the teeth treated with MTA. Although this demonstrated good pulpal compatibility, it must be kept in mind that these were not diseased teeth with compromised pulps.

Several studies compared the clinical performance of calcium-enriched cement (CEM) with MTA in both pulp capping and pulpotomy applications. The first was a histologic comparison of a CEM (Biodentine; Septodont) with MTA in caries-free permanent molars scheduled for orthodontic extraction. 181 The results after 6 weeks showed similar dentin bridge formation in these healthy pulps.

A second study compared CEM with MTA for pulpotomies on caries exposed immature permanent first molars. 182 Clinical symptoms and radiographs were used to follow 51 treated teeth over 12 months, looking for signs of apical closure. All teeth showed pulp survival and signs of continuous root development with more than 70% apical closure in both materials. Another randomized clinical trial compared CEM with MTA in permanent molars with irreversible pulpitis in 413 participants. 183 Participants were followed clinically and radiographically for 12 months. Results showed no differences in pain symptoms, with a more than 90% clinical and radiographic success rate in both materials.

A fourth study compared the clinical success of MTA with CEM as a direct pulp capping material in primary molars. 184 This trial compared clinical and radiographic success for 20 months after placing direct pulp caps on 42 symptom-free carious vital primary molars. Only 1 tooth required extraction because of failure, and clinical/radiographic success rates were similar at 89% for CEM and 95% for MTA. The studies thus far show that calcium enriched cement and MTA perform similarly as direct pulp capping and pulpotomy materials.

One study looked at indirect pulp capping in a randomized clinical trial comparing calcium hydroxide, Portland cement, and MTA. 185 Each material was placed over deep lesions where incomplete caries removal was done. Teeth were reentered after 6 months and remaining diseased dentin evaluated for clinical color, consistency, and microbiology. All 3 materials had a high overall success rate of 90.3%, with residual carious dentin showing consistent signs of sclerosis and lower bacterial counts. These findings offer further support for the ability to arrest active lesions with partial excavation and perhaps for the provision of permanent restorations without the need for reentry.

A large comparative trial of direct pulp capping with calcium hydroxide and MTA was published from the Northwest Practice-based Research Collaborative in Evidence-based Dentistry. 186 Teeth in 376 individuals were randomly assigned treatment and evaluated clinically and radiographically for the subsequent 2 years. The probability of failure at 24 months was 31.5% for calcium hydroxide and 19.7% for MTA, with MTA demonstrating a statistically superior performance in this practice-based comparison.

Last, a retrospective study of the outcomes of root perforations repaired with MTA was done on 90 teeth. 187 The mean follow-up interval was 3.4 years, and 66 (73.3%) of teeth were classified as healed by clinical radiographic assessment. Teeth where the lesion originally presented with the perforation site communicating with the oral cavity had the lowest success rate.

Although uncertainty may still surrounding the performance of new root canal obturation materials, the performance of newer pulp capping and pulpotomy materials consistently demonstrates that products such as MTA, Portland cement, and CEM provide consistent and predictable success.

OCCCLUSION AND TMD

The quest for a greater understanding of the temporomandibular joint (TMJ) and occlusion continued in 2013, with numerous articles published in the dental literature. Several topics were addressed throughout the year in a number of different publications.

A study by Cuccia et al 188 evaluated the arterial blood flow in 10 individuals without signs or symptoms of TMD. The cohort consisted of 5 men and 5 women with ages ranging from 25 to 46 years (mean 36 years) who underwent contrast-enhanced computed tomographic scanning.

The blood supply to the TMJ is circumferential. Every vessel within a radius of 3 cm contributes branches to

The Journal of Prosthetic Dentistry

Donovan et al
the joint capsule and contributes one or two branches to it. The blood vessels to the TMJ mainly originate from the superficial temporal artery, which is approximately 3.8 mm in diameter, and the maxillary artery, which is approximately 3.2 mm in diameter. In the retrodiscal tissue, which is responsible for the nutrition of the TMJs, are the branches of the maxillary artery (posterior auricular, anterior tympanic, and meningeal medial arteries) and the temporomandibular veins, as well as the auriculotemporal and posterior auricular nerves.

A number of imaging techniques have been used to assess the TMJs. The most prevalent alteration involving the TMJs are dysfunctional conditions (internal derangement) and nondysfunctional diseases (arthritis, infections, coronoid process hyperplasia, secondary neoplastic process, fractures, synovial chondromatosis (SC), and avascular necrosis of the condyle). Computed tomography and magnetic resonance imaging (MRI) are important in the diagnosis of diseases of this region because they provide greater accuracy than conventional radiology and because their anatomic resolution is higher. The 3-dimensional volume rendering of computed tomography angiography is a promising noninvasive diagnostic tool for evaluating the vascular anatomy of TMJs, for further understanding TMJ disorders (TMD) as related to vascular abnormality, and for improving the planning of surgical procedures.

The diagnosis of TMD generated several articles. An article by Al-Jamali et al. outlines the pitfalls that may arise from a preoccupation with TMJ pain and dysfunction and confirms the importance of early detection and the exclusion of malignancy as a cause of TMJ-related symptoms. Physicians often diagnose functional disorders of the TMJ such as abnormal mandibular movements and orofacial pain as TMD without seriously considering other possibilities. Once this diagnosis has been made, moreover, only mechanical intraarticular and musculoligamentous disorders are considered. This narrow point of view regarding facial pain (mainly concentrating on the TMJ) can lead to a real risk of misdiagnosing the rare patient with a neoplastic tumor. Such patients present a serious diagnostic challenge, especially when the clinical signs of TMJ dysfunction are present. Therefore, the clinician must thoroughly review the patient’s medical history, perform an adequate physical examination, and use advanced imaging modalities to exclude nonarticular symptoms camouflaged as TMJ diseases before reaching a diagnosis of TMD alone.

A high index of suspicion is indicated when patients present with persistent typical and atypical facial pain and TMD symptoms. A detailed ear, nose, oral, and neurologic examination must be performed whenever persistence or worsening of TMJ symptoms occurs. If the treating physician recommends conservative treatment, it is mandatory to evaluate the success of this treatment. The patient has to be followed regularly to ensure improvement in his or her condition. Failure to improve, or worsening of the patient’s symptoms, is an absolute indication for referring the patient for radiologic investigation, which could eventually lead to a correct diagnosis and management. According to the authors, the failure of the patient with TMD to respond to the appropriate therapy and persistent complaints should alert physicians to consider malignancy in their differential diagnosis. Radiologic investigation is mandatory in such cases.

One of the articles related to TMJ diagnosis was authored by Sharma et al., who published a systematic review of joint vibration analysis in the diagnosis of TMD. The main finding of the systematic review was that the body of literature reviewed is currently unable to provide convincing evidence to support the reliability and diagnostic validity of joint vibration analysis in the diagnosis of TMD.

A second article related to electronic instrumentation by Haralur was a digital evaluation of functional occlusion parameters and their association with TMD. The functional dynamic occlusal contacts were evaluated by conventional and T-Scan (Tekscan Inc) analysis for 50 normal (control) joints (Group 1) and 50 participants with TMD (Group 2). The patient’s dynamic occlusal contacts were evaluated by both conventional and digital methods. Articulating article was used for conventional occlusal analysis. During conventional analysis, centric, lateral, and protrusive interferences were evaluated along with loss of vertical dimension. Digital occlusal analysis was performed with T-Scan III.

The results of the study showed a statistically significant difference (P=.027) in the type of occlusion between the TMD and control group. The majority of participants in the positive TMD group (Group II) had group function occlusion (66.0%), while the Group I control group had predominantly canine guided occlusion. Of the occlusal interference evaluated, balancing side interferences were found to have statistically significant correlations with TMD (P=.003). Working side and protrusive interferences had P values of .826 and .157 respectively, indicating a poor correlation with TMD.

A slide from centric relation to centric occlusion of more than 2 mm is considered an important occlusal parameter responsible for joint pathosis. From initial tooth contact (centric relation) to maximum intercuspal position, shifting of the mandible is observed in most individuals within the range of 1 to 2 mm. This slide is known as the centric slide and leads to mandibular instability if it exceeds 2 mm. This may further cause the muscle bracing of condyle and joint pathosis. The results of the study reconfirmed the strong influence of a centric slide of more than 2 mm on the initiation of TMD (P=.008).

The diagnosis of the TMJ through the use of imaging was a popular topic, with a number of articles on this topic published in 2013. Hunter and Kalathingal published a comprehensive review of different imaging options for TMJ diagnosis. Orofacial pain may be
attributed to a variety of disorders, including atypical idiopathic facial pain, TMD, diseases of odontogenic or soft tissue origin, neuralgia, and headaches. TMD is considered to be the main cause of pain in the orofacial region following pain of odontogenic origin. Research diagnostic criteria for TMD (RDC/TDM) were established and published in 1992. The RDC/TMD recommends arthrography and MRI for disk displacement and tomography for the evaluation of bony changes. Since the establishment of the RDC/TMD, additional imaging techniques have become available.

Diagnostic imaging, when indicated, is an important part of the examination process for patients with TMD and orofacial pain. Imaging may be used to confirm suspected disease, rule out disease, and gather additional information when the clinical diagnostic is equivocal or unclear. Indications for diagnostic imaging include trauma, changes in occlusion, limitation of opening/closed lock, presence of reciprocal click, crepitus, systemic diseases, swelling/infection, and failure of conservative treatment.

Imaging modalities for hard tissue evaluation include panoramic radiography and cone beam computed tomography (CBCT). Panoramic radiography is not listed as an option for evaluating hard tissue in the RDC/TMD. CBCT allows for the evaluation of osseous tissue with radiation exposures that are 10% or less of medical CT. The high spatial resolution of CBCT allows for the evaluation of early bony changes in the TMJ. CBCT has also been shown to perform better than conventional tomography, panoramic radiography, and magnetic resonance imaging (MRI) for the evaluation of the components of the TMJ.

MRI has superior soft tissue differentiation because of its improved contrast resolution over conventional tomography and CBCT. Therefore, MRI is used to evaluate the soft tissue components of the TMJ. MRI may be used to evaluate the position of the disk, the shape of the disk, the signal of the disk, the presence/absence of fluid within the joint space (joint effusion), the marrow signal of the condyle, the presence of loose bodies within the joint, pannus formation (in the case of inflammatory arthritides), and osseous changes.

Headaches are another indication for advanced imaging. A severe headache of sudden onset, a new-onset headache, a migraine of adult-onset cluster headaches, and a change in the nature of the headaches are all potential indications for brain imaging. Headaches may indicate the presence of tumors, aneurysms, or arteriovenous malformations. Depending on the cause of the headaches, CT or MRI or both may be necessary for diagnosis.

Krishnamoorthy et al. authored a article discussing CBCT imaging for TMJ assessment. Several radiographic methods are used to assess the TMJ, an area that is difficult to image because of the superimposition of adjacent structures and morphologic variations. The complexity of the TMD, however, demands a clear and precise image of the region for effective management of the patient. CBCT provides a definite advantage over other techniques because of its low radiation dose, smaller equipment, and ability to provide multiplanar reformation and 3D images. Research in the field of CBCT in TMJ imaging is promising. However, more systematic clinical studies, adequate training of personnel, and a complete understanding of the anatomic and functional dynamics of the TMJ are required to harness the true potential of this breakthrough technology.

The MRI of the TMJ was addressed by Lamot et al. TMJ dysfunction is a common condition that affects up to 39% of the population and is associated with a wide range of clinical signs and symptoms, such as pain, clicking, crepitus, restriction of motion, deviated jaw, headaches, vertigo, and tinnitus. MRI is the primary imaging technique in the diagnosis of TMJ dysfunction because it provides superior information about all joint structures in a noninvasive way. TMJ dysfunction is known to be of multifactorial origin, with internal derangement, osteoarthritis, and diffusion diagnosed by MRI being cited in the dental literature as major influences. Detecting early MRI signs of TMJ dysfunction is important because the advanced and irreversible phase is characterized by osteoarthritic changes.

The prevalence of disk displacement in symptomatic individuals is much higher than in the normal population. Disk displacement has been found in 77% to 94% of patients with symptoms of TMJ dysfunction referred for MRI and in 20% to 34% of the asymptomatic population. The aims of this study were to determine which of the morphologic manifestations detected by MRI correlate with the signs and symptoms of TMJ dysfunction and to assess the impact of sex and age on the occurrence of these manifestations.

The study group consisted of 144 participants (109 women and 35 men; mean age 39.4 years, range 12 to 81 years). One hundred ninety-nine (69%) of 288 joints were clinically symptomatic. Disk displacement was found in 69 (73%) of 94 clinically symptomatic joints on the right and in 80 (76%) of 105 clinically symptomatic joints on the left. On the right, 44 (47%) of 94 symptomatic joints had anterior displacement with reduction and 25 (27%) had anterior displacement without reduction, while no signs of disk displacement were found in 25 (27%) of the symptomatic joints. The numbers for the left side, with a total of 105 symptomatic joints, were 41 (39%) with reduction, 39 (37%) without reduction, and 25 (24%) with no signs of disk displacement. Osteoarthritis was recorded in 47 (50%) symptomatic joints on the right and in 59 (56%) symptomatic joints on the left and in 4 (8%) of 49 clinically asymptomatic joints on the right and in 5 (13%) of 39 asymptomatic joints on the left. Joint effusion was found only in clinically symptomatic joints, with 16 (17%) joints on the right and 13 (14%) joints on the left.

The results of the study showed that symptoms of TMJ dysfunction were associated with a high rate of TMJ disk
displacement. MRI confirmed disk displacement in 149 (75%) of 199 clinically symptomatic joints. This observation compares favorably with the results of other studies reporting a prevalence of TMJ disk displacement in the population, with TMJ dysfunction ranging from 64.4% to 89%, and supports the hypothesis that the pathogenesis of TMJ dysfunction is closely related to TMJ internal derangement. Among the 89 asymptomatic joints from this series, disk displacement was found in 42 individuals (47%). A prevalence of disk displacement of 30% to 39% among asymptomatic volunteers has been reported in the literature, which suggests that symptoms not associated with signs of internal derangement in the joint may be related to osteoarthritis, synovitis, joint effusion, or morphologic changes in the belly of the 2 lateral pterygoid muscles. Osteoarthritis was found in 52% of symptomatic joints and in 10% of asymptomatic joints. These observations only partially match the literature data, in which osteoarthritis is reported to be present in 11% to 58% of symptomatic joints and in 50% to 90% of asymptomatic joints. This mismatch is probably due to the lack of a uniform imaging criteria classification for diagnosing TMJ osteoarthritis.

This study found that MRI-recorded morphologic manifestations of TMJ dysfunction (disk displacement, effusion, osteoarthritis) were associated with the presence of symptoms of TMJ dysfunction. Sex did not correlate with disk displacement, osteoarthritis, or effusion of TMJ. Osteoarthritis was more common in the older population, and effusion was more common in the younger age group. This study confirmed the importance of both clinical examination and MRI in the diagnosis of TMJ dysfunction and consequently in the selection of the most appropriate therapy.

Another article was published correlating the changes observed in TMJ internal derangements assessed by MRI in symptomatic patients. TMD are a major cause of maxillofacial pain and involve changes in the masticatory muscles and internal derangement of the TMJ. Internal derangement describes an abnormal relation among the articular disk, condyle, and articular eminence and has been associated with clinical features such as articular pain and articular noises. Study of the articular structures seems essential to assess the pathogenesis of internal derangement, and MRI has advanced the study of the TMJ by identifying changes in soft and bony tissues. The images provide information about the position of the articular disk, quantitative data about the synovial fluid, and qualitative data about the conditions of the bony structures. Disk displacement is one of the most frequent types of TMD and occurs in the joints of symptomatic and asymptomatic individuals, with a high prevalence in women 20 to 40 years old. This intracapsular dysfunction leads to degenerative changes in the disk itself and in the articular surfaces. The disk is often displaced anteriorly, but a high incidence of lateral displacement also occurs.

Sagittal and coronal T1, T2, and proton density images of the joints of 71 symptomatic participants (22 men and 49 women; 13 to 69 years old; mean 38.7 years) were obtained after the participants had taken the medications prescribed by their physicians and dentists. Bilateral images were obtained with an open mouth (openings of 10, 20, and 30 mm) and a closed mouth (maximal intercuspation), for a total of 142 TMJs. All images were assessed by 2 experienced radiologists, and the definitive diagnoses were obtained by consensus. The data from their reports were used in this study.

All participants reporting at least 1 sign or symptom of TMD were included in this study. These symptoms included pain, limited mouth opening, TMJ clicking, and crepitation. The images of individuals who underwent surgical procedures or had inflammatory joint diseases, facial growth disturbances, facial bone trauma or fracture, and hyperplasia, or tumors in the mandible head region were excluded from the study.

The clinical examination alone is often insufficient to diagnose some conditions of the TMJ. MRI is considered the gold standard because it allows the evaluation of soft tissue, including the position and contour of the articular disk and bone changes. In regard to the form of the disk, the authors found that most joints assessed were normal, represented by 83 joints (58.5%). The elongated form was observed in 35 joints (24.6%), and the folded form was found in 24 joints (16.9%). Morphologic changes in the disk are recognized as an important characteristic of internal derangement; nonetheless, the configuration of the articular disk is considered as remaining normal in the initial stages of internal derangement. In regard to the anterior displacement of the disk, 76 joints (53.5%) were normal in the present sample, 34 (23.9%) showed disk displacement with reduction, 31 (21.8%) showed disk displacement without reduction, and only 1 (0.7%) joint showed posterior displacement. The negligible posterior displacement value found in this study is confirmed in the related literature that describes this occurrence as rare.

In conclusion, MRI allowed a clear assessment of the articular structures and correlations between bone and soft tissue, without defining a cause-and-effect relation. The prevalence of the observed changes was associated with the diagnosis of internal derangement, an observation underpinned by statistically proved correlations. Soft tissue changes, anatomic and positional, were also associated, but no correlations were found among the different bone changes. The presence of joint effusion was associated with bone and soft tissue changes, except for the articular eminence, leading to the conclusion that joint effusion is part of an inflammatory response. An interesting study by Claudino et al examined the pharyngeal airway of adolescents in relation to facial skeletal pattern. Many studies have assessed the relationship between craniofacial morphology and the pharyngeal airway.
in cephalometric radiographs. However, lateral radiographs are limited because they reproduce a 3-dimensional structure in a 2-dimensional manner that does not allow the assessment of cross-sectional areas and volumes of these structures. Techniques that allow the precise diagnosis of changes in the upper airway, considering their morphology and volume, are fundamental to ensure the normal development of the craniofacial complex in growing participants and the choice of an adequate treatment plan.

The main objective of this study was to assess the volumes of the upper pharyngeal portion and nasopharynx and the volume, minimum axial areas, and morphology of the lower pharyngeal portion and its segments (velopharynx, oropharynx, and hypopharynx) with CBCT scans of 13- to 20-year-old participants divided into Class I, Class II, and Class III groups according to their A point, nasion, B point angles.

Participants with a Class II relationship had significantly smaller lower pharyngeal areas, velopharynx and oropharynx minimum axial areas, and mean areas than did the Class III group, and a mean lower pharyngeal portion minimum axial area of 112.9 mm². One participant in the Class II group even had a minimum axial area smaller than 52 mm², which is considered severe. This finding led to the conclusion that individuals with a Class II relationship are more susceptible to the development of obstructive sleep apnea (OSA) syndrome than are patients with different skeletal patterns.

Orthodontists must be aware that specific dimensional characteristics, such as a greater constriction, might be associated with the skeletal pattern. Dimensional airway assessments of the upper airway that include 3- and 2-dimensional measurements such as those that were used in this study are relevant information for the orthodontic diagnosis and treatment plan. Considering this information, an orthodontist must define the best treatment for each patient, avoiding treatments that could compromise airway dimensions in those already prone to smaller dimensions in this structure.

In a study involving 17 participants with an average age of 16.8 years, Maglione et al analyzed the relationship between facial and/or condylar-mandibular asymmetry and joint disk displacement. TMJ disk displacement was diagnosed by means of clinical examination, nuclear magnetic resonance, panoramic radiography, and, in some individuals, scintigraphy and CT. All participants with facial and/or condylar-mandibular asymmetry had TMJ disk displacement. Almost all the patients had disk displacement without reduction, one had disk displacement with reduction, and another had partial reduction.

This study found that the smaller size of the condyle is often not limited to the condylar head but also involves its neck and sometimes the ascending ramus of the mandible. This means that the disk displacement and secondary degenerative process may affect the growth of the condylar-maxillary complex. The processes generated by internal derangement may affect the nutrition and lubrication of the mandibular condyle, leading to the alterations in function and normal physiology associated with degenerative processes. The degenerative processes include osteoarthrosis, which is the most characteristic. Osteoarthrosis originates in a non-inflammatory process characterized by cartilage abrasion, deterioration, and thinning. During the course of its development, secondary inflammatory processes may appear, with pain and alteration of the morphology, and with multiple cellular changes, including the increase in the number of osteoclasts and macrophages and subsequent infiltration of the synovia due to activation of A and B cells. This is followed by the appearance of inflammatory mediators of the type of interleukins, proteinases, and regulators of cartilage and bone formation, which appear to play an important role in the progression of osteoarthrosis at the molecular level.

As a result of these processes, the ability of the condylar cartilage to adapt is limited, enabling the occurrence of alterations in its morphology. Last, because of the items mentioned above, growth limitation would be the final outcome of disk displacement without reduction when the onset occurs during growing age. In experimental studies on animals, in which the TMJ disk was displaced surgically, growth decreased, with a shortening of the mandibular ramus and morphologic alteration of the joint cranial fossa.

When internal derangement is characterized by disk displacement, with its clinical sign of joint noise, at an early age, it should be observed closely for possible association with degenerative processes and their concomitant deformation and alteration of the growth of the condylar-mandibular complex. This may cause severe facial asymmetry, which is difficult to resolve once it has set in.

Branco et al investigated the association between headache and TMD in children in a study of 93 children with ages ranging from 6 to 14 years. Fifty-five percent of the total sample were girls. The clinical examination revealed an absence of malocclusion in 63.4% of the participants (n=59). Malocclusion involved anterior open occlusion (n=12) and anterior open occlusion associated with left (n=6) and right (n=6) posterior reverse articulation. Occlusal wear was found in 9 participants. When the group of participants was divided into younger (6 to 10 years) and older (11 to 16 years) subgroups, no significant difference was found regarding the presence of TMD and/or headache.

Additionally, no statistically significant sex differences were found regarding the presence of TMD and/or headache. Mild TMD was found in 35.5% of the participants (n=33), moderate TMD in 25.8% (n=24), and severe TMD in 11.9% (n=11). Headache was a major complaint in 54.9% (n=51) of the children and adolescents and was not associated with age, sex, type of occlusion, or occlusal wear. The absence of TMD was not associated
with headache (P = .26). The same was true for mild TMD (P = .622). However, headache was significantly associated with moderate (P = .04) and severe TMD (P = .001). Logistic regression analysis revealed that children or adolescents with moderate TMD had a 3-fold greater chance of having headaches and that those with severe TMD had a 16-fold greater chance of having headaches than those without TMD.

A systematic review was published to determine the incidence of TMD pain after whiplash trauma. Although the prevalence and incidence of TMD pain in the general population is well documented, knowledge about the prevalence and incidence of TMD pain in patients with whiplash-associated disorders (WAD) is lacking. Furthermore, whether the treatments normally advocated for patients with TMD pain are effective in patients with a combination of TMD pain and whiplash injury is unclear. Studies in animals and humans show a close biomechanical and anatomic relationship between the jaw and neck regions and suggest a functional linkage between the jaw-face and craniofacial sensorimotor systems. Because jaw function relies on linked motor control of the jaw and neck motor systems, pain and dysfunction in the neck may impair jaw function. In chronic WAD, an association has been shown between pain and dysfunction of the neck and disturbed jaw motor function. The findings include reduced amplitude for both mandibular and head-neck movements, disturbed coordination of jaw and head-neck movements, and reduced endurance during chewing. Several studies have demonstrated shared symptoms of neck pain and TMD. Thus, in studies of patients with TMD, neck pain is common, and in studies of patients with neck pain, TMD is common. Therefore, the aims of the present study were to assess, by systematic review of the literature, the prevalence and incidence of TMD pain after whiplash trauma, and whether treatments commonly used for TMD are equally effective in patients with only TMD pain and those with TMD/WAD pain.

This review suggested that the prevalence and incidence of TMD pain are increased after whiplash trauma. The intervention studies indicated limited treatment effect in patients with combined TMD pain and neck pain after whiplash trauma. This poorer treatment outcome suggests that TMD pain after whiplash trauma has a different pathophysiology than localized TMD pain and may be due to spread of pain and dysfunction between the neck and jaw regions, or may be part of a regional or generalized pain syndrome caused by sensitization mechanisms. Because WAD is a heterogeneous diagnosis, further studies on the relationship between TMD and WAD/posttraumatic neck pain should be designed to look for comorbidity in different possible pain generators such as facet joints, global neck muscles, deep anterior neck flexors, deep neck muscles, and jaw muscles and joints, as well as the coordination of their functions. Furthermore, sensitization, psychological, and social factors have to be considered. Well-designed prospective studies are needed to determine the incidence and possible risk indicators of TMD pain after whiplash trauma in order to provide better insights into the possible pathophysiologic and cognitive mechanisms involved.

TMJ surgery was discussed in a study by Jakhar et al. related to preserving the condyle and disk in the surgical treatment of Type III TMJ ankylosis. Temporomandibular ankylosis is a condition in which the condyle is fused to the glenoid fossa by bony or fibrous tissue. Conditions such as trauma, infection, inadequately surgical treatment of the TMJ region, or systemic disease may predispose the patient to ankylosis. In the past, no differentiation in the degree or type of ankylosis was made, and the aim of surgical treatment was simply to create a gap between the condyle and the cranial base. In 1985, Sawhney classified TMJ ankylosis into 4 types according to the severity observed on a tomogram. In Type I ankylosis, flattening or deformity of the condyle, with little joint space, is seen on the radiograph. At surgery, minimal bony fusion is present, but extensive fibrous adhesions can be found around the joint. This type of ankylosis is also called pseudoankylosis. In Type II, there is bony fusion of the outer edge of the articular surface, but there is no fusion within the deeper area of the joint. In Type III, there is a bridge of bone between the ramus and zygomatic arch. In these individuals, after the bony bridge is excised, the upper articular surface and articular disk on the deeper surface remain intact. Also, a condyle of reduced size and slightly medial to its normal anatomic position exists and is functional. In Type IV, the entire joint is replaced by a mass of bone, and the TMJ architecture is completely lost. Type III TMJ ankylosis is common, perhaps because untreated condyle fractures are the most common cause of TMJ ankylosis, and in fracture, the condyle is most often medially displaced. When fractured, both the condylar process and the disk are displaced and pulled in an anteromedial-inferior direction. Improper treatment of a displaced condylar process fracture results in the remaining stump ankylosis to the fossa, producing ankylosis Type III. The 3-dimensional and coronal CT scan can evaluate the nature and severity of the ankylosis in great detail. When the displaced condyle is clearly visible, treatment involving preservation of the condyle and excluding the use of any other autogenous or alloplastic graft becomes possible.

In this study, 90 patients with TMJ ankylosis Type III were treated by joint preservation, retaining the condyle and disk, and removing only the bony ankylosis in a mass lateral to the fossae. Postoperative mouth opening of more than 30 mm was obtained during the minimum follow-up period of 2 years, indicating the effectiveness of this procedure. The disk acts as interpositional material and helps prevent the recurrence of the ankylosis.

The proposed advantages of condylar and disk preservation in Type III ankylosis over the conventional total
resection procedure are as follows. Because resecting the bone on the medial aspect is not necessary, there is less chance of bleeding, particularly from the maxillary artery, and so surgery is relatively safe. The disk acts as an interpositional material and helps to prevent the recurrence of ankyloses. The existing ramus height is maintained, thus preventing open occlusion. The existing ramus height is maintained, thus preventing open occlusion. The existing ramus height is maintained, thus preventing open occlusion.

Another TMJ surgical article reviewed SC of the TMJ. SC is a metaplastic process in which the synovium of a given joint produces and ultimately secretes cartilaginous bodies into the joint space. This may stem from hypersecretory metaplasia of the mesenchymal remnants located within the synovial membrane and is most commonly found in larger joints (hip, knee, shoulder); however, it is nonetheless rare. The TMJ is even more rarely affected, with approximately 100 instances having been reported to date.

In the TMJ, this entity is almost uniformly unilateral. Although the process is usually confined to the superior joint space of the TMJ, variations in its presentation have been reported. Extra-articular progression and subsequent extension into the middle cranial fossa have been reported in 9 individuals, and inferior joint space involvement has also been reported. Patients with SC will frequently present with symptoms not dissimilar to other pathologic conditions of the TMJ. Therefore, obtaining an accurate diagnosis of SC requires a thorough history taking, clinical examination, and appropriate radiographic study; however, definitive diagnosis is confirmed histopathologically. The most common diagnostic modalities for SC include plain film radiography, MRI, and computed tomography.

The differential diagnoses include osteoarthritis, osteochondroma, chondrocalcinosis (pseudogout), pigmented villonodular synovitis, and osteochondritis dissecans. Thorough history taking (including histories of facial trauma and previous TMJ pathologies), clinical examination, and radiographic studies are thus paramount in making accurate preliminary diagnoses and ultimately prescribing proper treatment. Because of the lack of response with conservative measures, surgical removal is usually required. Treatment options consist of arthroscopy, arthrotomy with synovec- tomy, excision of cartilaginous bodies, and possible disectomy.

Future research efforts pertaining to SC with the limited number of patients will be challenging. Its relative infrequency in both clinical patients and literature reports has left much room for improvement in all facets of understanding the disease.

A third TMJ surgery article addresses an extracapsular approach to mandibular condylar fractures. Mandibular condylar fractures are common, occurring in 20% to 52% of mandibular fractures. Undiagnosed or incorrectly managed condylar fractures heal eventually with anatomic malalignment or malunion, frequently resulting in poor occlusion, reduced mouth opening with deviation, and limited lateral mandibular excursion. Condylar fractures with major dislocation can result in the shortening of the posterior facial height, thereby causing asymmetry.

The current literature contains many indications for, and methods of, mandibular condylar fracture treatment. Whereas almost all mandibular fractures are currently managed by open reduction and internal rigid fixation, this treatment is not always used for fractures affecting the condylar process. Condylar fractures differ markedly from other mandibular fractures with respect to the anatomy of surrounding tissues. Fractures affecting the mandibular symphysis, body, and/or angle are readily approached intraorally, but such approaches make optimal anatomic reduction and rigid fixation of condylar fractures difficult because the condyle and the fracture site are unfavorably aligned. For these reasons, mandibular condylar fractures are more easily managed by means of an external approach or an intraoral approach with the use of instrumental aids such as endoscopy.

Extraoral approaches are complicated by the need to avoid injury to the facial nerve and its branches, which run superficially to the condyle. In contrast, intraoral approaches, including those that use endoscopic guidance and dedicated instruments, can make fracture reduction and/or fixation extremely difficult, especially for high fractures and/or those with medial luxation of the proximal stump. Various recent reports have provided statistical evidence that the surgical treatment of extracapsular condylar fractures yields better functional and anatomic results compared to nonsurgical management in terms of bone morphology, occlusion, mouth opening, and jaw movement.

In this study, 87 participants (64 men, 23 women, with ages ranging from 9 to 83 and an average age of 36) underwent open reduction and rigid fixation for 100 extracapsular condylar fractures by means of a mini-retromandibular approach. Seventy-four participants presented with unilateral fractures, and 13 had bilateral fractures. The sample included 25 high- and middle-neck fractures, 26 low-neck fractures, and 49 subcondylar fractures. Forty-seven participants presented with associated fractures (34 in the mandibular symphysis/angle/body, 7 involving the zygoma/orbit/nose, and 6 panfacial). The average time required to manage each condylar fracture was 52 minutes (range 15 to 120 minutes). Two pediatric participants, a 12-year-old boy and a 9-year-old girl, presented with unilateral subcondylar fractures.

All patients underwent postoperative clinical and radiographic examinations, and all the patients who underwent surgery for bilateral condylar fractures had a postoperative CT scan. Dental occlusion and anatomic reduction were restored in all 100 condylar fractures. Anatomic repositioning was considered excellent in 96 patients and good in 4. Reductions were considered to be excellent when the condylar head was positioned correctly in the fossa.
and the condyle posterior border and condyle sigmoid notch lines were realigned perfectly. In all patients for whom CT images were available, bony contact and medial-lateral alignment were found to be optimal.

Postoperative infection developed in 3 patients. In all of these patients, access was obtained by means of a transparotid-transmasseteric approach. These patients were treated with antimicrobial therapy and wound irrigation. In 2 of these patients, an unsightly scar developed and was revised secondarily, with good final esthetic outcomes. One sialocele was observed, which resulted from the use of a transparotid-transmasseteric approach. It was managed conservatively with a compression dressing and antibiotic therapy. One plate fracture occurred 2 months after treatment despite the use of two 2.0 mm plates. Four patients experienced transient palsy of the buccal branch of the facial nerve, which resolved spontaneously in all patients after 2 months with no treatment. No permanent deficit of any facial nerve branch was observed. No patient showed condylar head resorption.

Until recently, the medical literature has stated, without good evidence, that mandibular condylar fractures in patients younger than 12 to 14 years should not be treated surgically. This assertion was based on the intrinsic healing potential of the growing condyle, which was believed to lead to good functional healing, even with nonsurgical management. This concept certainly holds true for incomplete, greenstick fractures, intraarticular fractures, and those with minimal displacement, but recent studies have suggested that much better results can be achieved with surgical treatment in fractures with major displacement or loss of contact between bony stumps.

In terms of occlusion, Abduo authored a systemic review of occlusal schemes for complete dentures. Within the limitations of the systematic review, the conclusions were the use of anatomic teeth in conventionally bilaterally balanced occlusion or lingualized bilaterally balanced occlusion, both equally acceptable to patients in relation to masticatory ability, esthetics, comfort, and speech. There is some evidence that lingualized bilaterally balanced occlusion is beneficial for patients with severely resorbed ridges in terms of mastication and stability. Additionally, anterior tooth-guided occlusion can be cautiously considered as an option for lateral occlusal guidance of complete dentures; however, clear clinical and technical guidelines are still needed. Last, esthetic factors may affect patient perceptions of the occlusal scheme.

Kois et al authored an article discussing the occlusal errors generated at the maxillary incisal edge position related to discrepancies in the arbitrary horizontal axis location and to the thickness of the interocclusal record. Forty-three men and 30 women with ages ranging from 18 to 54 with a mean age of 34 participated in the study. An earbow was used to register each participant’s arbitrary horizontal axis. A mathematical model was used to evaluate the magnitude of occlusal errors produced by the variation of the arbitrary transverse horizontal axis to the maxillary central incisor edge and the interocclusal record thickness. Three variations in interocclusal record thickness at 1, 2, and 3 mm were used to determine the occlusal discrepancy created in the arc of closure by selecting an arithmetic average for the horizontal axis location. The magnitude of occlusal error at the central incisor ranged from 0.45 to 1.25 mm with a 1 mm thick interocclusal record, 1.82 to 5.00 mm with a 2 mm thick interocclusal record, and 4.09 to 11.26 mm with a 3 mm thick interocclusal record. The conclusions of this article were that the distance between the arbitrary transverse horizontal axis and the maxillary central incisal edge was not influenced by the sex or height of the participants investigated. On the basis of the mathematical model, variations in the distance between an arbitrary transverse horizontal axis and the maxillary central incisal edge resulted in minor occlusal discrepancies at the central incisor contact (0.45 to 11.26 μm).

Orthodontic articles included an article by Panahi et al with a 32-year follow-up of Herbst appliance therapy. Fourteen patients from a sample of 22 with Class II, Division 1 malocclusions consecutively treated with the banded Herbst appliance were reexamined 32 years after therapy. Dental casts were analyzed from before (T1) and after (T2) treatment, and at 6 years (T3) and 32 years (T4) after treatment. Minor changes in maxillary and mandibular dental arch perimeters and arch widths were seen during treatment (T1-T2) and after treatment (T2-T4). Mandibular incisor irregularity remained, on average, unchanged from T1 to T2 but increased continuously during the 32-year follow-up period (T2-T4). Class II molar and canine relationships were normalized in most patients from T1 to T2. During the early posttreatment period (T2-T3), there was a minor relapse; during the late posttreatment period (T3-T4), molar and canine relationships remained, on average, unchanged. Horizontal and vertical overlap were reduced to normal values in all participants during treatment (T1-T2). After treatment (T2-T4), horizontal overlap remained, on average, unchanged, but vertical overlap increased insignificantly.

Stability was found in 64% of the patients for sagittal molar relationships, in 14% for sagittal canine relationships, in 86% for horizontal overlap, and in 86% for vertical overlap. A Class II relapse seemed to be caused by an unstable intercuspatation of the occluding teeth, a persisting oral habit, or an insufficient retention regimen after treatment. Most posttreatment changes occurred during the first 6 years after treatment. After the age of 20 years, only minor changes were noted. Long-term posttreatment changes in maxillary and mandibular dental arch perimeters and widths as well as in mandibular incisor irregularity seemed to be independent of treatment and a result of physiologic dentoskeletal changes throughout adulthood.
Janson et al.206 authored a systematic review to evaluate the true effects of Class II elastics in Class II malocclusion treatment. A search was performed on PubMed, Scopus, Web of Science, Embase, Medline, and Cochrane databases, complemented by a hand search. Study eligibility criteria were the application of Class II elastics in Class II malocclusion treatment and the presentation of dental or skeletal outcomes of treatment. All age groups were included. The search identified 417 articles, 11 of which fulfilled the inclusion criteria. Four studies examined the isolated effects of Class II elastics, and 7 were comparisons between a single use of elastics and another method for Class II malocclusion correction. Because of the differences in treatment modalities in these articles, a meta-analysis was not possible. On the basis of the current literature, Class II elastics were found to be effective in correcting Class II malocclusions, and their effects are primarily dentoalveolar. Therefore, they are similar to the effects of fixed functional appliances in the long term, placing these 2 methods close to each other when evaluating treatment effectiveness. Little attention has been given to the effects of Class II elastics on the soft tissues in Class II malocclusion treatment.

### SLEEP-DISORDERED BREATHING

A randomized long-term controlled study evaluated dental changes associated with oral appliance therapy versus continuous positive airway pressure (CPAP) therapy for the treatment of OSA207. Dental casts were acquired and analyzed at baseline and then again at a 2-year follow-up. At baseline, no significant difference in characteristics was found between the oral appliance and CPAP groups. At 2 years, the oral appliance group was found to have a decrease in vertical overlap (-1.2 ± 1.1 mm) and horizontal overlap (-1.5 ± 1.5 mm), as well as a larger change in anterior-posterior occlusion (-1.3 ± 1.5 mm) than the CPAP group. A significant association was also found between the change in vertical overlap and the amount of mandibular protrusion. No tendency to develop an anterior open occlusion was found in either group. Changes in interproximal spaces were found to occur in both the maxillary and mandibular arches for both groups. Because oral appliance therapy is considered a lifelong treatment, and because adverse dental effects may occur, patients should be managed by a dentist well versed in the field of dental sleep medicine.

Another study followed 511 consecutive participants with symptomatic OSA presenting for cardiorespiratory evaluation.208 Self-reported questionnaires were used to determine jaw symptoms, tooth grinding and clenching during sleep, morning oral dryness, morning heartburn sensation, and pain in the neck and back. Nineteen percent of the patients (n = 96) reported at least 1 jaw symptom. The presence of jaw symptoms was reported more frequently with an apnea-hypopnea index (AHI) of less than 15 (25%) than with an AHI of 15 or more (15%), which was confirmed with multiple logistic regression analysis. As the OSA severity worsens, the occurrence of jaw symptoms tends to diminish. Those individuals with an AHI of less than 15 are often treated with oral appliances, so the practitioner needs to monitor for their occurrence to be able to deal with them appropriately.

An important randomized controlled study compared the effectiveness of mandibular advancement devices (MADs) with CPAP therapy for the treatment of OSA.205 CPAP is considered the first treatment of choice for OSA; however, oral appliance therapy is a viable alternative. MADs have proven to have similar effectiveness in important health outcomes, especially in the case of mild OSA. This particular trial used recruitment criteria that increased the participants with moderate to severe AHI; it included newly diagnosed patients of at least 20 years of age, with an AHI above 10 and at least 2 symptoms of OSA (snoring, fragmented sleep, witnessed apnea, and excessive daytime sleepiness). In evaluating the health outcomes on blood pressure, quality-of-life measures, and neurocognitive function, the effects of treatment with a properly titrated MAD were similar to those of CPAP, especially for patients with moderate to severe OSA. This may be due to the greater efficacy of CPAP being offset by inferior compliance relative to the use of the oral appliance. This study strongly challenges the current practice of only recommending oral appliance therapy in cases of mild to moderate OSA.

Another study set out to evaluate the incidence and prevalence of TMD in individuals using a MAD to treat OSA and to evaluate the development of posterior open occlusion (POB).210 At baseline, 19.8% of the patients had TMD; after an initial decrease to 14.5% on the second appointment 118 days later, the prevalence of temporomandibular dysfunction increased to 19.4% on the third visit at 208 days. At visit 4 (413 days), TMD prevalence decreased to 8.2%. The incidence of temporomandibular symptoms was 10.6% on visit 2 and decreased as the trial progressed, with only 2 patients developing TMD from visit 3 to 4. POB was found to develop with an average incidence of 6.1% per visit. The prevalence of POB was 5.8% on the visit 2, 9.4% on visit 3, and 17.9% on visit 4. The authors concluded that the use of a MAD may contribute to the development of TMD in a small number of patients, but these signs are most likely transient. Patients with preexisting TMD do not experience significant exacerbation of those signs and symptoms with oral appliance therapy, and the MAD may actually be therapeutic over time, contributing to a decrease in TMD. POB developed over the course of treatment in 17.9% of the participants; however, only 28.6% of these participants were even aware of any dental changes.

A longitudinal cohort study sought to evaluate the sleep quality and impact of the nocturnal use of complete dentures on sleep quality in a group of elderly edentulous patients over a 1-year
A cohort of 153 participants took part in the 1-year follow-up. Perceived quality of sleep and daytime somnolence were evaluated with the Pittsburgh Sleep Quality Index (PSQI, score 0 to 21) and the Epworth Sleepiness Scale (ESS, score 0 to 24) at baseline and follow-up. Data were also gathered on oral health-related quality of life, conventional versus implant-retained mandibular dentures, nocturnal wear of dentures, and sociodemographic status. The study found no statistically significant differences detected in the global PSQI mean scores and ESS mean scores from baseline (PSQI 4.77 ±3.32; ESS 5.35 ±3.72) to the follow-up evaluation (PSQI 5.04 ±3.50; ESS 5.53 ±4.34). The results of this study suggest that wearing complete dentures while sleeping has little effect on sleep quality or daytime sleepiness.

A Japanese study examined the relationship between self-reported sleep bruxism (SB) and age and the effects of tooth loss on such reporting.212 This cross-sectional study collected data from 1930 participants with ages ranging from 18 to 89 years. They used questionnaires and clinical dental examinations to assess sleep and orofacial complaints. Overall, the prevalence of self-reported SB was 8%; it increased from the age group of 15 to 18 years of age (5.5%) to the age group of 19 to 44 years of age (9% to 11%). Conversely, SB decreased among those 65 years or older (3%), showing that the prevalence was lowest in the elderly population. The authors found that the number of missing teeth was not related to SB; SB was not significantly associated with 25%, 50%, or 75% of tooth loss, or with the number of teeth lost. Current awareness of SB was highly associated with a childhood awareness of SB. The prevalence of most sleep disorders increases with age; SB is unique in that it has an age-dependent decrease. The authors acknowledged that physiologic parameters improve the objective diagnosis of SB. However, screening such a large sample size with polysomnograms would be cost prohibitive; therefore, a subjective assessment is appropriate for such an epidemiologic study.

Another group discussed the potential for increased occlusal loads during sleep, especially in the presence of SB.213 Patients with SB typically report frequent grinding noises during sleep, and an electromyogram will demonstrate a consecutive increase in the amount and strength of rhythmic masticatory muscle activity. Other types of masticatory muscle activity can be nonspecifically activated during sleep, including tooth tapping, sleep talking, and nonrhythmic contractions related to nonspecific body movements. These movements occur more frequently in sleep disorders, and the clinical signs and symptoms of SB can be found in individuals with sleep-disordered breathing. As a person ages, sleep becomes more compromised; the elderly population experiences a high prevalence of sleep disorders, as well as a need for more prostodontic rehabilitations because of the condition of the dentition. Therefore, dental clinicians providing complete mouth reconstructive dentistry need to be knowledgeable about sleep medicine to address sleep-disordered breathing and manage the airway.

PROSTHODONTICS

Again in 2013, a large volume of high-quality material was published related to the extensive topic of prostodontics. Included in this review are articles providing new and important information. Many topic-oriented and systematic reviews published in 2013 cannot possibly be covered here, given space and time limitations. For interested readers, articles addressing the following topics, specifically relevant to prostodontics, may be of interest: prostodontic materials,214 prosthetic occlusion,215-219 dental esthetics,220,221 prostodontic maintenance,222 preprosthetic surgical considerations,223-225 3-dimensional anatomy of the tongue,226 immediate loading of dental implants,227 restorative outcomes of 1-piece implants,228,229 implant abutments,230 implant treatment considerations,231-240 burning mouth syndrome,241 xerostomia,242,243 dental wear,244-246 diagnostics,247 and TMJ considerations.248-250

As the profession’s drive toward evidence-based practice intensifies, clinicians are tasked to develop a clear understanding of fundamental concepts related to gathering, evaluating, reporting, and clinically applying sound evidence. For interested individuals, an excellent and highly recommended overview of evidence-based prostodontics was recently published.251 Additionally, recent reports covering critical appraisal of clinical significance versus statistical significance,252 strength of evidence,253 metaanalysis,254 and evidence assessment tools for clinicians255 are also available.

For convenience and clarity, this review of prostodontic literature is divided into the following subtopics: conventional removable prostodontics, conventional fixed prostodontics, implant-supported removable prostodontics, and implant-supported fixed prostodontics (including single crowns, partial fixed dental prostheses, and fixed complete dental prostheses).

Conventional removable prostodontics

A healthy denture foundation is considered fundamental to successful removable prostodontic therapy. Despite favorable general heath, edentulous individuals may experience denture stomatitis. Determining etiologic factors that contribute to denture stomatitis in otherwise healthy individuals may shed light on intervention directed at improving the denture foundation and enhancing therapeutic prognosis.

With this in mind, Altarawneh et al256 observed healthy edentulous patients affected by denture stomatitis to determine interactions between Candida, dentures, and mucosal tissues by considering exfoliative cytolgy, Candida levels in saliva and on mucosa/denture surfaces, salivary flow rate, and xerostomic conditions. This single-center case-control
cross-sectional study enrolled 32 edentulous participants (15 with moderate to severe denture stomatitis; 17 unaffected controls; mean age 64.8 years) based on specific inclusion and exclusion criteria.

Denture retention and stability were qualified according to the Kapur index. Xerostomia questionnaires were completed, salivary flow rates measured, and saliva samples collected (stimulated and unstimulated). Exfoliative cytological smears, denture surface swabs, and full-thickness punch biopsies were also performed.

Results indicated that denture stomatitis in otherwise healthy edentulous individuals may have a unique pathogenesis different from other oral candidiasis. Participants with denture stomatitis demonstrated higher mucosal inflammatory cell counts and more prevalent Candida albicans in saliva and on denture surfaces. However, experimental groups were statistically similar with respect to salivary flow rates, mucosal wetness, frequency of dry mouth, mucosal Candida counts, and presence of cytological hyphae.

The authors concluded that the prominent etiologic factors for denture stomatitis in otherwise healthy edentulous individuals appear to be the presence of Candida on dentures and in saliva. Other frequently cited factors may be less important in this population. It was suggested that treatment for denture stomatitis should first focus on sanitizing existing prostheses and/or the fabrication of new dentures.

Biofilm formation and the presence of Candida species are strongly associated with denture stomatitis. Although Candida albicans and non-albicans Candida species may be found on denture and oral surfaces in patients without signs of denture stomatitis, a quantitative presence of Candida has been associated with the onset of this multifactorial disease. To better understand the multifactorial nature of denture stomatitis, Valentini et al conducted a randomized crossover double-blind in situ clinical trial to consider the influence of biofilm age (7, 14, or 21 days), prosthesis surface (acrylic resin or denture liner), and condition of the soft tissue denture foundation (healthy or denture stomatitis).

Thirty complete denture wearers (26 women, 4 men, mean age 60.9 years) were enrolled onto the clinical trial; 15 were diagnosed as healthy Candida carriers and 15 were diagnosed with denture stomatitis. Two 6 × 6 × 3 mm recesses were prepared in the palatal intaglio surfaces of all maxillary dentures. Depending on the experimental phase, each recess was randomly filled with one of the following: acrylic denture base resin, silicone soft denture liner, or acrylic resin soft denture liner. Participants wore the experimental dentures during 2 phases of 21 days each, with a washout period of 7 days between phases. Counts of viable microorganisms in the accumulated biofilms on specimens were determined after 7, 14, and 21 days.

Data analysis revealed that non-albicans Candida species counts were higher in patients with denture stomatitis; patients with disease showed higher Streptococcus mutans counts after 7 days; longer biofilm formation periods did not result in biofilm composition differences; and soft denture liners supported higher Candida counts than denture base acrylic resin.

The authors recommend that the use of the silicone liners should be carefully considered in patients with denture stomatitis because they support high levels of non-albicans Candida, a species known to be difficult to treat. In general, the denture liners evaluated in this study accumulated greater amounts of biofilm than typical denture base resin and should therefore be used cautiously.

In managing edentulous patients, procedures that facilitate comfortable oral/masticatory function and optimal esthetics likely contribute to successful therapy. Complete denture occlusion is thought to affect the biologic, physiologic, biomechanical, and esthetic aspects of prosthesis function and in turn influence patient satisfaction. Thus, optimizing prosthesis occlusion is a desirable goal when restoring patients with edentulism. With this in mind, a recent systematic review qualitatively assessed the effect of complete denture occlusal schemes on the subjective appraisals of patients with edentulism and on the objective evaluations of treatment outcomes of clinicians. Specific factors considered included posterior denture tooth occlusal morphology, posterior tooth arrangement, and eccentric occlusal guidance.

A comprehensive electronic literature search of the topic initial yielded 565 articles. Upon review and applications of inclusion and exclusion criteria, 12 articles entered the systematic review. Most of these articles reported on crossover and prospective investigations. Studies included anatomic (cuspied) teeth and flat teeth. Posterior tooth arrangements included conventional bilateral balanced occlusion, lingualized bilateral balanced occlusion, anterior tooth-guided occlusion, and monoplane occlusion. Selected studies did not indicate the degree of balance in the monoplane occlusions investigated.

Findings indicated that anatomic teeth arranged for conventional and lingualized bilateral balance were acceptable to patients, with lingualized bilateral balance favored because of improved masticatory ability and prosthesis stability in severe edentulous ridge atrophy; that anterior tooth-guided occlusion may be considered, but clear clinical and technical guidelines must be developed; and that esthetic factors may affect subjective occlusal assessments and denture acceptance as reported by patients.

The author points out that little high-quality evidence is available to guide complete denture occlusion decisions. Clean comparison of the studies reported in this systematic review was encumbered by significant variability in the study designs and evaluation parameters used to draw conclusions.

The clinical characteristics of stability and retention are important during complete denture fabrication and definitive function. Achieving adequate stability and retention may be challenging. Appropriate use of denture
adhesives can facilitate treatment efficiency for clinicians and complete denture comfort and function for patients. This is particularly true when dealing with severely atrophic edentulous ridges. To investigate the in vitro efficacy of available denture adhesives, Kore et al 262 evaluated the tensile bond strength of 3 cream adhesives, Fixodent (Procter & Gamble), Super Poligrip (GlaxoSmithKline GB), and Efferdent (Prestige Brands Inc), as well as 1 wafer adhesive, SeaBond (Combe Inc), on 3 different denture base resins, Lucitone 199 (Dentsply Int'l Inc), SR Ivocap (Ivoclar Vivadent), and Eclipse (Dentsply Int'l Inc), at various intervals up to 24 hours. Artificial saliva with mucin was used as a control.

Tensile bond strength tests complied with American Dental Association specifications. Denture base resin cylinders measuring $20 \times 25$ mm were processed and finished. Experimental specimens were fabricated by sandwiching a measured amount of denture adhesive (or the control substance) between denture base resin cylinders. After 5 minutes in a humidifier, experimental specimens were subjected to direct tensile load to failure. After the 5-minute test series, resin cylinders were cleaned and adhesively reconnected for tensile loading at 3 hours. This experimental procedure was repeated for load-to-failure testing at 6, 12, and 24 hours.

Results indicated that the tensile bond strengths provided by Fixodent, Super Poligrip, and SeaBond were similar and were greater than those provided by Efferdent. All adhesives tested outperformed the control substance. When comparing denture base resins, Lucitone 199 exhibited the greatest tensile bond strengths with all adhesives. In general, tensile bond strengths were indirectly related to time, regardless of adhesive or resin.

Under true clinical conditions, the degradation of denture adhesive bonding may relate in part to a gradual breakdown of the adhesive material.

**Conventional fixed prosthodontics**

Currently, a host of factors generally guide clinical decisions on the apical extension of tooth preparation during fixed prostodontic procedures. As clinical manipulations approach the gingival tissues, clinicians must consider caries susceptibility of a planned restoration margin placed within the gingival crevice (subgingival), at the free gingival margin (equigingival), or in the oral cavity (supragingival). To assess the available literature addressing this issue, Papageorgiou et al 261 systematically reviewed the effect of fixed prostodontic margin location on the secondary caries susceptibility of natural abutments.

The preliminary examination of available databases, including second references and hand searching, identified 5657 articles on this topic. The application of selection criteria to this list qualified 22 reports, published between 1990 and 2012, for inclusion in the systematic review. Further evaluation of these articles revealed great variation in study design, statistical analysis, and the reporting of results. Ultimately, random-effects metaanalysis could be carried out with only 2 studies that reported on marginal secondary caries at supra-, equi-, and subgingival locations, thus making comparisons possible.

The results of this systematic review and metaanalysis failed to detect statistically different secondary caries rates related to supra-, equi-, or subgingival restorative margin locations over a 10-year recall period. The data tended to indicate a lower secondary caries rate associated with subgingival margins at 15-year recall, although the small number and limitations of the included studies weakens any conclusion. Ultimately, the authors stated that because of the significant qualitative and quantitative limitations in the available reports, no conclusive evidence exists regarding fixed prostodontic margin placement and the incidence of secondary caries.

Various ceramic systems have been developed for the fabrication of highly esthetic fixed prostodontic restorations. In addition to esthetic appearance, biocompatibility, resistance to fracture, and favorable wear characteristics, the success of ceramic restorations relies on the accuracy and precision of marginal adaptation. A systematic review published by Contrepois et al 262 investigated the quality of the marginal adaptation of restorations fabricated by various ceramic systems and identified factors that influence marginal fit.

A search of available scientific literature revealed 469 reports on the marginal fit of ceramic crowns. The application of selection criteria narrowed the pool of articles to 54, which were included in the review. These articles were published between 1994 and 2012, reported on 17 different ceramic systems, and included 48 in vitro and 6 in vivo investigations.

The results indicated the marginal adaptations for all the ceramic systems evaluated were generally clinically acceptable. With 120 $\mu$m as the maximum tolerable marginal opening, 263 94.9% of reported marginal discrepancies were less than or equal to 120 $\mu$m (range 3.7 to 174 $\mu$m). The metaanalysis of data and/or ceramic system ranking in terms of potential for accuracy was impossible because of significant heterogeneity in the research design. The review identified 4 factors likely to influence marginal fit: finish line configuration, cement space, veneer processing, and cementation.

The authors concluded that the selection of a ceramic system for clinical restorations should not be based primarily on its potential for marginal accuracy, but rather on its potential to meet the clinical and esthetic requirements of the patient. Additionally, the authors recommended the use of x-ray microtomographic evaluation and measurement for future studies. This process permits nondestructive, 3-dimensional, precise identification of critical distances, with a sufficient
The surge of interest in zirconia-based fixed prosthodontic systems continued in 2013. Current market-driven wisdom indicates that yttrium partially stabilized crystalline tetragonal zirconia (Y-TZP) partial fixed dental prostheses are capable of withstanding the expected posterior physiologic loading, thus providing an acceptable alternative to historically proven metal ceramic restorative systems. Adequate comparison requires mean clinical observation periods of more than 5 years.

Rinke et al\(^\text{264}\) prospectively evaluated the clinical performance of conventionally cemented zirconia-based posterior 3- and 4-unit partial fixed dental prostheses in order to compare survival/success rates and possible risk factors (veneering porcelain, oral location, span) with the data reported for similar metal ceramic restorations. Seventy-five participants (36 women, 39 men, mean age 49.4 years) were treated between 2001 and 2005. Abutments were prepared according to the manufacturer’s recommendations. Copy-milled partial fixed dental prosthesis zirconia frameworks were veneered with thermally matched porcelain. Ninety-nine posterior fixed prostheses (39 maxillary, 60 mandibular) were luted with zinc phosphate cement. The restorations were evaluated at 6-month intervals.

Within the 7-year observation period, 19 restorations failed (12 technical complications, 6 biologic complications, 1 unknown), and 32 restorations required significant maintenance, yielding an overall Kaplan-Meier survival rate of 83.4% and a success rate of 57.9%. None of the risk factors evaluated significantly affected survival or success.

The authors concluded that the survival/success results observed for zirconia-based partial fixed dental prostheses were inferior to the clinical performance expected for similar metal ceramic prostheses, according to the current literature. Complications included veneer chipping, framework fracture, and loss of restoration retention. Importantly, failure and complication rates increased substantially between 4 and 7 years, highlighting the need for longer observation periods in the assessment of the clinical performance of ceramic systems.

Various zirconia parent materials have entered the dental market for application as posterior dental restorations touting good esthetics and acceptable mechanical properties. Passia et al\(^\text{265}\) reported on a prospective randomized controlled clinical trial designed to evaluate the midterm (5 year) clinical outcome of shrink-free ZrSiO\(_4\)-ceramic complete-coverage (Everest HPC, KaVo) mandibular and maxillary premolar and molar crowns. Complete-coverage gold crowns served as control.

Between 2004 and 2007, a total of 223 participants entered the clinical trial and were randomly assigned to experimental groups. One hundred twenty-three participants received a ZrSiO\(_4\)-ceramic crown, and 100 participants received a gold crown (83 maxillary, 140 mandibular, 15 premolar, 208 molar). Standard tooth preparations were accomplished, and all crowns were placed with glass-ionomer cement. Surface roughness, fracture, marginal integrity, marginal caries, marginal discoloration, marginal opening, crown retention, endodontic status, and periodontal health were clinically assessed at recall evaluations conducted at 6, 12, 24, 36, 48, and 60 months.

Results indicated survival (Kaplan-Meier) probabilities at the 6, 12, 24, 36, 48, and 60 months observations for the ZrSiO\(_4\)-ceramic crowns of 98.3%, 92.0%, 84.7%, 79%, and 73.2% and for the gold crowns of 99%, 97.9%, 95.7%, 94.6%, and 92.3% respectively. The survival probability differences between the groups were significant, with ZrSiO\(_4\)-ceramic crowns demonstrating a 3.13-fold higher probability of failure. Gold crowns were observed to be less rough and to have less marginal discoloration. The probability of marginal discoloration for ZrSiO\(_4\)-ceramic crowns was 49.5 times greater than for gold crowns. The most common ZrSiO\(_4\)-ceramic crown failure mode was fracture. On the basis of the midterm results recorded in this clinical trial, the authors could not recommend the use of shrink-free ZrSiO\(_4\)-ceramic crowns for the restoration of posterior teeth.

As the dental profession ventures deeper into the digital world, scientific validation for emerging clinical and laboratory technologies must keep pace with market flow. Nowhere is that more important than with digital impressions, the starting point of fixed prosthodontic laboratory fabrication. Digital impression making is user friendly, patient friendly, easily correctable, and adaptable to the digital fabrication workflow; but are digital impression systems accurate? To address this question, Kim et al\(^\text{266}\) selected a digital impression system, iTero (Align Technology Inc), and measured working die accuracy compared to dies resulting from conventional polyvinyl siloxane impressions.

A maxillary metallic cast with a prepared central incisor, second premolar, and second molar served as the experimental model. Fifteen digital impressions of the experimental model were made, resulting in computer-aided design and computer-aided manufacturing (CAD/CAM) working casts milled from polyurethane stock. Fifteen conventional polyvinyl siloxane impressions were made of the experimental model and cast in Type IV dental stone. All tooth preparation dies from the polyurethane and Type IV stone working casts were digitized (Q700; 3Shape) and superimposed on digitized reference images of the experimental model by using a face-to-face method. Dimensional differences were quantified and statistically compared.

The results indicate that the mean absolute dimensional difference relative to the experimental model was 23.9 ±17.6 µm for digital dies and 17.6 ±45.6 µm for stone dies. Working dies generated from conventional polyvinyl siloxane impressions were significantly more accurate, although the authors suggested that all casts evaluated were clinically acceptable for crown.
fabrication. The authors recommended that future studies be carried out to examine prostheses derived from digital impressions compared to prostheses produced from conventional impressions.

**Implant-assisted removable prosthodontics**

A reasonable consensus has developed related to the advantages of implant-assisted mandibular overdentures as compared to conventional complete dentures; they are improved masticatory function, increased maximum occlusal force, and prevention of residual ridge atrophy. Beyond specific levels of edentulous function, recent studies focusing on improved quality of life have gained popularity. A number of quality-of-life articles related to implant overdenture therapy appeared in the 2013 literature. Although all will not be addressed in the current review, representatives will be discussed.

Harris et al conducted a prospective randomized controlled clinical trial comparing mandibular 2-implant overdentures with conventional complete dentures in order to qualify quality of life and overall patient satisfaction. One hundred twenty-two edentulous participants (83 women, 39 men, mean age 64.4 years) were enrolled. Baseline questionnaires addressing oral function, denture satisfaction, and quality of life were administered. All participants received new complete dentures. After wearing the new dentures for 3 months, questionnaires were again administered. Further participants were randomly distributed to 2 groups: conventional complete dentures (control) or maxillary complete dentures opposed by mandibular implant overdentures (experimental). The experimental group received 2 anterior mandibular implants that were loaded by using bar attachments 8 weeks after placement. Third and final questionnaires were administered 3 weeks after the previous questionnaires in the control group and 3 weeks after implant loading in the experimental group.

Patient responses from the questionnaires were compiled as numeric data and statistically evaluated. The results indicated significant improvements in denture satisfaction and quality of life for all patients 3 months after receiving new conventional complete dentures. No further improvements were identified in the complete denture group at 6 months. Three months after implant loading, the mandibular implant overdenture group demonstrated significant additional perceived improvements in functional limitation, physical pain, psychological discomfort, physical disability, social disability, psychological disability, handicap, and perceived improvements in 10 of the 11 denture satisfaction criteria. The authors concluded that, compared to good-quality conventional complete dentures, implant-assisted mandibular overdentures significantly increased patient satisfaction, perceived oral function, and perceived oral health-related quality of life.

Several factors may influence patients’ and clinicians’ satisfaction with implant-assisted overdentures. Several of these factors were addressed by Harris et al, as detailed above. Due consideration must also be given to the patient’s ability to adequately clean the oral cavity, including all elements of the prosthesis and all associated oral tissues. With this in mind, Cordaro et al retrospectively compared the Locator attachment system (Zest Anchors LLC) and a CAD/CAM bar and clip system, CAM StructSURE (BIOMET 3i) used to assist mandibular overdentures on 4 interferominal implants. A subjective professional evaluation of the treatment results was made, and the impact on the patient’s quality of life was measured.

A population of 39 edentulous patients treated in 2008 at a single facility with 4 mandibular interferominal implants incorporated into mandibular overdentures was identified on the basis of a review of treatment records. An individual Locator attachment group consisted of 11 women, 8 men, mean age 64.4 years, with 76 total implants, and a mean clinical follow-up of 13 months. A bar and clip attachment group was characterized by 12 women, 8 men, mean age 60.5 years, with 80 total implants, and a mean clinical follow-up of 18 months. Visual analogs were used to record patient satisfaction and to facilitate the professional assessments of 3 dentists not involved with the original treatment. Clinical parameters of perimplant soft tissue health, implant mobility, and success were included.

Patient satisfaction was high, and a marked similarity was noted for all criteria except “ease of cleaning.” Patients considered the Locator abutments easier to clean than the bar and clip attachments. Clinicians indicated that although the bar and clip attachment system was sufficient, individual Locator abutments yielded better hygiene maintenance, better perimplant soft tissue conditions, and better retention. Although no implants were lost in either group, the Locator group revealed significantly better values for the clinical parameters of PI, PD, and BOP. Calculus was present on 45% of the surfaces in the bar group, while only 21% of Locator abutment surfaces showed calculus.

The authors concluded that, within the limitations of this retrospective investigation, the results clearly demonstrated that hygiene maintenance was more complicated around bars than around individual Locator abutments. Although patient satisfaction was high for both attachment systems, on the basis of the criteria evaluated, clinicians appeared to prefer the Locator attachment system.

If favorable outcomes have been observed for mandibular, Locator-retained, complete implant overdentures, perhaps similar results exist for edentulous maxillary restorations. Along this line of inquiry, Zou et al reported on a 3-year prospective clinic trial evaluating the treatment outcomes in edentulous maxillae of using 4-implant overdentures retained by 3 different attachment systems.
Thirty patients (18 women, 12 men, mean age 60.4 years) fulfilling established clinical criteria were enrolled onto this prospective investigation. All patients received 4 maxillary implants. Three experimental groups were developed on the basis of planned overdenture attachment designs: telescopic crown and sleeve attachment, bar and clip attachment, and individual Locator attachment (Zest Anchor). Ten patients were assigned to each experimental group. Annual clinical evaluations recorded PI, calculus presence, gingival index, bleeding index, PD, and radiographic bone loss. Prosthodontic complications (implant loss/fracture, retention screw loosening, abutment fracture, prosthesis fracture, needed prosthesis reline, attachment activation, attachment replacement, prosthesis marginal adaptation) were recorded. Patient satisfaction (esthetics, comfort, speech, function) was evaluated by means of a questionnaire.

All patients remained available throughout the 3-year observational period. All 120 implants in 30 participants integrated and remained in function (100% implant survival and success). No significant differences were recorded for clinical effectiveness, PD, or periimplant bone loss among the 3 experimental groups. Although patient satisfaction was generally high for all groups, the individual Locator attachment group exhibited more favorable periimplant hygienic parameters, fewer prosthodontic maintenance needs, and reduced complication rates. The telescopic crown and sleeve group required the greatest number of maintenance interventions, and the bar and clip group experienced the highest incidence of gingival hyperplasia adjacent to prosthetic components.

The authors concluded that, within the limitations of the current investigation, the overdenture attachment system used does not seem to adversely affect implant survival or success. Although patients were generally satisfied with all of the attachment designs investigated, individual Locators attachments were associated with improved periimplant hygiene parameters and reduced midterm maintenance requirements. The authors cited the need for additional prospective investigations involving larger patient populations and longer functional observation periods.

The use of dental implants to support, retain, and stabilize complete overdentures has been shown to improve several measures of oral function, including increased occlusal force generation. To avoid fracture, care must be taken, as the overdenture base thins to accommodate the incorporation of the implant attachment components. To compound structural durability concerns, attachment components are often incorporated into the overdenture base by using clinical pickup procedures at the time of prosthesis placement. Reliable pickup techniques and materials must be available to avoid subsequent overdenture failure under elevated occlusal loads.

To investigate the best clinical methods, Domingo et al designed an in vitro protocol that compared the flexural strength of 4 different methods for chairside direct pickup of metal overdenture attachment housings. Eighty heat-polymerized denture base resin bars (Lucitone 199, Dentsply Intl Inc) were processed and finished. Bar specimens measured 11.5 x 9.1 x 39 mm. An 8.5 x 5 mm hole was drilled in the center of each bar to accommodate the pickup of titanium (Ti-6Al-4V alloy) implant attachment housings with 4 different repair materials: autopolymerized acrylic resin, Acraweld (Henry Schein Inc), light-polymerized acrylic resin with bonding agent, Triad Gel (Dentsply Intl Inc), autopolymerized resin with silanated, Rocatec, and RelyX Ceramic Primer (3M ESPE) housings, and light-polymerized resin with bonding agent and silanated housings. The flexural strength (load to fracture) of the prepared bar specimens was measured by using 3-point bending in a universal testing machine.

The results indicated the mean maximum strength of the autopolymerized acrylic resin groups was significantly greater than that of the light-polymerized acrylic resin groups. Additionally, silanation significantly increased strength. All failures appeared to be adhesive in nature. Failures in the light-polymerized resin groups appeared to occur between the denture base and pickup resins, while failures in the autopolymerizing resin groups appeared to occur between the repair material and the housing surface.

Within the limitations of the in vitro study, the authors concluded that the flexural strength of autopolymerized acrylic resin with silanated metal attachment housings was significantly higher than that of autopolymerized acrylic resin alone, light-polymerized acrylic resin alone, or light-polymerized acrylic resin with silanated attachment housings. Autopolymerized acrylic resin, in general, produced stronger constructs than the light-polymerized materials used.

Implant-supported fixed prosthodontics

Recently, significant attention has been paid to clinical complications arising from residual subgingival cement resulting from placement of implant-supported fixed prostheses. Although not newly recognized, growing concern related to residual cement has caused dentists to take a second look at the pros and cons of cement versus screw retention.

Korsch et al published a retrospective clinical observational study on 71 participants (mean age 60.7 years) treated between 2009 and 2010 with 126 implants (69 in women, 57 in men) supporting fixed cement-retained restorations. Abutment finish lines for all restorations were no greater than 1.5 mm subgingivally. A 2-component provisional methacrylate cement, applied with a small brush to internal crown/retainer surfaces, was used at placement. A dental probe, floss, and/or plastic curette were used to remove excess cement.

On follow-up (mean 261 days after placement), excess subgingival cement was occasionally identified in association with periimplant suppuration.
Because residual cement could not effectively be removed in situ, all patients were recalled for retreatment and documentation. Retreatment involved perimplant probing noting bleeding/suppuration, crown/abutment removal, visual assessment for residual cement, cement elimination, CHX applications, abutment replacement, crown re cementation (zinc oxide eugenol provisional cement), and recall examination at 3 to 4 weeks after retreatment.

The results indicated that at retreatment, BOP was seen around 54.8% of implants, suppuration around 12.7%, and residual cement identified on 59.5% of crowns/abutments. Of those restorations affected by residual cement, BOP was evident for 80% and suppuration for 21.3%. At the retreatment follow-up, BOP was associated with only 12.3% of implants evaluated with no detectable suppuration.

The authors concluded that residual subgingival cement associated with implant-supported fixed prostheses will result in BOP in most patients and suppuration in some. The authors recommended that high clinical priority be given to efficient and effective elimination of excess cement at the time of restoration placement. In the absence of esthetic demand, cement margins should be located at accessible levels for optimal cleaning of excess cement. If deep subgingival interfaces cannot be avoided, screw retention should be considered.

In further consideration of excess cement in implant prosthodontics, Chee et al287 used an in vitro protocol to compare the amount of excess cement resulting from implant crown placement with 4 methods of cement application and 2 cements. The 4 methods of cement application were application to the 1 mm marginal area of the internal surface only, application to the apical half of the axial walls only, application to entire axial wall surfaces only, and filling the crown with cement and seating on a polyvinyl siloxane die before placement. The 2 cements investigated were a zinc oxide eugenol interim cement and a resin-modified glass ionomer definitive cement.

Forty Type III gold alloy crowns were fabricated to fit “cement-to” implant abutment analogs. Cement was then mixed on a pad, weighed, and applied to the crowns as described. The crowns were seated on abutment analogs and clamped under constant load for 10 minutes. The amount of cement remaining on the pad and the amount of applied cement was calculated. The excess cement from specimens was collected and weighed.

The data analysis indicated no differences between the cements studied. The greatest amount of applied cement and the least excess cement resulted when a silicone die was used to displace cement before crown placement. The volume of the applied cement and the excess cement measured for the other application methods were statistically similar.

The authors suggested that the use of a silicone die to displace applied cement produces a uniform layer of luting agent distributed evenly over the internal surface of the crown. This optimal distribution of luting agent minimizes excess cement after placement of the restoration.

The esthetic advantages of zirconia implant abutments for fixed prosthodontic replacement of teeth in the anterior regions of the mouth are obvious. However, is a decision based on the expected structural integrity of the components of a zirconia abutment rather than a metal abutment justified? In an effort to validate intraoral applications, Foong et al288 designed an in vitro study to determine the fracture resistance to cyclic loading of stock internal connection titanium and zirconia “cement-to” abutments.

Eleven specimens representing an implant-supported, cement-retained, anatomically average maxillary right central incisor were prepared for each of 2 experimental groups. The first group incorporated titanium stock abutments (TiDesign 3.5/4.5, 4.5 mm in diameter, 1.5 mm in height; AstraTech Dental). Twenty-two implants (OsseoSpeed, 4×9 mm; AstraTech Dental) fixed in resin mounting blocks received experimental abutments fastened with titanium screws to 20 Ncm. Twenty-two identical CAD/CAM base metal crowns were milled, fitted, luted with a resin cement, and stored at room temperature in saline for 24 hours.

The specimens were loaded to failure (palatal surface, 2 mm from incisal edge, 30 degrees to long axis) with a cyclic, isometric, stepped-fatigue, load-controlled protocol (120 to 300 cycles/min, 2 to 5 Hz, 50 to 400 N) with graphite lubrication and saline moisture in a closed-loop servohydraulic test frame. The number of cycles and maximum loads at failure were recorded. Microscopic observations were also recorded after failure.

Mean fracture load and cycles to failure were significantly greater for titanium (270 N and 81 935 cycles) than for zirconia (140 N and 26 296 cycles) abutments. Modes of failure for titanium abutment specimens included fracture or plastic deformation of the screw and plastic deformation of the abutment and implant. The failure mode identified for zirconia abutments was fracture at the apical aspect of the abutment (internal hexagonal portion) without damage to the screw or implant.

The authors concluded that, within the limitations of this in vitro protocol, titanium stock “cement-to” implant abutments withstood twice the load to failure and 3 times the cycles to failure compared to geometrically similar zirconia abutments. Both experimental groups failed under loading conditions considered physiologically realistic. Regular-sized zirconia abutments should be used cautiously, only when low occlusal loading conditions are expected and only when esthetic demands override the need for improved structural integrity and durability.
The maintenance of prosthetic retention screw preload and durable screw joint stability are important to successful clinical function in implant-supported fixed prostheses. With a wide variety of available abutment designs and materials, the informed selection of components is essential. Butignon et al. evaluated the effectiveness of 3 different abutment designs in the maintenance of retention screw preload before and after cyclic loading. Additionally, possible load-related microdamage was evaluated with scanning electron microscopy (SEM).

According to the abutment type used in specimen fabrication, the experimental groups consisted of the following: prefabricated titanium attached directly to the implant body, premachined gold-interface cast-to attached directly to the implant body cast with gold alloy, and prefabricated zirconia attached directly to the implant body. The abutments were fastened to external hexagon implants (Titamax Ti Cortical, 3.75×13 mm; Neodent) mounted in epoxy resin blocks. The manufacturer recommended that titanium alloy retention screws be tightened to 20 Ncm and then retightened to 20 Ncm to minimize embedment relaxation.

Static load testing was accomplished on 5 specimens from each experimental group. These specimens were fixed in a test frame (30 degrees to implant’s long axis) and received a static load of 5 N (0.5 mm/min crosshead speed) until failure. Before cyclic loading, the reverse torque values for retention screws in 10 specimens from each group were measured with a calibrated, standardized digital torque gage. Next, these specimens were subjected to cyclic loading in the test frame (30 degrees to implant’s long axis) with 40% of the ultimate static failure load from the weakest group identified during initial static load testing. Cyclic loading between 11 and 211 N at 15 Hz was applied until 500 000 cycles were achieved. Specimens were again subjected to reverse torque testing with the same digital torque gage.

The results indicated no significant differences in screw preloads measured before the cyclic loading of specimens. After cyclic loading, the retention screw preloads for all abutment types decreased significantly. The zirconia abutment screws showed the greatest preload deterioration (compared to precyclic loading values), and the titanium abutment screws showed the least (the difference between the 2 was significant). Scanning electron microscopic evaluation revealed considerable surface damage to all abutment interfaces (wear, kneading, and material loss) resulting from cyclic loading. No surface damage was identified on the retention screws.

The authors concluded that a reduction in retention screw preload should be expected according to the physiologically realistic cyclic loading of titanium, gold, and zirconia abutments. This reduction in preload is particularly prevalent with prefabricated zirconia abutments, as indicated in this in vitro study. Strict clinical recall schedules should be considered for patients receiving zirconia abutments to ensure careful evaluation and the reestablishment of screw joint stability when indicated.

A reduced number of teeth can make mastication more difficult and lead to avoidance of foods requiring rigorous masticatory effort (fruits, vegetables, fibrous foods). Therefore, an important motivation for seeking prosthodontic replacement of missing teeth is rehabilitating acceptable masticatory function. Several studies published in 2013 and cited earlier in this review indicated a direct relationship between masticatory ability and improved quality of life. Tjabakhsh et al. reported on a multicenter prospective clinical trial evaluating the quality of food choices, food selection patterns, and eating behaviors over a 5-year period in an edentulous patient population before and after placement of conventional maxillary complete dentures opposed by implant-support mandibular fixed complete dentures.

Thirty-two edentulous individuals (23 women, 9 men, mean age 58 years) met the inclusion criteria and were enrolled onto the trial. Participants entered the trial as experienced conventional complete dentures wearers of between 1 and 20 years. Treatment intervention involved placing 5 to 6 mandibular interforaminal implants and restoration with screw-retained implant-supported mandibular complete-arch prostheses opposed by new maxillary conventional complete dentures.

Dietary data were collected at baseline (before study interventions) and at 1 and 5 years after treatment with 2 instruments. The first, a standardized 4-day food diary managed by participants, recorded food intake and portion sizes. Additionally, a dietary habits questionnaire was used to record demographic information, age, weight, eating habits, food selections, meal locations, eating pleasure, digestion, ease of chewing, and vitamin intake.

Statistical assessments revealed a decrease in difficulty masticating hard, course, and fibrous food from baseline (conventional dentures) to 5 years after treatment. Concurrently, the intake of vegetable portions increased significantly. Significant improvement in comfort while eating in public venues and overall enjoyment of eating were noted, with half the participants expressing discomfort when using original complete dentures and only 4% making similar claims at the 5-year assessment. Participants also noted significant improvement in mastication and swallowing over the observation period.

The authors concluded that for the population studied, replacing conventional complete dentures with screw-retained implant-supported mandibular complete-arch prostheses opposed by new maxillary conventional complete dentures improved the overall eating experience for participants and increased the intake of hard, fibrous foods as a result of improved masticatory ability. These beneficial effects may relate to
enhanced nutritional status and improved quality of life.

Efficient mastication involves the coordinated orofacial muscular function and detailed central nervous system modulation of incoming sensory signals. Periodontal mechanoreceptors are known to contribute important sensory feedback secondary to tooth loading during mastication. Individuals with missing teeth who receive tooth-supported or implant-supported dental restorations have decreased sensory feedback because of reduced periodontal mechanoreceptor output. In turn, this reduced sensory feedback may interfere with both the intensity and spatial aspects of jaw motor function, leading to compromised biting and masticatory behavior.

To further decipher this complicated system of neuromuscular masticatory coordination, Svensson et al observed human motor behavior during a novel “manipulation-and-split” oral task. Thirty participants were enrolled onto the experimental protocol: 10 participants (5 women, 5 men, mean age 70 years) possessed bimaxillary metal ceramic tooth-supported fixed restorations; the teeth of 10 participants (3 women, 7 men, mean age 72 years) were restored with bimaxillary metal-resin implant-supported fixed restorations; and 10 controls (4 women, 6 men, mean age 66 years) had intact natural dentitions. The experimental task required tongue and lip manipulations to move a spherical piece of candy (10 mm in diameter) from the mid-dorsum of the tongue to between the front teeth and split the candy into exactly equal-sized parts. The resulting fractured pieces were measured to assess the accuracy of the split. Mandibular motion, masseter electromyography, and sounds emanating from the fracture of the candy were recorded. Each participant repeated the experimental task 15 times.

The results indicated that the dentate controls were significantly better than the other groups at precisely splitting the candy. The prosthetic groups were inferior, but statistically similar in this measure. Vertical jaw movements were similar among the 3 groups. While performing with less task-oriented precision, the tooth-supported and implant-supported prostheses groups accomplished the oral maneuver more rapidly than controls. Better split performance by dentate individuals may reflect the time consumed in precise food positioning and the generation of finely tuned occlusal force vectors in preparation for the experimental task.

The authors suggested that the manipulation-and-split maneuver studied requires a high degree of oral senso-motor skill/coordination that is likely dependent on spatial contact information, originating in part from the periodontal mechanoreceptors. Although this form of sensory information is readily available to dentate individuals, those missing teeth and restored with tooth-supported prostheses likely receive somewhat impaired signaling, and patients restored with implant-supported fixed restorations may be lacking this sensory input completely.

The availability of a tooth-colored indirect restorative material that readily integrates into known dental manufacturing processes and possesses adequate mechanical properties for oral use may prove beneficial. Early experience with zirconia, although not without concerns, has demonstrated promise in this area. Careful clinical observation of this material in function over time is essential to accurately qualify its utility in prosthodontics. To address this need, Papasyriyados and La conducted a retrospective case series study evaluating edentulous CAD/CAM zirconia-based implant-supported fixed complete dentures to ascertain midterm (up to 4 years) results and to record technical complications and associated risk factors.

Between 2007 and 2009, 16 edentulous arches in 14 consecutive patients (10 women, 4 men, mean age 58 years) were restored with 16 CAD/CAM zirconia-based implant-supported fixed complete dentures (10 maxillary, 4 mandibular restorations). Each edentulous jaw received between 5 and 8 implants. Framework patterns were fabricated incorporating a 2 mm cutback and adequate support for tooth- and tissue-colored feldspathic veneering porcelain. The patterns were copy milled in zirconia and subsequently veneered to the anatomic contour. The prostheses contained between 12 and 14 dental units. Fourteen of the restorations were 1-piece constructions, 2 were segmented at the midline, and all were screw-retained at the implant level. Passive framework fit was assessed radiographically by using the single-screw test and hand instrument exploration.

Data collection at the last annual recall (after 2 to 4 years of function) involved the assessment of function and esthetics (questionnaire), as well as biological (periimplant bone/soft tissue status) and technical complications (framework fracture, porcelain chipping/fracture, retention screw loosening/fracture). Dental records were reviewed to identify complications encountered before the final data collection.

The findings revealed 100% implant survival and 100% prosthesis survival. Eleven of 16 prostheses were structurally sound, while 5 prostheses (31.25%) demonstrated veneer chipping/fracture (3 minor and 2 major complications). High patient satisfaction was evident at baseline and final recall, with no retention-screw loosening noted during the observation period. A median radiographic marginal bone loss of 0.1 mm was calculated, and no clinically discernable GR was noted. Three risk factors were identified for porcelain chipping: the presence of parafunctional activity (bruxism), the presence of an opposing implant-supported fixed complete denture, and the absence of an occlusal night guard.

The authors concluded that CAD/CAM zirconia-based implant-supported fixed complete dentures followed for up to 4 years in function appear to provide a reasonable prosthodontic option for the management of edentulism, but are not without complications. Although patient satisfaction with function and esthetics was high, a chewing rate of...
31.25% may complicate maintenance efforts over the life of the restoration.

**IMPLANT DENTISTRY**

Two different articles studied the effect of implant-abutment connection on bone levels.

The concept of platform switching provides a narrower abutment diameter than the implant. This gap in dimensions is thought to allow for an additional biologic width distance, which may prevent the apical early bone resorption following the establishment of the biologic width. To clinically test this claim, investigators compared standard 4 mm implants versus platform switching implants of 3.3 mm installed in the same 25 participants. Bone level changes were recorded for 3 years. Time influenced bone levels, but the platform switching design had no effect on bone levels.

Another group of investigators retrospectively compared 3 different implant abutment connections: external hexagon, internal octagon, and internal Morse taper. One hundred three implants in 63 participants were evaluated radiographically at 3 time points: at the time of prostheses delivery (approximately 4 months after placement), and 3 and 6 months after the start of loading. No statistical differences could be detected in bone levels among the 3 different implant-abutment connections. However, the different time point influenced bone levels, no matter the connection.

Buser et al provided a 6-year prospective evaluation of 20 consecutively treated patients with single-unit implants in the esthetic zone. Implants inserted 4 to 8 weeks after tooth extraction were combined with a guided bone regeneration procedure using deproteinized bovine bone mineral (Bio-Oss; Geistlich Pharma NA) and a non-cross-linked collagen membrane. At 6 years, all implants were integrated, without periimplantitis. Soft tissue levels and bone levels were excellent, with a mean modified Pink Esthetic Score of 8.25 (range 5 to 10). The mean distance between the implant shoulder and the first bone-to-implant contact was 0.44 mm. All implants had a detectable (on CBCT) buccal bone plate with a mean thickness of 1.06 mm at the platform level.

The investigators evaluated 26 participants, 11 of whom received 3-unit partial fixed dental prostheses and 15 of whom received implant-supported single unit crowns. A prospective preference trial was performed in which patients were informed and chose the treatment they desired. Patient perception questionnaires were completed before treatment, 1 month after completion, and annually. The costs of fabrication and maintenance through scheduled and emergency visits were recorded. The effects of treatment were estimated as quality-adjusted-tooth years (QATY). One QATY corresponds to 1 sound tooth over a 1-year period. In terms of patient perception, the 2 treatments were similar. With regard to cost effectiveness, the implant single restoration was the most effective, and the QATY increased over time for this therapeutic option. At 3 and 10 years, implants became the preferred strategy. CBCT was used by investigators on 39 consecutive patients to evaluate bone volume immediately after extraction and at 8 weeks in the anterior region of the maxilla. At the time of extraction, the mean central bone wall thickness at a location 3 mm apical from the crestal bone was 0.8 mm, with 69% of the sites below 1 mm. After 8 weeks, the median vertical and horizontal bone losses were 5.2 mm (48% of the original height) and 0.3 mm (3.8% of original width) respectively. The authors further divided the samples into thin- and thick-wall phenotypes. Thin and thick walls had median dimensions of 0.7 and 1.4 mm respectively. Vertical bone loss in thin-wall phenotypes was 7.5 mm (62% of initial), and the corresponding figure for thick-wall phenotypes was 1.1 mm (9% of initial thickness). These differences were statistically significant. This study provided clear clinical guidelines for predicting bone remodeling at 8 weeks and demonstrated that this remodeling is critically dependent on the facial bone wall phenotype.

A retrospective evaluation was performed on 2 groups of patients who had either misfitting margins (10 patients) or well-fitting margins (7 patients) on single-unit cemented implant restorations. The misfit group had either open or overhanging margins. The open (or overhang) and closed margins were detected from periapical radiographs. The mean recall time after prosthetic delivery was 34.7 months. The mean bone loss was 0.27 mm for the open margin group and 0.01 mm for the closed margin group. This difference was statistically significant. This study clearly demonstrated a strong correlation between poor marginal integrity and excessive bone remodeling around implants.

A 2-center study was conducted comparing turned and TiUnite implants (Nobel Biocare USA LLC) placed within the same 96 participants. The turned and TiUnite implants were respectively followed up for a mean of 7.3 and 7.5 years. The cumulative success rate of each implant surface was 90.3% and 96.6% for the turned and TiUnite respectively, with a significant advantage for the TiUnite surface. The mean marginal bone levels after 6 years were 1.86 and 2.13 mm for TiUnite and turned respectively, which were statistically different. Further analysis of the data demonstrated that 35.8% of TiUnite and 46.9% of turned surfaces implants presented a mean marginal bone level 3 mm or more from the implant-abutment junction after 6 years in function. Similar figures were obtained in a subgroup of implants (31 for each surface) for which baseline and recall radiographs were available to compute the mean marginal bone remodeling during more than 6 years. In this subgroup, 48.5% of TiUnite implants and 51.6% of turned implants had more than 3 mm of mean marginal bone remodeling. Interestingly, this study found only 4 patients (4.2%) and 10 implants (2%) with periimplantitis, and 9 of the 10 implants with periimplantitis were...
TiUnite surface implants. However, the authors did not include BOP data, which is associated with radiographic bone loss for the diagnosis of peri-implantitis. Despite not looking at the question of periimplantitis per se, the data in this article demonstrated that bone resorption occurs around both types of implants, a finding in accordance with previous reports.

An 8-year retrospective comparative analysis was performed to evaluate the outcome of natural teeth adjacent to implant-supported partial fixed dental prostheses and that of natural teeth serving as abutments for partial fixed dental prostheses. One hundred twenty-seven patients were included to provide 2 groups of 61 and 66 patients for implant-supported restorations and tooth-supported restorations, respectively. The 8-year cumulative complication rate for teeth adjacent to implant-supported restorations was 7.9% and was 40.7% for the teeth supporting partial fixed dental prostheses. This study elegantly demonstrated that the use of implants in edentulous spaces promotes the health of adjacent teeth.

One study demonstrated an increase in inflammatory markers at the time of implant surgery and 2 months later in patients susceptible to periodontitis. This again demonstrated the link between the periimplant soft tissue condition and periodontal condition, both of which are sustained by similar inflammatory reactions.

A multicenter prospective clinical trial evaluated the results of implant-assisted mandibular Kennedy class I partial removable dental prostheses (PRDP). Forty-eight patients were divided into a control group, which received conventional PRDP, and 3 test groups with second molar position implants to help support the PRDP. Each test group was in a different geographic location (New Zealand, Columbia, and the Netherlands), and the control group (PRDP alone) was in New Zealand. The implants were initially provided with abutment healing caps for 6 months, and the caps were then replaced with ball attachments. The participants were followed for up to 3 years. Oral health impact questionnaires (OHIP) and a visual analog scale were used to assess patient satisfaction with numerous outcomes at various time points throughout the study. Overall, participants were highly satisfied with the implant-assisted PRDP. The retentive attachment further improved OHIP and comfort scores.

An interesting study compared results with block onlay bone grafts versus particulate grafts mixed with platelet-rich plasma in 15 participants with atrophied maxillae. No significant differences were found at 5 years despite a larger marginal bone alteration in the block side at the time of grafting. Most of the resorption occurred during the first year.

A metaanalysis was conducted to determine whether differences in bone levels existed between screw- and cement-retained restorations. The authors concluded that no differences could be found on the basis of available data. This demonstrates once again that many variables can affect bone levels around implants and that isolating a single variable is often impossible. It also demonstrates that significance between variables can be found in well-controlled studies designed with a specific purpose.

A Cochrane Collaboration metaanalysis on the available data concerning the role of antibiotics in implant success was published in 2013. It concluded that the preoperative use of antibiotics (2 to 3 g amoxicillin 1 hour before surgery) is recommended to prevent implant failure. No conclusion could be drawn regarding the role of postoperative antibiotics, and therefore no recommendation for their use was provided.

Another Cochrane metaanalysis evaluated the available evidence to determine the role of different loading times on implant success. Again, no conclusion could be drawn in favor of any specific protocol, as all studied loading sequences seem to provide similar outcomes. A very slight significant difference was found in terms of bone level stability in favor of immediate loading, which is not likely to be clinically significant.

REFERENCES


100. Cook DC, Mealey BL. Histologic comparison of healing following tooth extraction with ridge preservation using two different xenograft protocols. J Periodontol 2013;84:585-94.


270. Jofre J, Castiglioni X, Lobos CA. In


289. Butignon LE, de Almeida Basilio M, de Oliveira AT, Gomes R. In


292. Koutouzi T, Catania D, Neiva K, Wallet SM. In


Noteworthy Abstracts of the Current Literature

Multifactorial evaluation of implant failure: A 19-year retrospective study

Han HJ, Kim S, Han DH.

Purpose. Dental implants generally provide good results as replacements for missing teeth, but a few patients experience implant failure. The aim of this retrospective study was to analyze the characteristics and causes of implant failures in hopes of reducing future failures.

Materials And Methods. Patients who received one or more implants at the Dental Hospital of Yonsei University College of Dentistry between February 1991 and May 2009 were included in this study. Data including age, sex, medical history, habits (eg, smoking and drinking), bone quality, primary stability, implant size, implant surface, additional surgical procedures, prosthetic type, clinical symptoms, implant failure date, and causes of implant failure were obtained through a chart review. Follow-up radiographs were compared to those obtained at baseline. The Pearson chi-square test and Fisher exact test were used to evaluate the correlations between risk factors and implant failure.

Results. In total, 879 patients received 2,796 implants; 150 implants in 91 patients had failed. Early and late implant failures occurred with 86 (57.3%) and 64 (42.7%) implants, respectively. The main causes of early and late implant failures were inflammation (47%) and overloading (53%), respectively. When the cause of early implant failure was inflammation, the failure rate was significantly higher for implants in the anterior maxilla; implants with poor primary stability, a machined surface, or a length exceeding 15 mm; and implants placed with a reconstructive procedure and two-stage surgery. When late implant failure was caused by overloading, the failure rate was significantly higher for implants with a machined surface, placed with a reconstructive procedure and/or two-stage surgery, and supporting telescopic dentures.

Conclusion. Within the limitations of this study, the major causes of implant failure are inflammation and overloading, and they differ between early and late implant failures.

Reprinted with permission of Quintessence Publishing.