

ANNUAL REVIEW

Annual review of selected scientific literature: Report of the
Committee on Scientific Investigation of the American
Academy of Restorative Dentistry



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This review was conducted to help the busy dentist keep abreast of the latest scientific information regarding the clinical practice of dentistry. The authors, all of whom are considered experts, were each asked to peruse the scientific literature in their discipline for 2014 and review the articles for important information that may affect treatment decisions. Comments on experimental methodology, statistical evaluation, and the overall validity of the conclusions are included in many of the reviews. The reviews are not meant to stand alone but are merely intended to inform the interested reader about discoveries in the past year. The readers are then invited to go to the source for more detail.

The information in this review is extremely valuable in light of the constant call for dentists to practice evidence-based dentistry and the explosion in both the number of journals and articles related to the profession of dentistry. It is a monumental task for practitioners to locate studies pertinent to current clinical issues but an even greater one to evaluate the validity of the scientific methods used in any study and the relative validity of the conclusions reached.

One issue addressed in this report is the increasing number of systematic reviews (SRs) published each year. These SRs are ranked at or near the top of the hierarchy of scientific evidence. However, SRs can only answer key

questions and provide clinical guidance when the clinical trials included in the reviews have sufficient scientific validity. Sadly, the authors of many SRs admit that the quality of the reviewed trials is low, that the confounding variables have not been controlled, and that the likelihood of bias is high. The conclusions reached in many SRs may not be valid and can actually lead clinicians in the wrong direction.

The analysis of the scientific literature published in 2014 is divided into 7 sections: (1) dental materials, (2) periodontics, (3) prosthodontics, (4) occlusion and temporomandibular disorders, (5) sleep-disordered breathing, (6) implant dentistry, and (7) dental caries and cariology.

DENTAL MATERIALS

Restoration repair and replacement

Studies continue to evaluate the efficacy of repairing defective dental restorations. Two SRs were published in 2014 that evaluated the literature related to the replacement versus repair of composite resin restorations and amalgam restorations.^{1,2} Both SRs reviewed studies in adult molar or premolar teeth comparing complete replacement of the restoration with repairing the restoration using the same material as the original restoration. The reviews were also limited to randomized controlled

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trials (RCTs), including split-mouth studies. The search strategy retrieved 298 potential studies related to composite resin restorations and 201 potential studies related to amalgam, but of these not 1 RCT could be identified that answered the original PICO (patient, intervention, comparison, outcome) question. These reviews serve as a reminder of the poor state of the science related to this important clinical question.

One larger retrospective cohort review of dental records for U.S. Navy and Marine Corps personnel evaluated the frequency of replacement for posterior composite resin and amalgam restorations.³ A total of 1050 composite resin (565) and amalgam (485) restorations were followed in 247 patients for an average of 2.8 years. The overall replacement rate was 5.7% over this period, with no difference in replacement risk or rates between composite resin and amalgam restorations. Multisurface restorations had a higher risk of replacement, as did restorations in patients at high risk for caries. One noted limitation of this study, however, was the inherent selection bias for material choice, wherein multisurface restorations were more often restored with amalgam at nearly a 2:1 ratio. Another limitation was the relatively short term of service (2.8 years) of the restorations.

An ongoing study of repair longevity in composite resin restorations provided 10-year results. In this study, adult patients with restorations originally treatment planned for replacement but clinically judged as repairable were randomly assigned to either replacement or repair.⁴ The 2 treatment cohorts demonstrated statistically similar outcomes with regard to marginal adaptation, secondary caries, anatomic form, and color, demonstrating that repairs are safe and effective options for limited clinical defects.

Two papers that used data from the Dental Practice-Based Research Network (DPBRN) were published in 2014. The first was a cross-sectional study of consecutive restorations that needed repair or replacement and looked at the reasons for repair or replacement, the tooth surfaces involved, the materials used, and the patient demographics.⁵ One advantage of DPBRN studies is the number of restorations (9875), patients (7502), and practices (197) that can be assessed. In this study, 75% of the defective restorations were replaced and 25% were repaired. Most were amalgam (56%), and the most common repair material was composite resin (56%). Amalgam was more likely to be replaced with composite resin when the choice was a replacement, the tooth was not a molar, the tooth was in the maxillary arch, and the original restoration was single surface. The second DPBRN paper also looked at the influence of who placed the original restoration on the decision to repair or replace.⁶ With a similarly large sample size and similar study design, dentists who placed the original restoration

were significantly more likely to repair a restoration when it was in a molar tooth, when the original restoration was amalgam, and when the defect was a material fracture. Both of these studies provide a descriptive profile of clinical decision outcomes but still fail to provide guidance for clinical decision making. Someday, perhaps, we will harness the power of the large numbers of restoration repairs and replacements with an assessment of clinical outcomes followed in these studies to provide such guidance.

Adhesives

It was a slow year for clinical adhesive research, with most published studies related to laboratory evaluations of every possible parameter relating, or, in some cases, not relating to adhesion and microleakage. Microtensile bond testing continues to be the favored method of evaluating adhesion, and the battle continues between 1-step, 2-step, and 3-step systems. One study of particular relevance looked at methods of decontaminating an etched dentin surface after it had been contaminated with blood.⁷ The etched and contaminated dentin was subjected to water rinsing, re-etching, sodium hypochlorite, sodium hypochlorite/sodium ascorbate, hydrogen peroxide, or ethanol. Two adhesives, acetone-based Prime & Bond (Dentsply Intl) and ethanol-based Adper Single Bond 2 (3M ESPE) were compared after decontamination by microtensile bond testing. The results showed that re-etching and sodium hypochlorite rinsing restored bond strengths to those of the original uncontaminated control for both adhesive systems.

In the battle of 1-step versus 2 step systems, 1 paper provided 8-year results from a randomized comparison of Class II nanohybrid resin restorations.⁸ One hundred and fifty-eight of the original 165 restorations were available for recall. The total failure rate was 13.3% over 8 years, with no difference between the 2 adhesive systems. Both adhesives appeared to provide good clinical performance, with annual failure rates of 1.6%, and most failures were due to material fracture rather than adhesive failure.

For every success story, however, there is an equal but opposite tale of failure. A 3-year prospective clinical evaluation of the 1-step adhesive Futurabond NR (VOCO America) was tested in the classic Class V non-carious cervical lesion model.⁹ One hundred and twenty-two restorations were followed in 42 participants, and, after 3 years, 25% of the restorations were lost, and 65% of the remaining restorations were rated as excellent or acceptable. A similar study compared the active versus passive application of 2 one-step systems over 24 months.¹⁰ In this case, the active scrubbing method of application showed a significantly higher retention rate of 96.8% versus 87.1% for the passive application, with no difference between the 2 adhesive systems.

One of the more interesting papers published on adhesives in 2014 was a review article describing adhesive materials with bioprotective or biopromoting properties.¹¹ Many or most of these adhesives are under development as part of a larger movement to develop dental restorative systems that inhibit disease, or, in some cases, reverse the effects of the disease. Bioprotective functions are described as features that protect the adhesive interface from intrinsic and extrinsic factor-induced degradation, while biopromoting functions mimic or promote the biomineralization process within tooth tissues. More recently, biopromotion has also added the function of promoting pulp repair and regeneration. One class of these materials is the agent-releasing antibacterial adhesives, in which additives such as chlorhexidine and silver have been added either as releasable antimicrobials or permanently incorporated components. The advantage of releasable compounds is that they can act at a distance from the interface. Besides being antimicrobial in nature, compounds such as chlorhexidine have been added to inhibit the matrix metalloproteinase (MMP)-induced enzymatic degradation of dentin collagen. Silver ions and silver nanoparticles have antimicrobial, antiviral, and antifungal properties, but controlling the release kinetics and the particle dispersion are just 2 of the issues with this technology. An issue related to releasable compounds is the regulatory scrutiny that these therapeutic medical devices may face.

Nonagent-releasing antibacterial adhesives are a class of materials in which the antimicrobial compound is chemically bound to the matrix polymer network. An example is the use of quaternary ammonium monomers that, when incorporated, can inhibit the growth of bacteria at the interface. One advantage of these systems is that the antimicrobial property is not lost over time because of release; the limitation is that they only affect bacteria in direct contact with the adhesive.

Another class of materials described in this paper is adhesives with anti-MMP functions, such as the previously mentioned chlorhexidine additives. In addition to chlorhexidine, the quaternary ammonia monomers also appear to have the ability to inhibit MMPs but do not have the limitation of eventually leaching out of the adhesive. Adhesives with collagen protective cross-linking agents are also available. These materials prevent the protease-induced breakdown of dentin collagen by increasing the cross-linking stabilization with agents such as glutaraldehyde and carbodiimide hydrochloride. Nature-derived cross-linkers with potentially lower toxicity are being investigated for this purpose.

The biopromoting adhesives include materials incorporating remineralizing compounds such as fluoride and amorphous calcium phosphate. The challenges to be overcome with these materials are controlling the release

kinetics, maintaining material strength, and exhausting the active ingredients by leaching over time. Pulp repair and regeneration has been limited primarily to adhesives that promote dentin bridge formation as part of vital pulp therapy. Adhesives with calcium phosphate and peptide additives have been shown to promote bridge formation equivalent to calcium hydroxide, with the added benefits of better adhesion and structural integrity. All of these approaches to developing biofunctional adhesives have many technical, regulatory, and market hurdles to overcome before they become part of the clinical armamentarium. They are, however, a glimpse of the future of dental materials.

Sealants and infiltration

Two notable papers in 2014 addressed the safety of pit and fissure sealants. The first was another analysis of the results of the New England Children's Amalgam Trial, in which a mild association had been previously reported between composite resin restorations and psychosocial but not neurophysiologic or physical outcomes.¹² That analysis did not take into account the sealants and preventive resin restorations (PRRs) that were also placed during the trial period. This paper looked at the association between the surface years of sealants and PRRs over the 5-year follow-up of 534 previously treated 10-year-olds. The findings showed no association between the exposure levels to sealants or PRRs and behavioral, neuropsychological, or physical development in these children. A second study looked at the urinary bisphenol A concentrations in 1001 children taking part in the 2003-2004 National Health and Nutrition Examination Survey (NHANES) and associated the concentrations with the number of composite resin restorations and sealants present.¹³ No statistically significant association was found between the number of sealants or restorations and high urinary bisphenol A.

A number of papers also evaluated the sealing of carious lesions. One paper monitored the progression of carious lesions through a clear sealant over 44 months.¹⁴ The authors reported no evidence of International Caries Detection and Assessment System (ICDAS)-rated lesion progression in 228 permanent teeth at 12 months and minor increases at 24 and 44 months. Radiographic progression was 1% at 12 months, 3% at 24 months, and 9% at 44 months; however, only 4 teeth progressed to ICDAS ≥ 5 with frank cavitation. Overall, sealants were 100% effective at 12 months and 98% effective at 44 months in managing occlusal caries with original ICDAS ratings of 0-4. A similar study on primary teeth compared sealing lesions reaching the outer half of dentin ($n=17$) with a control treatment of restoration with composite resin ($n=19$).¹⁵ Clinical and radiographic evaluation at 6, 12, and 18 months showed better clinical survival of the restorations, but no difference in radiographic lesion

progression between restorations and sealed lesions. Lastly, a paper compared glass ionomer ART (atraumatic restorative treatment) sealant and a fluoride-releasing sealant in permanent molars with deep fissures or incipient caries.¹⁶ The teeth were evaluated every 6 months for 2 years and showed a high level of no dentin caries (>90%) for both materials, even though retention of the resin sealant was significantly higher (73% versus 50%). A number of factors including the ionomer fluoride release, the timing of interruption in lesion susceptibility, and the baseline risk level may have accounted for this seeming discrepancy in lesion progression versus sealant retention.

A few papers also looked at the perception and attitudes of both providers and patients with regard to sealants. One paper looked at the evidence-based clinical knowledge and attitudes of 163 Florida dentists by using a survey tool.¹⁷ Sealant usage and knowledge of the current American Dental Association (ADA) recommendations were assessed and associated with a number of demographic and professional characteristics. Years since graduation and reliance on peers for information did not correlate with clinical knowledge, and male dentists and those accepting new patients with Medicaid demonstrated higher sealant knowledge. Most participating dentists used sealants and communicated positive attitudes toward them but demonstrated a low overall knowledge of their appropriate use according to the ADA recommendations. One interesting study looked at the acceptability of sealants from a child's perspective.¹⁸ Too often our research focuses on clinical outcomes and the provider's perspective without considering the patient's point of view. In this study, a 3-point faces scale for positive, neutral, and negative response was used to rate the experiences of 200 children between 3 and 16 years of age who had received sealants. More than 96% recorded a positive or neutral response when asked about the ease of coping with the procedure. Children who had had sealants in the past found them easier to tolerate than those receiving them for the first time, and nearly half were ambivalent about the taste or associated feeling. The authors also noted that the "vast majority of children were satisfied with the explanations provided by their operator," but that does not necessarily mean they believed a single word. As all of us who treat children quickly learn, you can fool an adult, but children will see through you every time.

One notable paper in 2014 reviewed the clinical effectiveness and cost effectiveness of sealants in children and adolescents with a high risk for caries as part of a report for the German health care system.¹⁹ An SR was conducted to evaluate the medical, economic, ethical, social, and legal implications of sealant use. For medical evaluation, the search identified 1249 publications, of which 104 were potentially relevant to the question and

19 were randomized or quasi-randomized controlled trials. Most of the trials compared sealed permanent molars with nonsealed controls, and a high risk for caries was reported in 7 of these trials. All RCTs exhibited a risk of selection and/or detection bias in favor of sealants. The conclusions of the review were that results have shown the protective effects of sealants compared with no sealants and with professional fluoride application. This effect was especially strong for children at higher risk. The economic review identified 263 publications, of which 63 were considered potentially relevant and 14 were reviewed in detail. Eight were prospective or retrospective studies and 5 were economic models. The economic models indicated savings from the use of sealants in children and adolescents at a high risk for caries, but results of the economic studies were mixed. Both suggested that cost savings were more likely with longer follow-up. The ethical, social, and legal review identified 39 publications, but none addressed relevant aspects of the questions.

Silver diamine fluoride

Silver diamine fluoride (SDF) has been used in many parts of the world to control caries and as an interim therapy. The first Food and Drug Administration 510(k) clearance of an SDF product was granted in July 2014, with indications for topical desensitizing and fluoride varnish as a predicate device. No product has yet appeared in the U.S. market. Although SDF is cleared for topical desensitizing, more literature is emerging related to its caries-arresting properties. One paper in 2014 provided an ex vivo analysis of the physicochemical and structural differences between primary tooth caries treated in vivo with SDF and untreated primary tooth caries.²⁰ Micro-computed tomography (CT), scanning electron microscopy, and transmission electron microscopy of exfoliated primary teeth showed that the SDF-treated lesions had a highly remineralized zone rich in calcium phosphate on the surface layer of the arrested dentin. These results indicate that the antimicrobial effect of the silver ions may not be the only mechanism of SDF.

One other paper related to SDF worth noting is a clinical report of a young teenager with rampant caries related to immune deficiency after bone marrow transplantation.²¹ Although considered to low level of evidence, this report illustrates a dramatic arrest and treatment of rampant caries that is encouraging. The patient presented with severe rampant caries affecting both permanent and primary teeth. The teeth were treated topically with SDF to arrest the lesions and reduce sensitivity. Those with pulpal involvement were endodontically treated, and interim restorations were gradually placed to restore function and appearance. SDF is very similar in composition to the silver nitrate solution once recommended as a cavity cleanser by G.V. Black

and later as the principal ingredient in Howe's solution, also used as a cavity cleanser and topical antimicrobial. Hopefully, we will see more evidence emerge for this promising method of managing severe caries.

Xylitol

A review of xylitol was included as part of the U.S. Preventive Services Task Force update of the 2004 recommendation for the prevention of dental caries in children younger than 5 years.²² The results of this updated review concluded that fluoride supplementation and professionally applied fluoride, while associated with a higher risk of fluorosis, are effective in preventing caries in high-risk children younger than 5 years. The report noted that 3 trials reported no clear impact of xylitol on the caries incidence in children, and 2 of these trials reported diarrhea as an adverse effect. Xylitol was, therefore, not included in the final recommendations.

Another study of 562 children aged 5 to 6 years looked at the effect of xylitol gummy bear snacks on caries progression in a population of inner-city school children.²³ This was a double-blind, cluster-randomized trial with 7.8 g/day of xylitol administered through gummy bears 3 times daily. Placebo bears were used as a control, other standard preventive measures were provided, and decayed, missing, and filled surfaces were monitored from kindergarten through second grade. The comparison of xylitol and the placebo for permanent and primary teeth showed no significant additional benefit for xylitol beyond that provided by the other preventive measures. Perhaps gummy worms would have been a better choice.

Another study looked at the impact of xylitol on cavitated and noncavitated lesions in caries-active adults.²⁴ In this trial, 538 adults aged 21 to 80 years were given either 5 g/day of xylitol in five 1 g lozenges or placebo lozenges and followed over 3 years. The mean annualized lesion transition scores from sound to carious favored xylitol, but the difference was neither clinically nor statistically significant.

Composite resin

In 2014, the Academy of Operative Dentistry–European Section published much needed guidance on posterior composite resins.²⁵ This document described the current state of the science and of the social, environmental, and usage trends for composite resins. It presented a listing of appropriate indications for use that included treatment of primary lesions of caries, replacement of existing defective direct restorations, replacement of most inlays, repair of existing direct and indirect restorations, restoration of endodontically treated teeth that do not require the protection afforded by an extracoronary restoration, restoration of fractured and cracked teeth, and restoration of teeth affected by tooth wear or erosion.

The Academy recognized the huge variability in available materials and techniques and made no specific technique recommendations beyond using magnification aids and following the manufacturer's instructions. The primary contraindication noted was the need for moisture control, and the use of rubber dam was recommended. Several special circumstances are described, such as sclerotic dentin and deep gingival margins, wherein specific variations in technique may be warranted. Conservative cavity designs with a greater reliance on adhesion, enamel bevels on anterior restorations, and nonbeveled gingival margins on the proximal boxes of posterior restorations are the key features of the cavity design recommendations. The section on the management of exposed dentin includes recommendations for etching and bonding over the routine use of liners where there is no pulpal involvement, and the use of mineral trioxide aggregate (MTA) for the management of pulp exposures. The recommended bonding systems are 2-step self-etching and 3-step etch and rinse systems. Self-etch systems are noted to be associated with more marginal staining, and the additional phosphoric acid etching of enamel is recommended where possible. Composite resin selection recommendations include the posterior use of microhybrid and nanohybrid materials with at least 60% by volume of filler loading. Layering is recommended to achieve adequate polymerization, although evidence is lacking to show that this technique reduces shrinkage stress. Newer low shrinkage resins are mentioned, but not specifically recommended because of a lack of clinical evidence of superiority. Both quartz halogen and light-emitting diode polymerization units are described with no specific preference recommended other than monitoring the output and using adequate polymerization times. To establish proximal contacts and contour, clear matrix bands and clear wedges are noted as being ineffective, and the recommendations include thinner metal and sectional matrix bands with wood or flexible plastic wedges. However, sectional systems can result in overhangs and these margins must be carefully monitored and finished. The only caution included in finishing is to avoid overheating the restoration. The ability to repair defective composite resin restorations is noted, and repairs are recommended when the majority of the restoration concerned is intact and caries free. This set of evidence-based recommendations is a good working document that should provide a basis for teaching and practicing composite resin restoration techniques. Hopefully, the document will be frequently reviewed and updated.

One new article on the potential renal toxicity of composite resin restorations was yet another publication coming out of the New England Children's Amalgam Trial, wherein resin-based restorations were used as the

control in 417 children aged between 6 and 10 years.²⁶ Three markers of renal function were assessed, and no association was found between exposure to dental composite resins, compomers, or sealants and levels of renal function.

Two papers looked at the association between composite resin restorations and endodontic complications. The first was an SR that asked whether the risk of endodontic complications was greater with composite resin restorations than with other restorations.²⁷ The initial search identified 1043 publications, of which 10 were considered relevant to the review. The level of evidence in these studies was considered low, and little or no difference was noted between teeth restored with composite resin and amalgam.

A second paper compared the time-lapse between restoration placement and endodontic intervention for different restoration types and tooth surfaces in a university dental school database.²⁸ The overall mean time between restoration placement and subsequent endodontic intervention was 270 days, with composite resin at 247 days and amalgam at 294 days. From the standpoint of risk, composite resin restorations were found to be 1.9 times more likely than amalgam and 5.7 times more likely than crowns to be associated with subsequent endodontic intervention. Teeth with 2 or more restored surfaces were also at significantly greater risk than those with single surface restorations.

Several papers in 2014 assessed the longevity of composite resin restorations. One 13-year recall described 41 of an original 61 restorations placed by 2 clinicians in Class I and Class II lesions of permanent teeth.²⁹ Twenty-five of the 41 restorations were intact and acceptable, 2 had secondary caries, and 14 were not present or had replacement restorations. Unfortunately, there was no way of determining the reason for these replacements, and the small sample size limited the power of this study.

A larger prospective follow-up of permanent tooth restorations in children and adolescents provided an 8-year assessment of performance.³⁰ In this study, 115 dentists placed 4355 restorations, and the cumulative survival rate at 8 years was 84%. The most frequent reasons for failure were secondary caries (57%), post-operative sensitivity (10%), and material fracture (6%). Of the recurrent caries replacements, a large proportion were due to primary caries on non-restored surfaces. Another interesting note was that greater sensitivity and shorter longevity were also associated with restorations requiring a base material. Composite resin restorations replacing cusps in permanent premolars were evaluated for 5 years in a study comparing direct and indirect approaches.³¹ Two clinicians placed 176 restorations in 157 patients, 92 direct and 84 indirect. Five-year survival rates were approximately 87%, and no statistical difference

was found in the survival rates of direct and indirect restorations. The mode of failure was predominantly adhesive.

One study assessed the longevity of posterior primary restorations in children attending a public pediatric dental clinic.³² The study followed 565 restorations in 329 children for up to 4 years or until normal exfoliation. Annual failure rates were 9.5% for composite resin, 12.2% for resin-ionomer, and 12.9% for conventional glass ionomer restorations, with composite resin exhibiting a significantly lower risk of failure than the 2 ionomers.

The performance of silorane low shrinkage composite resins was documented in 2 studies of 3-year comparisons with methacrylate-based composites. The first evaluated 82 Class II restorations on molars and premolars randomly assigned to either Filtek LS (3M ESPE) or Tetric EvoCeram (Ivoclar Vivadent).³³ At 36 months, the recall rate was 89% and no difference was found in any measured parameter between the 2 materials. The second study compared 156 restorations using either Filtek P90 (3M ESPE) or QuiXfil (Dentsply Intl) in Class II restorations.³⁴ Annual failure rates were under 2% for both materials, and no significant difference was found between the materials for any clinical measure. Silorane systems continue to demonstrate equivalence to methacrylate-based composite in clinical trials but have yet to exhibit signs of superiority.

Lastly, an SR looked at the influence of rubber dam isolation on the longevity of tooth-colored restorations.³⁵ The search identified 484 studies, of which 9 were considered potentially relevant to the question. Five were included in the final analysis, and, in 4 of these, the use of rubber dam did not improve longevity over cotton roll isolation. Only 2 studies, however, were considered as having a low risk of bias. Again, a sad state of science for such an important clinical question.

Amalgam

Two recent events will greatly affect the continued use of amalgam. The first was last year's adoption of a global treaty by the United Nations Environmental Program that outlines the gradual phase down of human uses of mercury to achieve a lasting reduction in environmental mercury.³⁶ The Minamata Convention proposed no outright ban on amalgam, but called for a gradual "phase down" of the use of mercury in dental fillings. An editorial published in *Quintessence International* in 2014 provides an excellent overview of the international perspective on this treaty and how countries are reacting to this new reality. The authors point out that the phase down will be challenging for all of us, but essential. Ideally, we would like to phase down the need for restorations in general, but until that time

comes, we should be looking to the “phasing in of a modern, alternative approach to the restoration of posterior teeth.”

The second more recent event was the Environmental Protection Agency (EPA) publication of the proposed rule *Effluent Limitation Guidelines and Standards for the Dental Category (Proposed Rule)*.³⁷ This proposed rule outlines the mandatory adoption of ADA Best Management Practices for Amalgam Waste, including the installation of amalgam separators in all dental facilities that place or remove dental amalgam. This ruling is the result of the failure of dentistry to adequately adopt the voluntary use of amalgam separators and is the product of careful and lengthy negotiations between organized dentistry and the EPA. The proposed rule calls for systems that meet the requirements of the standard ISO 11143 Amalgam Separators. However, there is some discrepancy in this requirement in that the proposed EPA rule calls for a separation efficiency of 99%, while the ISO standard requires 95% efficiency. Once published as a final rule, all dental offices generating amalgam waste will be required to document compliance within a given period and periodically from then on.

An SR compared the clinical performance of amalgam and composite resin restorations in posterior teeth.³⁸ The search identified 2205 references, of which 7 trials with 10 articles were included in the detailed review. Two parallel group trials included 1645 composite resin restorations and 1365 amalgam restorations, and the remaining 5 split-mouth trials included 1620 composite and 570 amalgam restorations. All 7 trials were rated to be at high risk for bias. While the evidence was considered of low quality, all trial results were consistent in that amalgam restorations exhibited a lower risk for failure and secondary caries, although no difference was found in the risk for fracture between the 2 materials.

Two clinical studies looked at the endodontic outcomes associated with amalgam restorations. The first was a cross-sectional study that radiographically compared the endodontic status of 440 individuals with restorations originally placed in vital teeth.³⁹ There was no significant difference found between the radiographically observed frequency of apical periodontitis for teeth restored with composite resin (1.3%) and for teeth restored with amalgam (1.1%). The second study was similar in nature in that it compared amalgam and composite resin, but the outcome was the critical time before restoration placement and subsequent endodontic intervention.²⁸ In this study, the mean time between restoration placement and endodontic intervention was 294 days, which was significantly longer than that of composite resin at 247 days. While this may be an interesting fact, the clinical relevance is questionable.

One interesting study looked at the impact of amalgam stained dentin on the performance of subsequently placed adhesive composite resin restorations.⁴⁰ Cusp-replacing posterior composite resin restorations were placed as replacements for existing amalgam using a 3-step total-etch adhesive and followed for an average of 40.3 months (7- to 96-month range). The cumulative survival rate for 118 restorations was 96.6% with an annual failure rate of 0.9%. These results confirm that dentin that has been previously exposed to amalgam is not compromised when it comes to adhesion and the performance of composite resin replacement restorations.

Another aspect of amalgam to consider is the presence of image artifacts on cone beam CT (CBCT) images adjacent to amalgam restorations. A laboratory study using a silicone phantom and extracted teeth evaluated the impact of amalgam-induced artifacts on the sensitivity and specificity of caries detection in adjacent proximal surfaces.⁴¹ Tooth-phantom images obtained with the CBCT system (NewTom, 3D; QR s.r.l.) were reconstructed and digitally sectioned mesiodistally and compared with the same teeth sectioned and observed with a light microscope to confirm lesion presence. The sensitivity of CBCT image detection to enamel caries adjacent to amalgam was approximately 0.3 and for dentin was approximately 0.5. Specificity for enamel was 0.5 and was 0.4 for dentin. Intraobserver reliability was fairly good at 0.84, but interobserver reliability was only 0.49. The low specificity and sensitivity values indicate that CBCT scans should not be used to diagnose caries when amalgam restorations are nearby.

And in the world of the bizarre, yet another paper was published on the impact of amalgam on self-reported health symptoms. This study was described as a “large longitudinal non-blind sample of participants from a preventative health program” that tracked 14 self-reported health symptoms “proposed to be mercury dependent sub-clinical measures of mental and physical health.”⁴² Urinary mercury levels were correlated with the likelihood of change for any of the 14 self-reported symptoms after amalgam removal. As expected and demonstrated in prior studies, removal of amalgam reduced urinary mercury to similar levels as in people with no amalgam fillings. Also not surprisingly, the removal of fillings increased the likelihood of self-reported symptom improvement, often referred to as the Hawthorne effect.

Lastly, a clinical report of the removal of an amalgam tattoo was worthy of notice.⁴³ A 54-year-old woman had had a large amalgam tattoo on the alveolar mucosa between the maxillary right canine and left central incisor for over 20 years that was described as being removed with multiple surgeries.⁴³ First, amalgam fragments were removed from the underlying

bone, followed by a subepithelial connective tissue graft (CTG) and acellular dermal matrix (ADM), followed 7 weeks later by a gingivoplasty. Fortunately, the tattoo was successfully removed, but a good tattoo artist could have modified the original to mimic the Mona Lisa in considerably less time and at a much lower cost.

Endodontic materials

Clinical studies continue to support the success of MTA for various endodontic applications. One study in 2014 reported 5-year results comparing MTA with adhesive composite resin for root-end sealing.⁴⁴ A total of 271 of 339 patients were recalled at 5 years, and the overall rate of healed treatments was 84.5% with MTA at 92.5% and composite resin at 76.6%. MTA performed significantly better than composite resin for surgical root-end sealing. Root perforations were also studied clinically and radiographically in 64 MTA repairs.⁴⁵ Examinations varied from 12 to 107 months after treatment (median 27.5 months), and the results showed that 86% were healed and both result in lower provider experience and placement of a post after treatment were associated with a higher risk of failure.

MTA was compared with calcium hydroxide for apexification of 40 necrotic immature permanent incisors in children aged 6 to 10 years.⁴⁶ MTA or calcium hydroxide was also placed either by hand or by ultrasonic instrumentation. MTA resulted in the fastest time to formation of a hard tissue barrier, but calcium hydroxide resulted in greater amount of root elongation during apexification/apexogenesis. This difference in length, however, was less than 1.5 mm.

MTA was also evaluated as a vital pulpotomy material for permanent teeth with closed apices.⁴⁷ Inflamed pulp tissue was completely removed from 27 molars and 2 premolars, followed by irrigation with 2% sodium hypochlorite and cotton pellet hemostasis. The pulp orifices were covered with white MTA and sealed with interim restorative material covered with a definitive restoration. The teeth were evaluated clinically and radiographically for up to 47 months (mean 25 months). Twenty six of 29 teeth remained asymptomatic, with 3 requiring subsequent root canal treatment. A second direct pulp capping study was a longer-term report in which MTA was compared with calcium hydroxide.⁴⁸ One hundred twenty-nine teeth were followed for 24 to 123 months (median 42 months), with an overall success rate of 80.5% for the MTA and 59% for the calcium hydroxide. One interesting outcome was that teeth restored 2 days or more after pulp capping had a significantly worse prognosis, regardless of the material used.

An SR was published that looked at the effectiveness of primary molar pulpotomies with MTA.⁴⁹ The results

showed that MTA was more effective than formocresol and stainless steel restorations were more successful than amalgam restorations after the pulpotomies.

PERIODONTICS

This year's review covers systemic conditions affecting periodontal health, periimplantitis, factors relating to the assessment of periodontal disease and its treatment, the use of lasers to treat periodontal disease, periodontal regeneration, gingival recession adjacent to teeth, and implants and alveolar ridge preservation.

Systemic conditions

The relationship of systemic disease to periodontal disease is an interesting question. One study evaluated the ability of second-, third-, and fourth-year dental students to identify systemic conditions associated with periodontal disease and the risk factors important to that association.⁵⁰ Further, medications that affect the periodontium and how these factors apply to clinical decisions regarding the treatment and referral of patients were evaluated. A 21-question survey was administered at one U.S. dental school in the spring semester of 2012 to elicit students' knowledge and confidence regarding clinical reasoning. The response rate was 86%. Periodontal risk factors were accurately selected by at least 50% of students in all 3 classes; these were poorly controlled diabetes, ≥ 6 -mm pockets posteriorly, and lack of response to previous nonsurgical therapy. Confidence in knowledge, knowledge of risk factors, and knowledge of medications affecting the periodontium improved with training and were predictive of better referral decision making. The greatest impact of training was seen on the students' ability to make correct decisions about referral and treatment for 7 clinical scenarios. Although the study found a large increase in the students' abilities from the second through fourth years, the mean of 4.6 (out of 7) for the fourth-year students shows that, on average, those students missed correct treatment or referral in more than 2 of 7 clinical situations. These results suggest that dental curricula should emphasize more critical decision making with respect to referral and treatment criteria in managing patients with periodontal disease.

The relationship of coronary heart disease to periodontal infections is important. Data are scarce on the impact of the periodontal condition in the control of biomarkers in patients with cardiovascular disease (CVD). The purpose of 1 study was to assess whether periodontal inflammation and tissue breakdown are associated with C-reactive protein (CRP) and lipids in participants with stable heart disease.⁵¹ This cross-sectional study included 93 patients with stable coronary artery disease who were in outpatient care for at least 6 months. After applying a structured questionnaire,

periodontal examinations were performed by 2 calibrated periodontists in 6 sites per tooth for all teeth. Blood specimens were collected from patients on the day of the periodontal examination to determine the levels of CRP, lipids, and glycated hemoglobin. Overall, the specimen presented high levels of periodontal inflammation and tissue breakdown. Unadjusted mean concentrations of triglycerides (TGs), very low density lipoprotein cholesterol, and glucose were significantly higher in individuals with severe periodontitis. When multiple linear regression models were applied, the number of teeth with a clinical attachment loss of at least 6 mm and the presence of severe periodontitis were significantly associated with higher CRP concentrations. Bleeding on probing (BOP) was significantly associated with TGs, total cholesterol, and non-high density lipoprotein cholesterol. In this sample of patients with stable CVD, the current periodontal inflammation and tissue breakdown were associated with cardiovascular inflammatory markers such as CRP and lipid profile.

Another study determined the influence of nonsurgical mechanical periodontal treatment on inflammatory markers related to the risk for cardiovascular disease.⁵² A total of 64 patients with severe chronic periodontitis were randomly subjected to immediate periodontal treatment (test group, $n=32$) or to delayed periodontal treatment, without treatment during the study period (control group, $n=32$). Clinical periodontal and laboratory examinations were performed at baseline (T0), 2 months (T2), and 6 months (T6) after the initial examinations (control group) or completion of periodontal treatment (test group). After 2 months of periodontal treatment, a significant reduction of the erythrocyte sedimentation rate (ESR) ($P=.002$) and TGs ($P=.004$) was found in the test group. The median values of CRP ($P<.001$), ESR ($P<.001$), total cholesterol ($P<.001$), and TGs ($P=.015$) were reduced after 6 months of periodontal treatment in the test group. The nonsurgical periodontal treatment was effective in reducing the levels of systemic inflammation markers and improved the lipid profile in participants with severe chronic periodontitis. Periodontitis may influence the hyper-inflammatory response in patients with severe asthma as a result of immune-inflammatory changes.

Few studies have examined the relationship of individual periodontal parameters with individual systemic biomarkers. One study assessed the possible association between specific clinical parameters of periodontitis and systemic biomarkers of coronary heart disease risk in patients with coronary heart disease and periodontitis.⁵³ Patients with angiographically proven coronary heart disease with concomitant periodontitis ($n=317$) aged older than 30 years and without other systemic illness were examined. Periodontal clinical parameters of BOP, probing depth (PD), and clinical attachment level (CAL)

and systemic levels of high-sensitivity CRP, fibrinogen (FIB), and white blood cells (WBCs) were noted and analyzed to identify associations through linear and stepwise multiple regression analyses. Unadjusted linear regression showed significant associations between periodontal and systemic parameters. The strongest association ($r=.629$; $P<.001$) was found between BOP (the periodontal inflammation marker) and CRP levels (the systemic inflammation marker). Stepwise regression analysis models revealed that BOP was a predictor of systemic CRP levels ($P<.001$). BOP was the only periodontal parameter significantly associated with each systemic parameter (CRP, FIB, and WBC). In patients with coronary heart disease and periodontitis, BOP is strongly associated with systemic CRP levels; this association possibly reflects the potential significance of the local periodontal inflammatory burden for systemic inflammation.

One interesting study evaluated the influence of periodontitis on severe asthma in adults.⁵⁴ The case-control designed study comprised 220 adults: 113 diagnosed with asthma (case group) and 107 without a diagnosis of asthma (control group). The diagnosis of periodontitis was established after a complete clinical examination using PD, CAL, and BOP. The diagnosis of severe asthma was based on the criteria recommended by the 2012 Global Initiative for Asthma. Descriptive analyses of the variables were performed, followed by bivariate analyses using the χ^2 test. Association measurements (odds ratio [OR]), with and without adjustment for potential confounders, were obtained. A significance level of 5% was used. The OR unadjusted for the main association was 4.38 (95% confidence interval [CI] 2.47-7.75). In the logistic regression model, after adjusting for age, education level, osteoporosis, smoking habit, and body mass index (BMI), the OR adjusted was 4.82 (95% CI 2.66-8.76), which was statistically significant. Individuals with periodontal infection were approximately 5 times more likely to have bronchial inflammation than those without such periodontal tissue infection. The findings demonstrate the influence of periodontitis on severe asthma, given that the frequency of periodontitis is higher in individuals with severe asthma than in those without a diagnosis of bronchial inflammation.

Interest is growing in comparing periodontal conditions among countries. One study compared periodontal disease conditions in 3 elderly populations: one from Japan and 2 from Germany.⁵⁵ The study compared periodontal data of 70-year-old participants from the Niigata Study with 65- to 74-year-old participants from the Study of Health in Pomerania (SHIP) and from Germany (DMS III). A total of 489, 399, and 549 dentate participants were analyzed, respectively. Recording protocols were standardized. Older German participants

in SHIP and DMS III had significantly more severe periodontal conditions and fewer remaining teeth compared with those in the Niigata Study, although differences were less pronounced in DMS III. German participants showed a significantly different pattern of various periodontal risk factors compared with Japanese participants. Even after adjustment for putative periodontal risk factors, SHIP participants still presented significantly higher adjusted values for most periodontal parameters compared with the Niigata Study participants ($P<.05$). Periodontitis was more prevalent in SHIP compared with the Niigata Study, even after comprehensive risk factor adjustment. The differences among studies could be explained because the risk factors were not fully explored.

The purpose of another study was to evaluate bias associated with 9 identified partial-mouth periodontal examination protocols in estimating periodontitis prevalence using the periodontitis case definition given by the Centers for Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP).⁵⁶ The prevalence of complete-mouth examination was determined in a sample of 3667 adults ≥ 30 years old from the NHANES 2009-2010. Prevalence, absolute bias, relative bias, sensitivity, and inflation factor were derived for these protocols according to the CDC/AAP definition and half-reduced CDC/AAP definition as $\leq 50\%$ of sites were measured. Bias in moderate and severe periodontitis prevalence ranged from 11.1% to 52.5% for the full-mouth mesiobuccal-distolingual protocol and 27.1% to 76.3% for the half-mouth mesiobuccal protocol according to the CDC/AAP definition. With the half-reduced CDC/AAP definition, the half-mouth 4 sites protocol provided a small absolute bias (3.2%) and a relative bias (9.3%) for the estimates of moderate periodontitis prevalence; corresponding biases for severe periodontitis were -1.2% and -10.2% . Periodontitis prevalence can be estimated with limited bias when a half-mouth 4 sites protocol and a half-reduced CDC/AAP case definition are used in combination.

Periimplantitis

The prevention of any disease process should be the cornerstone of any health care provision. This idea is well established in dentistry with plaque-associated diseases such as periodontitis and caries but is at the current time less developed for periimplantitis. One review identified potential modifiable and nonmodifiable risk factors for periimplantitis development and detailed strategies for the prevention of the disease.⁵⁷ Risk factors include poor oral hygiene, previous history of periodontitis, smoking, genetic factors, occlusal overload, and foreign body reactions. Local factors include soft tissue and bone quality, implant positioning, restoration design, and the condition of the implant-abutment interface.

The purpose of an SR and meta-analysis was to assess the role of smoking as a risk factor for periimplantitis.⁵⁸ A search of 6 electronic databases and a manual search identified in 5876 unique publications. After selection, only 7 studies were included in the SR. Dichotomous data were expressed as risk ratios (RRs) and 95% CIs. The pooled effect was considered significant for $\alpha=.05$. The implant-based metaanalysis revealed a higher and significant risk of periimplantitis in smokers (RR 2.1, 95% CI 1.34-3.29, $P=.001$) compared with nonsmokers, but the patient-based meta-analysis did not reveal any significant differences for the risk of periimplantitis in smokers (RR 1.17, 95% CI 0.78-1.75, $P=.46$). The authors concluded that there is little evidence that smoking is a risk factor for periimplantitis. However, given the low number of the included studies and their poor quality, future studies are needed to confirm these results. This is a classic example of how the conclusion of an SR may be misleading.

Another review noted that, due to prevalence rates of up to 56% and without multilateral prevention and therapy concepts, periimplantitis can lead to the loss of implants.⁵⁹ The purpose of this review was to provide an overview of current data and to give advice for practitioners regarding the diagnosis, prevention, and treatment of periimplant disease.

Specific continuous evaluation and the elimination of risk factors (smoking, systemic diseases, and periodontitis) are effective precautions. In addition to aspects of osseointegration, the type and structure of the implant surface are of importance. For the treatment of periimplant disease, various conservative and surgical approaches are available. Mucositis and moderate forms of periimplantitis can be treated effectively using conservative methods. These include the use of different manual ablations, laser-supported systems, and photodynamic therapy, all of which may be extended by local or systemic antibiotics. It is possible to regain osseointegration. In patients with advanced periimplantitis, surgical therapies are more effective than conservative approaches. Depending on the configuration of the defects, resective surgery can be carried out to eliminate periimplant lesions, whereas regenerative therapies may be suitable for defect filling. The cumulative interceptive supportive therapy protocol serves as a guide for the treatment of periimplantitis.

The following study compared 2 regenerative surgical treatments for periimplantitis over 5 years.⁶⁰ Twenty-five individuals with periimplantitis remained at the study endpoint. They were treated with a bone substitute and a resorbable membrane (13 individuals with 23 implants) (group 1) or with bone substitute alone (12 individuals with 22 implants) (group 2). All study individuals were kept on a strict maintenance program every third month. Five-year follow-up demonstrated clinical and

radiographic improvements in both groups. No implants were lost because of the progression of periimplantitis. PDs were reduced by 3 ± 2.4 mm in group 1 and 3.3 ± 2.09 mm in group 2 (NS). In both groups, radiographic evidence of bone gain was significant ($P < .001$). At year 5, the average defect fill was 1.3 mm (SD ± 1.4 mm) in group 1 and 1.1 mm (SD ± 1.2 mm) in group 2 (mean difference 0.4, 95% CI -0.3, 1.2; $P = .24$). BOP decreased in both groups. Baseline and year 5 plaque scores did not differ between groups and was reduced from 50% to 15%. Both procedures resulted in stable conditions. The additional use of a membrane did not improve the outcome.

The purpose of another study was to evaluate the outcomes of conventional periodontal maintenance therapy in patients surgically treated for periimplantitis.⁶¹ Twenty-seven patients with 149 dental implants were monitored every 6 months over 5 years. At each recall visit, the prostheses were removed to allow proper access for implant examination and supragingival and subgingival instrumentation. Subgingival instrumentation was performed using an ultrasonic instrument with 0.12% chlorhexidine irrigation. At baseline (6 months following periimplant surgery), 149 implants (78 not treated and 71 treated) were available for analysis. Of the 71 treated implants, 43 presented a healthy periimplant condition, while 28 had residual periimplant pockets of either 4 to 5 mm or ≥ 6 mm associated with BOP/sup-puration. The longitudinal evaluation revealed that the plaque and bleeding index scores were low during the entire follow-up period and healthy periimplant conditions were maintained for both the 78 nontreated and the 43 treated "healthy" implants. Of the 28 implants with residual pockets, 9 showed clinical attachment loss during the 5-year follow-up. Thus, of 71 treated implants, probing attachment loss occurred in only 9 (13%) of the implants in 4 patients during the 5-year period. The presence of residual pockets at 3 or 4 sites of the implants (circumferential type of pockets) was frequently associated with increased probing pocket depth (PPD) and attachment loss, while this was not the case for implants with the presence of pockets at 1 or 2 sites only (site specific). In patients with a high standard of oral hygiene and enrolled in a recall system every 6 months, the periimplant conditions obtained after periimplant surgery remained stable for the majority of participants and implants during a 5-year period. The presence of residual pockets around the circumference of the implants seemed to be a high predictor of disease progression.

The purpose of the next study was to evaluate the success of treatments aimed at the resolution of periimplantitis in patients with osseointegrated implants.⁶² The relevant literature was accessed by 2 reviewers to identify case series and comparative studies describing the treatment of periimplantitis with a follow-up of at least 3 months and was assessed independently. For the

purposes of this review, a composite criterion for successful treatment outcome was used, which comprised implant survival with a mean PD less than 5 mm and no further bone loss. A total of 43 publications were included: 4 papers describing 3 nonsurgical case series, 13 papers describing 10 comparative studies of nonsurgical interventions, 15 papers describing 14 surgical case series, and 11 papers describing 6 comparative studies of surgical interventions. No trials comparing nonsurgical with surgical interventions were found. The length of follow-up varied from 3 months to 7.5 years. Because of the heterogeneity of the study designs, periimplantitis case definitions, outcome variables, and reporting, no meta-analysis was performed. Eleven studies could be evaluated according to a composite success criterion. Commonalities in treatment approaches among studies included a pretreatment phase, cause-related therapy, and a maintenance care phase. While the available evidence does not allow any specific recommendations for the therapy of periimplantitis, successful treatment outcomes at 12 months were reported in a majority of patients in 7 studies. Although favorable short-term outcomes were reported in many studies, lack of disease resolution as well as progression or recurrence of disease and implant loss despite treatment were also reported. The reported outcomes must be viewed in the context of the varied periimplantitis case definitions and the severity of the disease included as well as the heterogeneity in study design, length of follow-up, and exclusion/inclusion criteria.

The purpose of the following meta-analysis was to investigate whether a prophylactic antibiotic regimen can have positive effects on implant failure rates and postoperative infection when healthy individuals receive dental implant treatment.⁶³ An electronic search without time or language restrictions was undertaken in March 2014. Eligibility criteria included clinical human studies, randomized or not. The search strategy identified 14 publications. The I(2) statistic was used to express the percentage of the total variation across studies because of heterogeneity. The inverse variance method was used with a fixed- or random-effects model, depending on the heterogeneity. The estimates of relative effect were expressed in risk ratio (RR) with 95% CI. Six studies were judged to be at high risk of bias, whereas 1 study was considered at moderate risk and 6 studies were considered at low risk of bias. The test for overall effect showed that the difference between the procedures (use versus non-use of antibiotics) significantly affected the implant failure rates ($P = .0002$), with a RR of 0.55 (95% CI 0.41-0.75). The number needed to treat to prevent 1 patient having an implant failure was 50 (95% CI 33-100). No apparent significant effects of prophylactic antibiotics on the occurrence of postoperative infections were found in healthy patients receiving implants. A sensitivity analysis

did not reveal a difference when studies judged as having high risk of bias were not considered. The results have to be interpreted with caution because of the presence of several confounding factors in the included studies.

Periimplant health has also been recently associated with BMI and metabolic syndrome. A cross-sectional study was conducted to examine the relationships between the BMI, waist circumference (WC), and total body fat percentage and markers of inflammation around dental implants in 73 participants with stable periodontal maintenance.⁶⁴ The study visit consisted of a physical examination that included anthropologic measurements of body composition (BMI, WC, body fat %) and intraoral assessments (full-mouth plaque index, periodontal and periimplant comprehensive examinations); periimplant sulcular fluid (PISF) was collected of the study implants. The levels of interleukin (IL)-1alpha, IL-1beta, IL-6, IL-8, IL-10, IL-12, IL-17, tumor necrosis factor-alpha, CRP, osteoprotegerin, leptin, and adiponectin in the PISF were measured using multiplex proteomic immunoassays. After adjustments for covariates, regression analyses revealed a statistically significant correlation between IL-1beta in PISF and WC. The presence of IL-1beta, a major proinflammatory cytokine in the PISF, and WC, a reliable measure of central obesity suggests weight control may be a cofactor in periimplant health.

Periodontal disease assessment and treatment

Identifying the most accurate long-term prognosis for a tooth or the affected dentition is a long-held goal in treatment planning. A commonly asked question is whether extracting a multirrooted tooth and replacing it with a dental implant is better for the patient than retaining it. Multiple publications have attempted to provide evidence for the use of decision-making algorithms to answer this question. One group investigated risk factors for the loss of multirrooted teeth in participants treated for periodontitis and enrolled in supportive periodontal therapy (SPT).⁶⁵ A total of 172 participants were examined before and after active periodontal therapy and after a mean of 11.5 ± 5.2 (SD) years of SPT. The association of risk factors with a multirrooted tooth was analyzed with multilevel logistic regression. Teeth with no furcation or Class I involvement were not a risk factor for tooth loss. However, Class II or III furcation involvement (FI) and smoking habits were associated with increased tooth loss.

If evidence exists supporting the retention of Class I furcally involved molar teeth, examination of the associated costs of this treatment is prudent. Another group of investigators compared the cost-effectiveness of retaining or replacing molars with FI, assessing the cost-effectiveness of retaining FI molars with periodontal treatments versus replacing them with implant-supported crowns (ISCs).⁶⁶ Using tooth-level Markov

statistical modeling, they followed a molar with FI degree I or II/III in a 50-year-old patient over his lifetime. Tooth-retaining periodontal treatments, such as scaling and root planing (SRP), flap debridement, root resection, guided-tissue regeneration, and tunneling, were compared with tooth replacement using ISCs. They analyzed cost, time until first re-treatment, and total time of tooth or implant retention. The model adopted a private payer perspective within the German health care system. Transition probabilities (will the tooth require a secondary procedure such as root canal therapy) were calculated based on current evidence derived from SRs. The model demonstrated that despite requiring retreatment later than other strategies, ISCs were the most costly therapy. Compared with most periodontal treatments, ISCs were retained for a shorter time than natural teeth, regardless of the degree of FI, the patients' age, or risk profile (smoker/nonsmoker), indicating that retaining FI molars with periodontal treatments might be more cost-effective than replacing them with ISCs.

Investigators reported on a retrospective study examining 816 molars in 102 patients with moderate-to-severe periodontitis.⁶⁷ The data were derived from chart reviews in a private practice of patients who had been in periodontal maintenance for at least 15 years. The purpose of this study was to develop a scoring index to determine periodontal prognosis on molars. The 6 factors evaluated (age, PD, mobility, FI, smoking, and molar type) were assigned a numeric score based upon a statistical analysis. The sum of the scores for all factors was used to determine the prognosis score for each molar. Only patients with all first and second molars at the initial examination qualified for the study. Treatment procedures for the molar teeth during period of study was not uniform, but almost all molars received some form of surgical treatment. A multivariable regression analysis was performed, and a model was proposed based upon a scoring system that examined age, number of furcations per tooth, smoking, pocket depth, mobility, and molar type. The posttreatment time ranged from 15 to 40 years and averaged 24 years. When the study was completed, of the 639 molars that survived (78%), 588 (92%) were periodontally healthy. In molars with lower pretreatment scores (clinically healthier), the 15-year survival rates ranged from 96% to 98% and for molars with higher scores, the survival rates ranged from 67% to 86%.

Full-mouth tooth extraction has been considered a factor that may permanently alter the oral habitat and influence the oral microbiologic community. Investigators studied the effect of full-mouth tooth extraction on the oral microflora, with emphasis on the presence and load of *Aggregatibacter actinomycetemcomitans* and *Porphyromonas gingivalis*.⁶⁸ Saliva, tongue, buccal and gingival

mucosa, and subgingival plaque/prosthesis specimens were obtained from 30 adult patients with moderate to advanced periodontitis who were scheduled for complete-mouth tooth extractions. Aerobic and anaerobic culture techniques and quantitative real-time polymerase chain reaction (qPCR) were used to detect oral pathogens. The investigators found that complete-mouth tooth extraction reduced *A. actinomycetemcomitans* and *P. gingivalis* to below detection level in 15 of 16 previously positive patients using culture techniques and in 8 of 16 previously positive patients using qPCR. Those patients remaining qPCR-positive showed a significant reduction in load of these bacteria. However, in some patients, *A. actinomycetemcomitans* and *P. gingivalis* persisted in the edentulous oral cavity up to 3 months after complete-mouth tooth extraction.

Periodontal regeneration

Promising clinical outcomes have been reported with the combination of enamel matrix derivative (EMD) and allograft materials in the treatment of intrabony defects. Two investigators conducted an RCT to determine the relative efficacy of EMD/freeze-dried bone allograft (FDBA) versus EMD/demineralized freeze-dried bone allograft (DFDBA) for intrabony defects.⁶⁹ A randomized parallel trial was conducted in a private practice. Sixty-nine participants were randomly assigned to 1 of 3 groups: EMD/FDBA (EF) intervention group (n=23), EMD/DFDBA (ED) intervention group (n=23), and EMD alone without graft material (E) as a negative control group (n=23). All of the grafting material had minocycline added. The primary outcomes were the absolute change in PD reduction and CAL gain from baseline to 1- and 3-year follow-up. Sixty-seven participants (EF, n=21; ED, n=23; E, n=23) were analyzed. All groups demonstrated significant improvement in PD reduction and CAL gain from baseline. The changes for CALs at 3 years were EF (4.2 mm), ED (3.6 mm), and E (3.0 mm). The intervention groups (EF and ED) showed better treatment outcomes than the control group at 1 and 3 years. Statistically, the 2 bone graft groups were not significantly different from each other at 1 and 3 years.

Historically, achieving predictably good clinical outcomes in the treatment of noncontained intrabony defects has been more difficult. One group compared clinical outcomes in the treatment of deep noncontained intrabony defects by using deproteinized bovine bone mineral (DBBM) combined with either enamel matrix protein derivative (EMD) or collagen membrane (CM).⁷⁰ They enrolled 40 participants with multiple intrabony defects. Only 1 noncontained defect per participant with an intrabony depth ≥ 3 mm and located in the interproximal area of single-rooted and multirrooted teeth was randomly assigned to treatment with either EMD + DBBM (test: n=20) or CM + DBBM (control: n=20). The

primary outcome variable was the change in CAL between baseline and 12 months. The mean CAL gain at sites treated with EMD + DBBM was not statistically significantly different ($P=.82$) compared with CM + DBBM (3.8 versus 3.7 mm), demonstrating that regenerative therapy using either EMD + DBBM or CM + DBBM yielded comparable clinical outcomes in deep noncontained intrabony defects after 12 months.

Regeneration of the lost periodontium associated with suprabony defects has been even more elusive. In an SR examining the treatment of suprabony defects, investigators examined the possible adjunctive role of the use of EMD.⁷¹ RCTs comparing open flap debridement (OFD) versus EMD in periodontal suprabony defects were identified through electronic and manual searches. The primary outcome measures were tooth survival (TS) and CAL gain. PPD reduction and recession (REC) increase were secondary outcome measures. The search identified 1170 studies, of which only 3 articles met the inclusion criteria and were included. The studies reported on 99 participants and 358 teeth. No tooth was lost during follow-up (8 to 12 months). The adjunctive mean benefit of EMD was 1.2 mm for CAL, 1.2 mm for the PPD reduction, and -0.5 mm for the REC increase. A potential risk of bias was identified. No differences were noted in TS, but EMD application resulted in clinical and radiographic additional benefits compared with OFD alone. However, the authors cited the paucity of data, and the risk of methodologic and potential publication bias as reasons for exercising caution in interpreting these results.

Use of lasers in treatment of periodontal disease

The treatment of periodontal disease with a laser remains controversial. The paucity of controlled clinical trials, the variability in energies and wavelengths used, the timing and duration of the energy pulses, and commercial pressures have contributed to the unknown efficacy of this treatment.

One group of investigators compared the clinical efficiency of a diode laser (DL) as an adjunct to SRP in the treatment of patients with chronic periodontitis.⁷² A total of 30 participants (mean age 38.2 years) with chronic periodontitis were selected for this study. The participants were randomly assigned to 2 groups of 15 participants each as the control group and test group. The control group received only conventional SRP, and the test group received conventional SRP and DL (GaAlAs)-assisted pocket debridement. The clinical parameters (plaque index, BOP, PPD, and CAL) were recorded at baseline and day 60. When the groups were compared, there was statistically significant improvement in the PI score, decrease in BOP and PPD, and gain in CAL ($P<.001$) in both groups from baseline to day 60. From the results observed in this study, it was concluded that the use of a DL as an adjunct to SRP did not provide any

significant difference compared with the use of SRP alone in terms of clinical parameters.

Another group conducted an SR examining the effect of the thermal DL in nonsurgical periodontal debridement (SRP) during the initial phase of periodontal therapy.⁷³ The MEDLINE/PubMed, Cochrane Central Register of Controlled Trials, and EMBASE databases were searched up to September 2013. PPD and CAL were selected as outcome variables. Also plaque scores (PS), bleeding scores (BS), and the gingival index (GI) were considered outcome measures. Data were extracted and a metaanalysis was performed where appropriate. The metaanalysis evaluating PPD, CAL, and PS showed no significant effect. The only significance favoring adjunctive use of the DL was observed for the outcome parameters GI and BS. The investigators concluded that the collective evidence regarding the adjunctive use of the DL with SRP indicates that the combined treatment provides an effect comparable to that of SRP alone when PPD and CAL are the outcome variables. The authors stated that the “systematic review questions the adjunctive use of DL with traditional mechanical modalities of periodontal therapy in patients with periodontitis.”

Another SR compared the efficacy of the Er:YAG laser compared with SRP, either as an alternative form of treatment or an adjuvant in the treatment of chronic periodontitis.⁷⁴ Investigators performed a literature search of 6 electronic databases as well as manual searches up to July 2013. They conducted a metaanalysis as well as heterogeneity, sensitivity, subgroup, and power analyses to clarify and validate the pooled results. The 3-, 6-, and 12-month clinical outcomes were evaluated. The metaanalysis showed that the Er:YAG laser produced similar clinical improvements to SRP 3 months postoperatively. The 6- and 12-month observations of the Er:YAG laser and SRP revealed no differences, but this result was inconclusive because of great heterogeneity. The advantage of the Er:YAG laser as an adjuvant to SRP for periodontitis treatment was also not significant.

Soft tissue augmentation

In the treatment of gingival recession, clinicians have used varied gingival flap procedures to achieve root coverage. While coronally advanced open flap (CAF) procedures, with or without a biologic modifier or graft material, have been the most documented, more recent studies are examining the benefits of a tunneling or pouch technique. One group compared the clinical performance of the tunnel technique with a subepithelial CTG (TUN) versus a coronally advanced flap with EMD (CAF) in the treatment of gingival recession defects.⁷⁵ They used 3-dimensional (3D) digital measuring methods to study the healing dynamics at the connective tissue-grafted sites and evaluated the influence of the

thickness of the root covering the soft tissues on the outcome of surgical root coverage. Twenty-four participants contributed a total of 47 Miller Class I or II recessions for evaluation. Precise study casts collected at baseline and follow-up examinations were optically scanned and virtually superimposed to digitally evaluate the clinical outcome measures, including the mean marginal soft tissue thickness (THK). Healing dynamics were measured in a defined region of interest at connective tissue-grafted sites, where volume differences between time points were calculated. At 12 months, recession reduction and mean root coverage were significantly better at connective tissue-grafted sites treated in the TUN group (1.94 mm and 98.4%, respectively) compared with the nonaugmented sites of the CAF group (1.17 mm and 71.8%, respectively), and statistical analysis revealed a positive correlation of THK (1.63 mm TUN versus 0.91 mm CAF, $P<.001$) with both these variables. Soft tissue healing after surgical root coverage with connective tissue grafting was mainly accomplished after 6 months, with approximately two thirds of the augmented volume being maintained after 12 months. The TUN resulted in thicker gingiva and better clinical outcomes compared with CAF.

Using an RCT design, investigators compared a CAF (control group) with the pouch technique (test group), both of which procedures were combined with a CTG.⁷⁶ Forty consecutive participants were included, with 20 participants being allocated to each group. The level of recession coverage, keratinized tissue (KT) quantity, pink esthetic scores, and postoperative outcomes were assessed for a follow-up period of 6 months. After 6 months, both techniques allowed for the excellent mean root coverage of 96.3% in the control group and of 91.3% in the test group. Complete root coverage (CRC) was achieved in 89.5% (17/19) of the participants with recession in the control group and 79% (15/19) in the test group. A significant increase in KT height ($P=.0011$) was observed in the test group. A significant improvement in the pink esthetic score was found in the 2 groups, but gingival texture was significantly better in the test group ($P<.001$). No significant difference between the 2 groups was found in terms of morbidity outcomes. The pouch technique seemed to increase the height of KT better and provides good gingival-related esthetic outcomes.

The analysis of gingival augmentation studies is sometimes confounded by comparing the results from studies examining single site recession defects versus multiple site defects. Investigators compared the short- and long-term root coverage and esthetic outcomes of the CAF alone or in combination with a CTG for the treatment of multiple gingival recessions.⁷⁷ Fifty participants with multiple (≥ 2) adjacent gingival recessions (≥ 2 mm) in the maxilla were enrolled. Twenty-five

participants were randomly assigned to the control group (CAF) and the other 25 participants to the test group (CAF + CTG). Clinical outcomes were evaluated at 6 months, 1 year, and 5 years. No statistically significant difference was demonstrated between the 2 groups in terms of recession reduction and CRC at 6 months and 1 year. At 5 years, statistically greater recession reduction and probability of CRC, greater increase in buccal keratinized tissue height, and better contour evaluation were observed in the CAF + CTG group. However, better color match was demonstrated in CAF-treated participants at both 1 and 5 years.

An SR examining the efficacy of periodontal plastic procedures (PPP) in the treatment of multiple gingival recessions was performed.⁷⁸ RCTs on multiple gingival recession treatment of at least 6 months were identified through electronic databases and hand-searched journals. The primary outcomes were CRC and percentage of root coverage. Weighted means and forest plots were calculated for all PPP. Subgroup analysis was performed according to the type of flap. A Bayesian network meta-analysis on secondary outcomes was also performed. Nine trials with 208 participants and 858 recessions were identified. CRC after PPP was 24% to 89%. Mean weighted percentage of root coverage was 86.27% ($P < .01$). The heterogeneity of the literature prevented intertechnique comparison. CAF showed the higher variability in terms of CRC. Modified CAF and tunnel approaches showed the higher level of CRC. The network metaanalysis suggested that CAF plus graft showed the higher probability of being the best treatment. Indirect evidence indicated that CAF may benefit from newer variations of the technique and by the additional use of grafting.

The use of an ADM as a substitute for autogenous tissue is an accepted treatment for gingival recession. Investigators compared the use of 2 differently processed ADM products for root coverage in a prospective randomized multicenter study.⁷⁹ This study compared a freeze-dried acellular dermal matrix (FDADM) with a solvent-dehydrated acellular dermal matrix (SDADM) with regard to their ability to correct Miller Class I and II recession defects. Eighty individuals, each with a single maxillary anterior Miller Class I or II recession defect, were enrolled from 4 study centers. Participants were randomly assigned and treated with CAFs plus FDADM ($n=42$) or CAF plus SDADM ($n=38$). The gingival thickness (GT), recession depth, recession width, PD, CAL, GI, plaque index, patient discomfort, and wound healing index were recorded before surgery (day 0), immediately after surgery (day 1), and 2, 4, 12, 24, and 52 weeks postoperatively. When the clinical parameters were evaluated after 1 year, both groups showed significant ($P < .05$) improvement for most of the parameters evaluated compared with baseline (day 0). For example, the

percentage of root coverage was 77.21% for CAF + FDADM and 71.01% for CAF + SDADM. Conversely, no significant differences were observed between the 2 materials for any clinical parameter tested.

Some clinicians prefer to use autogenous material over an ADM in the treatment of multiple recession defects associated with a thin biotype. Investigators compared an ADM graft combined with a CAF with regard to complete defect coverage, esthetics, and patient satisfaction with CAF alone for multiple recessions with $GT < 0.8$ mm.⁸⁰ Forty-eight Miller Class I multiple recessions ≥ 3 mm were divided into test (CAF + ADM) and control (CAF) groups. At baseline and 12 months, the recession height (RH), KT height, GT, and mean and complete defect coverage were evaluated. Patient satisfaction, root coverage esthetics score (RES), and correlation between GT and defect coverage were also assessed. The mean and complete defect coverage were 94.84% and 83.33%, respectively, in the test group, and 74.99% and 50.00%, respectively, in the control group. Intergroup differences were statistically significant for RH reduction, attachment gain, KT and GT increase, mean defect coverage, and RES in favor of the test group ($P < .05$). A significant positive correlation was found between GT and mean defect coverage ($P < .05$). The authors concluded that a CAF in association with ADM can be proposed as a valid approach for the treatment of multiple recessions with a thin tissue biotype.

Soft tissue recession after immediate and early implant placement can also negatively affect the esthetic result. An SR was conducted to quantitatively estimate the esthetic outcomes of implants placed in post-extraction sites and to evaluate the influence of simultaneous bone augmentation procedures on these outcomes.⁸¹ Electronic and manual searches of the dental literature were performed to collect information on esthetic outcomes based on objective criteria for implants placed after extraction of maxillary anterior and premolar teeth. All levels of evidence were accepted (case series studies required a minimum of 5 cases). From 1686 titles, 114 full-text articles were evaluated and 50 records included for data extraction. The included studies reported on single-tooth implants adjacent to natural teeth, with no studies on multiple missing teeth identified. Considerable heterogeneity in study design was found, making metaanalysis impossible. The available evidence suggests that esthetic outcomes, determined by esthetic indices (predominantly the pink esthetic score) and positional changes of the periimplant mucosa, may be achieved for single-tooth implants placed after tooth extraction. Immediate (type 1) implant placement, however, is associated with a greater variability in outcomes and a higher frequency of recession of >1 mm of the midfacial mucosa compared with early (type 2 and type 3) implant placement. In 2 retrospective

studies of immediate (type 1) implant placement with bone graft, the facial bone wall was not detectable on CBCT in 36% and 57% of sites. These sites had more recession of the midfacial mucosa compared with sites with detectable facial bone. Two studies of early implant placement (types 2 and 3) combined with simultaneous bone augmentation with GBR (contour augmentation) demonstrated a high frequency (>90%) of facial bone wall visible on CBCT. Recent studies of immediate (type 1) placement imposed specific selection criteria, including thick tissue biotype and an intact facial socket wall, to reduce esthetic risk. They concluded that acceptable esthetic outcomes may be achieved with implants placed after extraction of teeth in the maxillary anterior and premolar areas of the dentition, but recession of the midfacial mucosa is a risk with immediate (type 1) placement.

Ridge preservation

Numerous studies examining the efficacy of procedures that aim to maintain the alveolar ridge volume after tooth extraction have been published. Comparison of these procedures is difficult because of the many materials used and the inherent variability of the extraction trauma and residual socket anatomies. One group conducted an SR assessing whether the use of a graft and/or membrane after tooth extraction improves the healing of the site dimensionally, radiographically, and/or histologically.⁸² MEDLINE, Cochrane Central Register of Controlled Trials, and EMBASE databases were searched. RCTs that included and compared healing after tooth extraction between a control (no intervention) and a graft and/or membrane (test) were selected. The titles and abstracts of 2861 papers were screened. Only 9 papers met the eligibility criteria and were selected for further analysis. Because of the varying graft materials used, the different methods of investigation, and the variation in follow-up times, a meta-analysis was not possible. This SR found that, clinically, the loss of width in the control sites ranged from 2.46 mm (SD 0.4 mm) to 4.56 mm (SD 0.33 mm) compared with 1.14 mm (SD 0.87 mm) to 2.5 mm (SD 1.2 mm) in the test sites. The loss of height in the control sites ranged from 0.9 mm (SD 1.6 mm) to 3.6 mm (SD 1.5 mm) compared with a gain of 1.3 mm (SD 2 mm) to a loss of 0.62 mm (SD 0.51 mm) in the test sites. Radiographically, the change in bone height in the control sites ranged from 0.51 mm (no SD) to 1.17 mm (SD 1.23 mm) compared with 0.02 mm (SD 1.2 mm) and 1 mm (SD 1.4 mm) in the test sites. The authors concluded there are limited data regarding the effectiveness of alveolar ridge preservation therapies when compared with a control. Overall, socket intervention therapies did reduce dimensional changes of the alveolar ridge after extraction but were unable to prevent

resorption. Histology did demonstrate a large proportion of residual graft material that may account for some of the difference in alveolar ridge dimensions at follow-up. The fate of the residual graft material is unknown in the osseointegrated environment.

Another SR aimed to determine the effect that filling sockets with a bone grafting material has on the prevention of postextraction alveolar ridge volume loss compared with tooth extraction alone in nonmolar teeth.⁸³ Five electronic databases were searched to identify randomized clinical trials that fulfilled the eligibility criteria. Outcome measures were mean horizontal ridge changes (buccolingual) and vertical ridge changes (midbuccal, midlingual, mesial, and distal). The influence of several variables of interest (flap elevation, membrane usage, and type of bone substitute used) on the outcomes of ridge preservation therapy was explored with subgroup analyses. The investigators found that alveolar ridge preservation was effective in limiting physiologic ridge reduction as compared with tooth extraction alone. The clinical magnitude of the effect was 1.89 mm in terms of buccolingual width, 2.07 mm for midbuccal height, 1.18 mm for midlingual height, 0.48 mm for mesial height, and 0.24 mm for distal height changes. Subgroup analyses revealed that flap elevation, the use of a membrane, and the application of a xenograft or an allograft are associated with superior outcomes, particularly for midbuccal and midlingual height preservation.

Not all extraction sockets heal uniformly or without complications. The investigators conducted an exploratory study to analyze the prevalence of extraction sockets showing erratic healing and to evaluate factors potentially impeding healing.⁸⁴ Erratic healing was defined as clinical observations of extraction sites showing fibrous scar tissue occupying the extraction site rather than bone after 12 or more weeks of healing. CT was used to evaluate characteristics and calculate Hounsfield unit scores for sites showing erratic healing. A total of 1226 dental records from a university dental hospital archives including patients subject to extractions before implant placement were evaluated. Seventy participants (5.71%) and 97 sites (4.24%) exhibited erratic extraction socket healing. Maxillary incisor/canine sites showed the lowest (0.47%), whereas mandibular molar sites the highest (5.41%) occurrence. In the multivariable analysis, erratic healing was more likely to occur in patients younger than 60 years old, patients with hypertension, in molar sites, and after single tooth extractions. CT showed the highest incidence of bone loss for the buccal wall (49.3%). The authors concluded that erratic extraction socket healing appears to be a not uncommon sequel and local factors seem to be major contributors to its occurrence.

Methods of maintaining alveolar bone volumes after extraction which do not use allografts or xenografts

have been described. One method involves the use of autologous platelet concentrates. The investigators performed an SR that evaluated the efficacy of platelet concentrates for alveolar socket healing after tooth extraction.⁸⁵ MEDLINE, Cochrane Central Register of Controlled Trials, and EMBASE databases were searched using a combination of specific search terms. The primary outcomes were postoperative complications, patient satisfaction, and postoperative discomfort. The secondary outcomes were any clinical, radiographic, histologic, and histomorphometric variables used to assess hard and soft tissue healing. A broad heterogeneity in the study characteristics and outcome variables used to assess hard tissue healing was observed. A metaanalysis of 2 studies reporting the histomorphometric evaluation of bone biopsies at 3-month follow-up showed greater bone formation when platelet concentrates were used compared with controls ($P < .001$; mean difference 20.41%, 95% CI 13.29%, 27.52%). The beneficial effects of platelet concentrates were generally but not systematically reported in most studies. The results of the metaanalysis of the present review are suggestive of a positive effect of platelet concentrates on bone formation in post-extraction sockets, but because of the limited amount and quality of available evidence, they need to be cautiously interpreted.

Two studies examined the potential benefit of combining a hard tissue graft with a soft tissue graft in the management of the extraction site in the esthetic zone. The first study described a case series of 58 extraction sockets which were consecutively completely filled with autogenous bone chips after tooth extraction in 49 patients.⁸⁶ At least half of the buccal alveolar wall was absent after tooth extraction in all sites. A free gingival-CTG from the palate sealed the grafted extraction site. Approximately 10 to 12 (mean, 10.9) weeks after socket augmentation, implants were inserted. A histomorphometric analysis was performed on trephine bone cores removed from the grafted sockets in 7 consecutive patients. Standardized volumetric measurements of the buccal alveolar contour were evaluated before tooth extraction and at 1 and 5 years after prosthetic incorporation. Implants could be inserted into 47 (81%) treated extraction sockets without additional grafting procedures. In 11 patients (19%), implant placement was combined with local grafting techniques. Bone grafts were mature and well revascularized 10 to 12 (mean, 10.9) weeks after socket augmentation. The mean amount of vital bone was 52% \pm 8.6%. Standardized volumetric measurements showed that 83.3% of the reference points representing the outer alveolar contour did not change significantly from baseline to 1 year after prosthetic incorporation and from baseline to 5 years after prosthetic incorporation.

The second study described the use of a connective tissue saddle graft combined with the insertion of a slowly resorbed bone graft into the socket.⁸⁷ A total of 14 patients needing tooth replacement in the esthetic region were included to receive a socket preservation procedure using a CTG. Impressions were obtained before the tooth extraction (baseline) and at 2, 4, and 12 weeks after the procedure. The corresponding gypsum casts were scanned, and the evolution of the soft tissue profile in relation to the baseline situation was assessed using imaging software. The insertion of saddled connective tissue appeared to compensate for the horizontal and vertical bone remodeling after a socket preservation procedure in most regions of the alveolar crest. After 12 weeks, the only significant change was located in the more cervical and central region of the alveolar process and reached a median drop of 0.62 mm from baseline. The minor changes found in the cervical region might disappear with the emergence profile of the prosthodontic components.

PROSTHODONTICS

Once again, the 2014 literature brought a wealth of information to the profession related to the ever-expanding topic of prosthodontics. Although the current review focuses on articles providing new and important information from clinical, laboratory, and scientific perspectives, many topic-oriented review articles were also published and may be of interest to readers. The topics reviewed include antiresorptive therapy,⁸⁸⁻⁹⁰ biomechanics,^{91,92} complete dentures,⁹³⁻⁹⁵ demographics,⁹⁶ diagnostics,⁹⁷⁻⁹⁹ digital dentistry,^{100,101} esthetics,^{102,103} evidence-based dentistry,¹⁰⁴⁻¹⁰⁶ fixed prosthodontics,¹⁰⁷⁻¹¹⁰ geriatrics,¹¹¹⁻¹¹³ implant prosthodontics,¹¹⁴⁻¹²² materials science,¹²³⁻¹³⁰ removable partial prosthodontics,¹³¹⁻¹³⁴ wear,^{135,136} xerostomia,¹³⁷ and zygomatic implants.¹³⁸⁻¹⁴⁰

For convenience and clarity, this review of the 2014 prosthodontic literature is divided into the following sub-topics: general prosthodontic considerations, conventional removable complete prosthodontics, conventional removable partial prosthodontics, conventional fixed prosthodontics, general implant prosthodontic considerations, implant removable prosthodontics, implant fixed prosthodontics, and prosthodontic materials.

General prosthodontic considerations

Dental esthetics drives much of what dental professionals do on a day-to-day basis, including restorative treatment planning, materials selection, and restoration design. Often, an esthetic compromise brings patient to the dental practice for cosmetic improvement. Physical appearance, including dental esthetics, impacts first impressions and human social

interactions. One group of investigators hypothesized that relatively minor changes in the value of tooth color would influence the perceived social appeal of full-face photographs.¹⁴¹

Using a cross-sectional study design, 555 adult participants viewed 1 of 6 possible full-face photographs of an unknown man or an unknown woman. The photographs depicted youthful faces with healthy smiles displaying well-aligned anterior teeth and incorporated 2 independent variables: tooth lightness/value (digitally lightened, natural, or digitally darkened color) and sex.

After reviewing the photograph provided, the participants completed a questionnaire comprised of 2 sections: an *observer section* for gathering each participant's sociodemographic, behavioral, and dental health information and a *photograph section* for recording the social appeal of the photograph provided. The participants were characterized by 6 independent variables (age, sex, educational level, place of residence, tooth brushing frequency, and self-reported health status). Four domains of photograph appeal were quantified (social, intellectual, psychological, and relational).

The authors examined the impact of a single dental attribute (tooth lightness/value) on the social judgments of the unknown observers. A statistical evaluation of the collected data revealed that tooth lightness influenced the social appeal of the observer, in that lightened smiles received the most favorable scores, while natural and darkened smiles were considered less socially appealing. Thus, tooth lightness was identified as the major predictor of social appeal. A perceptible change in tooth lightness influenced the positive perceptions of the observers with regard to the traits of happiness, social relations, and academic performance.

The authors indicated the existence of a "dental attractiveness stereotype." This stereotype is likely a factor for patients seeking esthetic dental alterations and the emergence of esthetic or cosmetic dental practices. The concomitant increase in the demand for commercial dental bleaching procedures, products, and practices seems intuitive.

Complete dental rehabilitation is often impossible or undesirable for older patients because of existing physical or mental conditions, limited access to oral health care, financial restrictions, or patient preferences. Often, dental treatment goals and planning that target acceptable function rather than the restoration of complete dentitions are more appropriate. To explore this concern, investigators systematically reviewed the current published evidence on the relationship between functional dentition status and masticatory ability in older adults (≥ 65 years old) as determined by questionnaires.¹¹²

An initial review of the MEDLINE database for publications up to 2011 provided 939 abstracts. A review of

this material and the application of exclusion criteria identified 18 studies published in 20 scientific reports. Data extracted from these reports were included in the present review.

Studies included in this review were cross-sectional and only partially represented older populations at a given time, indicating trends rather than rules. The included studies also lacked methodologic homogeneity in data collection and the interpretation of dental status. Data tended to reveal that masticatory ability was closely related to the number and distribution of remaining teeth. Although most older adults could function adequately with a shortened dental arch, this was not universally true, in that many reported compromised masticatory ability or altered food selection and preparation.

The authors suggested that the evidence indicated that the treatment for this patient population should focus on preserving the strategic elements of the dental arch critical to adequate oral function. The maintenance of existing conditions and occlusal stabilization without extending the dental arch appear most appropriate. When few teeth remain with severe masticatory impairment, unacceptable appearance, and ill-fitting prostheses, prosthetic treatment may be indicated. The authors recommended that long-term, well-defined, prospective studies be accomplished to obtain a clearer picture of the association between masticatory ability and functional tooth units.

Identifying and managing xerostomia is essential to providing optimal oral health care. This is particularly true when fixed, removable, or implant prosthodontics are indicated. The ADA Council on Scientific Affairs presented a practical, evidence-guided approach to managing xerostomia and salivary gland hypofunction that serves as an excellent review for practicing dentists, particularly those treating older adults.¹⁴² The authors reviewed pertinent literature detailing xerostomia and covering the function of saliva, etiologic factors, signs and symptoms, diagnostic considerations, and management strategies. Best evidence indicates that a detailed health history is critical to the early detection and identification of underlying etiologies. Comprehensive evaluation, diagnostic testing, periodic salivary flow assessment, and appropriate corrective actions may help prevent secondary oral disease.

The report recommended a comprehensive and systematic management strategy for xerostomia and hyposalivation, emphasizing patient education and lifestyle modifications (daily oral hygiene, regular dental visits, topical fluoride, and tobacco cessation), effective management of contributing systemic conditions and medications in consultation with other health care providers, preventive measures to reduce secondary oral disease, application of pharmacologic salivary stimulants,

and palliative treatment when indicated. The authors concluded that this evidence-guided approach to the effective management of xerostomia includes interventions directed at the relief of symptoms, reduction of complications, and quality of life improvement.

Edentulism, which has been called “the dental equivalent of mortality,”¹⁴³ is considered a predictor of mortality¹⁴⁴ and is found to diminish quality of life.¹⁴⁵ However, decades of marked reduction in prevalence remain poorly understood, yielding flawed projections and misdirected health goals. Available graphical and statistical methods permit more accurate projections. With this in mind, 1 group of investigators endeavored to quantify trends in edentulism prevalence among U.S. adults aged 15 years and older from 1957 through 2012, describe geographic and sociodemographic variation in edentulism in 2010, and project the prevalence of edentulism in 2050.¹⁴⁶

Time-series data from 5 national cross-sectional adult health surveys were created (1957-1958, $n \cong 100\ 000$; 1971-1975, $n=14\ 655$; 1988-1998, $n=18\ 011$; 1999-2002, $n=12\ 336$; and 2009-2012, $n=10\ 522$). Birth cohort analysis was used to identify and isolate age and cohort effects. Geographic and sociodemographic variations were investigated using an additional U.S. survey of 432 519 adults conducted in 2010. Prevalence through 2050 was projected with age-cohort regression models using the Monte-Carlo simulation of prediction intervals.

Across the half-century observation period, the prevalence of U.S. adult edentulism declined from 18.9% to 4.9%. The most influential determinant of the decline was the death of generations born before the 1940s, whose rate of edentulism incidence exceeded later cohorts. By 2010, edentulism had become a rare condition in high-income households and was essentially concentrated in areas with disproportionately high poverty and unemployment rates.

With the death of those born in the mid-20th century, the rate of decline in edentulism is projected to slow, reaching 2.6% by 2050. Population growth and population aging is expected to offset the continuing decline only partially. The predicted number of edentulous people in the U.S. in 2050 is 8.6 million, a 30% reduction compared with 12.2 million edentulous people in 2010.

The authors concluded by suggesting that the trends illustrated here will likely affect the provision of future dental care because tooth retention is a strong predictor of dental attendance. The projected slow decline in edentulism through 2050 refutes the premise of a consensus statement on implant overdentures that asserts the number will increase.¹⁴⁷ These trends may also impact dental education, in that declining patient populations affect educational efforts in removable prosthodontics.

Conventional removable complete denture prosthodontics

Aspiration is a known pathogenic mechanism for pneumonia, and poor oral health, lack of professional oral care, and inadequate oral hygiene have been identified as major risk factors among older adults. In an effort to identify modifiable oral health-related behavioral risk factors, a study from Japan¹⁴⁸ prospectively investigated associations between a constellation of oral health behaviors and incident pneumonia in a community of older adults (≥ 85 years of age).

A total of 524 older adults (228 men, 296 women, 453 denture wearers, mean 87.8 years of age) randomly selected from an ongoing survey of total health were identified thorough dental and medical examinations. Dental examinations included the assessment of dentures and oral hygiene. An initial questionnaire included 4 denture-related items: denture wear frequency, denture cleaning frequency, denture cleanser usage, and denture wear during sleep. Participants were followed annually up to 36 months. The outcomes of interest were serious pneumonia events, including the first hospitalization for or death due to pneumonia.

During the observation period, 48 serious pneumonia events (20 deaths and 28 acute hospitalizations) were identified. Among denture wearers, 186 (40.8%) participants who wore their dentures during sleep were at significantly higher risk for pneumonia than those who removed their dentures at night. Multivariate modeling revealed that overnight denture wear was independently associated with an approximately 2.4-fold higher risk for pneumonia. Those who wore dentures during sleep were more likely to have tongue and denture plaque, oral soft tissue inflammation, positive *Candida albicans* cultures, and higher circulating interleukin-6 levels (inflammation) compared with their counterparts. Further analysis indicated that the inflammatory and microbial burden of the oral cavity could provide a mechanistic link between denture wearing during sleep and incident pneumonia.

This study provides empirical evidence that denture wearing during sleep is associated not only with oral inflammatory and microbial burden but also with incident pneumonia, a potentially life-threatening condition in older adults. Improved personal oral and denture hygiene habits and regular professional evaluations to reinforce appropriate hygiene techniques should be considered in this at risk population. The authors suggest that the dissemination of evidence-based guidelines for denture care/maintenance¹⁴⁹ and oral health promotion programs with denture care components is necessary.

The causes of oral cancer are not fully understood, although multifactorial etiologies are likely. Risk factors include the use of alcohol and tobacco, dietary deficiency, high temperature food or beverage consumption, and poverty. The chronic mechanical irritation of the oral

mucosa, as occurs with ill-fitting dentures, may contribute to the development or severity of oral cancer.

An increased awareness of oral cancer risk factors, early detection, and appropriate management are of obvious importance. Investigators published a meta-analysis designed to evaluate the relationship between denture use and the development of oral cancer.¹⁵⁰ An attempt was made to determine whether the duration of denture wear (<5 years versus >5 years) or the use of ill-fitting dentures increased the likelihood of oral cancer development.

An SR of available databases from 1946 through August 2014 identified 191 articles on the topic (dentures and cancer, duration of denture use, comfort and fit of dentures). An initial screening and the application of eligibility criteria reduced the selection to 9 articles for the metaanalysis.

The results indicated that the wearing of dentures, by itself, is associated with only a slight (approximately $\times 1.4$) increased risk of oral cancer. However, the use of ill-fitting dentures appears to substantially (approximately $\times 4$) increase the risk. No association was found between the duration of denture use and cancer development. This could be because of the arbitrary definitions of duration assigned in the present analysis or because of the variable time allocations used in contributing reports.

Ill-fitting dentures appear to be a risk factor for the development of oral cancer. The application of this finding will increase patient and practitioner awareness of appropriate screening, resulting in the earlier detection of premalignant and malignant oral lesions. Earlier detection can improve patient prognosis and quality of life.

Adequate prosthesis support, stability, and retention are important to successful complete denture therapy. Denture tooth position and functional occlusal relationships may relate to patient comfort and satisfaction. Unfortunately, a sound evidence basis for the selection of optimal complete denture occlusion has not been established. To add to the existing body of evidence in this area, investigators reported on a randomized, crossover clinical trial investigating patient satisfaction with 3 complete denture occlusal schemes.¹⁵¹

Fifteen edentulous participants (mean 59 years of age) were enrolled. Participants were characterized as having ideal maxillomandibular relationships, healed edentulous ridges, and the absence of severe ridge atrophy. All participants received 3 dentures, each incorporating a different posterior occlusal scheme: cross-tooth cross-arch balance (CCB—maxillary facial and lingual functional cusps), lingualized balance (LB—only maxillary lingual functional cusps), and buccalized balance (BB—only mandibular facial functional cusps). Dentures were worn for 6 weeks in random order. At the 6-week crossover

point, patient satisfaction was assessed with a 19-item questionnaire (OHIP-Edent—Oral Health Impact Profile for Edentulous Patients).

A statistical evaluation of the collected data revealed that LB dentures were more comfortable for eating compared with CCB dentures, that LB and BB dentures caused less food avoidance than CCD dentures, that LB dentures were more uncomfortable than CCB dentures, and that BB dentures were associated with less physical disability than CCB dentures. No other differences were found to be statistically significant.

Based on patient responses to a satisfaction questionnaire, the authors concluded that CCB dentures were considered less comfortable in general and during eating and caused food avoidance. Compared with BB dentures, CCB dentures were associated with physical disability. Because of a small sample size, the results of this study cautiously suggest that buccalized occlusion can improve patient satisfaction with complete dentures.

Recently, the dental profession has seen a shift from clinical decision making based on personal experience and expert opinion in favor of best scientific evidence. RCTs are now widely accepted as the gold standard for providing strong, clinically significant evidence. However, an RCT must address clinically relevant outcomes in order to contribute to the decision making process. Investigators presented an SR of the existing literature addressing outcomes of interest in the area of removable prosthodontics and assessed the quality of these reports in the highest ranked prosthodontics journals.¹²²

A MEDLINE database search (1985-2011) and hand searching of 6 major related journals for published RCTs in removable prosthodontics were accomplished. The primary outcome of RCTs was considered the outcome of interest for this review. The Strength of Recommendation Taxonomy (SORT) system was used to classify outcomes. The quality of individual reports was assessed according to 4 domains related to bias (sequence generation/randomization, allocation concealment, blinding, and handling of withdrawals/losses).

The search initially identified 375 articles. After closer examination and criteria-based assessment, 86 RCT reports entered this review. The results indicated that less than half of the RCTs reported patient-oriented primary outcomes. Most of the publications did not clearly describe sequence generation or allocation concealment. Blinding was not applicable or not reported in most trials. The handling of patient withdrawals/losses was inadequate in half of the trials. This SR evaluated outcomes of interest and the methodologic qualities of RCTs in removable prosthodontics to help qualify the evidence available for clinical decision making. The authors suggested that future emphasis on patient-oriented outcomes might provide a better level of evidence and increase the clinical relevance for practicing clinicians.

Additionally, the methodologic quality of reports must improve in order to provide a better body of evidence in the field and increased support for clinical decision making.

Routine denture hygiene contributes favorably to oral health. Complicating the effective hygiene of edentulous and partially edentulous individuals is the tendency of microorganisms and debris to adhere to denture surfaces. Subsequent denture biofilm development may harbor pathogens related to oral mucosal lesions and inhalation pneumonia. To complicate matters, microbiologic adhesion appears to be facilitated by denture surface roughness.

Processes that contribute to denture surface roughness must be understood and avoided if possible. One group investigated whether surface abrasion related to brushing with dentifrice affects microorganism retention and influences subsequent denture cleansability.¹⁵² Denture base acrylic resin specimens were subjected to reciprocal linear brushing (800 strokes, 2.9-N force) with a toothpaste slurry of 3 distinct abrasivities: high abrasion (Colgate Luminous; Colgate Palmolive Ltd), medium abrasion (Colgate Total Whitening; Colgate Palmolive Ltd), and low abrasion (Colgate Cavity Protection; Colgate Palmolive Ltd). A nonabraded control was included. The resultant surfaces were microscopically characterized for roughness.

The adhesion of 2 microorganisms was investigated: *Candida albicans* (significantly related to denture stomatitis) and *Streptococcus oralis* (an early oral hard surface colonizer). Two assays were used. A "retention assay" compared cell retention on resin surfaces after a 1-hour exposure and standardized rinse, indicating the amount of attachment. Under atomic force microscopy, an "attachment strength assay" applied an increasing force onto attached cells until removal from the resin surface was observed.

The results indicated that both bacteria and yeast cells were retained in greater numbers on resin surfaces of increasing roughness. The cells attached most strongly to abraded resin surfaces with scratches of comparable size to the cells (that is, *streptococci* attached most strongly to low-abraded surfaces and yeast to high-abraded surfaces). In general, bacterial cells were harder to remove than yeast cells.

This investigation demonstrated that even small abrasions appear to enhance microbiologic retention on denture surfaces and reduce surface cleansability. The strength of attachment, rather than the amount of microbiologic debris, seems more important with respect to surface hygiene. The authors concluded that denture hygiene regimens should aim to remove microbial contamination and minimize surface abrasion to control the proliferation of denture plaque that may harbor potential pathogens.

Conventional removable partial prosthodontics

Mastication, an essential initial component of digestion, functions to particulate food, increasing its surface area and facilitating subsequent digestive processes. With tooth loss, mastication may be compromised, and the quality of posterior prosthetic occlusion can influence mandibular masticatory movement patterns. The type of prosthesis used in edentulism and partial edentulism may also affect mandibular masticatory movements. Investigators evaluated mandibular movements during mastication of 2 common test materials in complete (CD) and removable partial denture (RPD) wearers.¹⁵³

A total of 29 participants fitted with CDs (n=15, 65.9 ±7.9 years) or mandibular extension base RPDs (n=14, 61 ±8 years) were evaluated during the mastication of peanuts (a natural product) and Optocal (an artificial silicone-based product possessing constant substance and texture). A kinesiographic tracking instrument (JT-3D; BioResearch) was used to evaluate opening, closing, occlusal and masticatory cycle times, movement angle and maximum velocity on opening and closing, and total mastication area and cycle amplitudes. The results revealed that RPD wearers exhibited reduced opening and closing phases, shorter masticatory cycle time, and greater maximum velocities compared with CD wearers. The area and amplitude of the mastication envelope was smaller in the CD group. The test material did not influence the mastication cycles in any of the parameters evaluated.

The investigation was cross-sectional in design, limiting conclusions related to long-term masticatory function. However, in the short-term, RPD wearers were capable of a faster mastication sequence that demonstrates increased vertical and lateral jaw excursions compared with CD wearers. The authors suggested that these results are likely related to the improved retention and stability afforded by RPDs compared with CDs. When possible, the maintenance of natural teeth for improved masticatory function should be considered.

In recent years, the application of computer-aided design and computer aided manufacturing (CAD/CAM) has expanded into fixed, implant, and complete denture prosthodontics. However, limited information is available regarding the use of digital technologies in the fabrication of RPDs. One group of investigators published an intriguing paper worthy of review by clinicians.¹⁵⁴ The purpose of this clinical report was to pursue proof of concept and describe the clinical and laboratory workflow in the fabrication of an RPD framework and subsequent placement of the definitive restoration.

The report involved a 63-year-old patient with a maxillary unilateral edentulous space from lateral incisor to second premolar, opposing a complete mandibular natural dentition. The patient's entire maxillary arch was captured with an open source intraoral scanner (Cadent

iTero; Align Technology). Using the digital scan file, a milled polyurethane maxillary definitive cast and opposing mandibular working cast were produced. The casts and a fully executed laboratory prescription were forwarded to a commercial laboratory for digital design (SensAble System; SensAble Technologies, Inc) and fabrication of a 3D printed resin RPD framework pattern. The pattern was invested and cast using conventional lost wax casting methods.

Standard clinical and laboratory procedures were used to complete and place the definitive prosthesis. The addition of tin foil on the edentulous ridge facilitated the separation of the heat-activated denture base resin from the polyurethane definitive cast after processing. The fit was deemed acceptable and the patient accepted the prosthesis.

The authors suggested that 3D printed resin RPD framework patterns could facilitate trial placement to confirm fit and design. If necessary, the printed framework patterns could be modified chairside and the modifications carried forward into the final framework processing.

Although this clinical report supports intraoral scanning as an option for RPD framework fabrication in tooth-supported clinical situations, the authors were careful to mention potential disadvantages, including the need for multiple soft tissue scans and subsequent digital stitching to render the soft tissue aspects of the definitive cast and the inability to adequately scan physiologically determined vestibular extensions.

This preliminary report provided proof of concept for the use of a chairside intraoral scanner to accurately capture hard and soft tissue images for the manufacture of a definitive RPD. Additional clinical and laboratory investigation is necessary before this technology can be completely understood and optimally applied in removable partial prosthodontics.

While RPDs restore structure and function, a sound understanding of available prosthesis support and stress distribution to residual tissues on occlusal loading is essential to optimize prosthesis design and clinical performance. In vitro 3D modeling of the nonlinear, viscoelastic behavior of the supporting soft tissues will facilitate the assessment of critical RPD design considerations. Investigators evaluated the functional differences between 3 extension base RPD designs by incorporating known viscoelastic, nonlinear soft tissue properties into a 3D finite element analysis method.¹⁵⁶ The effects of the design on the abutment teeth and supporting mucosal tissues were compared.

A 3D finite element model was constructed from a single patient's computed tomographic dataset and corresponding dental cast. The partially edentulous mandibular model was missing the left first and second molars. The thickness of the cortical bone and ridge

mucosa was modeled using existing data. The periodontal ligament spaces were extrapolated from the scan data to a modeling thickness of 0.2 mm.

Three different RPDs were delivered to the patient. The intraoral casts of the seated prostheses were obtained and digitized for shape data and finite element modeling. The RPDs included an Akers model (Akers clasps on first and second premolar abutments), an RPI model (RPI clasp assembly on second premolar), and an embrasure clasp model (embrasure clasps and distal plate on first and second premolars). All designs incorporated contralateral clasp assemblies and a lingual bar major connector. The model was incrementally loaded at the molar occlusal surfaces.

The functional evaluation produced 2 results. First, the RPI model demonstrated the lowest stress concentrations on the supporting abutment with wide mucosa-borne support, indicating a design advantage over others tested. Second, the Akers model was distally displaced upon loading with stresses more concentrated on cortical bone and periodontal ligament compared with the RPI and embrasure clasp models.

The authors stated that these results were consistent with conventional theories of design and clinical experience, thus validating the mathematical modeling of nonlinear viscoelastic soft tissue behaviors with 3D finite element analysis for evaluating the extension base RPD design. While many additional clasp assembly and framework designs elements remain to be investigated using this modeling approach, these early results look promising for this experimental protocol.

The fit of the intaglio denture base surface against supporting oral tissue is an important factor when the need to relin or rebase RPDs is assessed. Making this clinical determination can be challenging. A predictable, quantitative, objective evaluation method would be helpful. Researchers sought to quantitatively record the adaptation of RPD denture bases to supporting tissues using a clinically convenient disclosing material and to identify a relationship between quality of fit and the need for denture relining.¹⁵⁶

Two experimental protocols were accomplished using a nonsetting pressure-indicating paste (titanium oxide and dimethylpolysiloxane), delivered through an 18-gauge (0.94 mm) syringe tip. In the first experiment (calibration), a bead of disclosing paste extruded onto a glass slab was sandwiched with a second glass slab. Spacers of predetermined thickness controlled the gap dimension between the glass slabs. The spread width of the paste was calculated relative to the glass slab gap dimension.

For the second experiment, a total of 123 RPDs from 70 patients were evaluated for denture base fit. Disclosing paste was extruded from an 18-gauge syringe tip onto denture bases corresponding to the crest of the

edentulous ridges. The RPDs were manually placed and seated onto abutments with clasp assemblies, avoiding overdisplacement of the denture bases. Denture base adaptation to supporting tissues was assessed by measuring the spread width of the disclosing paste. Multiple logistic regression was used to analyze the variables associated with diagnosing the need for a denture base reline, producing ORs and 95% CIs.

The results indicated that the spread width of the bead of disclosing paste was inversely proportional to the gap between the denture base and supporting tissues. Regression analysis revealed a statistically significant association between the need for a denture reline and the paste spread width. The need for a denture reline was indicated at a paste spread width of 2 mm or less.

This study investigated an objective, quantitative evaluation method for assessing denture base fit when managing patients with RPDs. The results suggest that the spread of a carefully placed bead of disclosing paste over the intaglio surface of the denture base is useful in discriminating the fit of the denture base and the need for a denture reline. A useful clinical diagnostic tool may emerge from this work.

Conventional fixed prosthodontics

In the recent past, a variety of claims have been made related to CAD/CAM techniques for dental prostheses. In-office machining, biocompatibility, strength, durability, esthetics, and fit have been the subject of inquiry. Regard for evidence-based decision making is considered essential to modern dental restorative planning and treatment. Investigators systematically reviewed the available literature to assess the precision fit of CAD/CAM fixed dental restorations as related to the systems used.¹⁰⁰

An initial electronic search of the literature produced between 2000 and 2012 yielded 230 articles on the subject. Once subjected to inclusion/exclusion criteria, 140 papers remained. These papers addressed inlay/onlays, copings, fixed partial denture (FPD) frameworks, crowns, and FPDs fabricated from feldspathic ceramic, leucite reinforced feldspathic ceramic, lithium disilicate, zirconia, and alumina.

After reviewing the data, the authors noted the wide diversity of methodologies used to assess prosthesis adaptation, ranging from individual direct linear measurements to volumetric space assessments with digital 3D mapping and micro-CT technology. The various methodologies included the number of measurement points (4 to 385 linear measurements up to more than 3500 measurements within 3D volumes), geometric tracking systems used to define abutment-prosthesis marginal gaps, and CAD/CAM parameter manipulations.

This review identified a significant range of marginal adaptation, internal fit, and external fit for the systems

reported. In general, the studies indicated the possibility of obtaining abutment-prosthesis gaps less than 80 μm . The authors appropriately point out that the current concern in CAD/CAM dental manufacturing is not one of absolute machining capability but rather parameter manipulation on a single machine with varying stock materials. The authors concluded by stating that limited clinical reports on CAD/CAM prosthesis accuracy and broad experimental protocol diversity limit definitive conclusions in this area of inquiry.

The workflow associated with contemporary fixed prosthodontics permits digital processing from oral impressions through restoration fabrication. Third generation clinical and laboratory equipment and processes already exist in the marketplace, even though clinical outcome data remain relatively inconsistent in the literature.

Clinicians interested in bringing this technology to patients on a daily basis need reliable information on restoration success and survival. With this in mind, researchers reported on a longitudinal retrospective evaluation of the success and failure rates of zirconia-based single crowns fabricated with a complete digital workflow and reevaluated at 1, 2, and 3 years after placement.¹⁵⁷

Seventy participants (mean age 45.9 years) with 86 crowns (13 anterior, 73 posterior) were treated by a single experienced operator. Treatment involved knife-edge finish line preparations; conventional tissue displacement; intraoral scanning (Lava COS; 3M ESPE) of preparations, adjacent teeth, opposing dentition, and occlusal registration incorporating quality controls; CAD/CAM fabrication of restoration copings (Lava; 3M ESPE); veneer application (Creation ZI-F; Jensen Dental); abutment cleaning; and cementation with dual-polymerizing self-adhesive resin (RelyX Unicem; 3M ESPE). Descriptive data were collected at restoration placement and during 1-, 2-, and 3-year reevaluations. Crowns exhibiting chipping and/or fracture qualified as failures.

Using the Kaplan-Meier survival analysis, 60 crowns were free of complications at 3 years, a 69.8% success rate. Failure rates of 9.3%, 14%, and 30.2% after 1, 2, and 3 years, respectively, were reported. Crown failure did not correlate with patient sex or abutment position.

The authors commented on the multifactorial nature of clinical ceramic failure, including initial strength, toughness, subcritical crack growth and stress corrosion, and residual stress related to mismatched coefficients of thermal expansion and heating/cooling rates during veneer application. In their final analysis, the authors indicated that fatigue-related chipping/fracture appeared to increase over the observation period, reaching a critical threshold at 2 years with exponential exacerbation thereafter.

Cohesive fracture or chipping of glass ceramic veneering materials is often the point of failure in highly

esthetic ceramic restorations. This is particularly true for glass ceramic veneered zirconia substructures. A number of possible causes have been suggested, including residual thermal stress within the veneer ceramic, mismatched coefficients of thermal expansion between substructure and veneer, substructure design/thickness, veneer thickness, and mechanical loading stress. Researchers hypothesized that a cusp-supporting zirconia substructure design can significantly decrease maximum tensile stresses in the veneering ceramic of a single crown.¹⁵⁸ To test their hypothesis, 3D finite element single crown models were developed and subjected to different loading scenarios.

Three-dimensional finite element models of identically contoured mandibular first molar crowns were developed. The first incorporated a substructure of consistent thickness of approximately 0.8 mm and a veneer of irregular thickness. The second model had a consistent veneer thickness of approximately 0.5 mm with an irregular, but cusp-supporting, substructure thickness. Zirconia, alumina, and a gold alloy were used as substructure materials, while dental glass ceramic served as the veneering material. The abutment was defined as incorporating dentin.

Finite element models were subjected to 2 different loading scenarios. The first was a physiologically normal load distributed through 9 gnathologically appropriate occlusal contacts. The second loading scenario represented an extreme, single contact occlusal interference concentrated on the distal-lingual cusp of the crown. A total force of 600 N was applied normal to the crown surface at the prescribed contacts in both scenarios, with the abutment constrained.

The results indicated that maximum tensile stress in the veneer material concentrated in the occlusal fissures for all models and materials tested. The cusp-supporting substructure significantly decreased the maximum tensile stresses in the glass ceramic by up to 30.5%. The maximum tensile stresses in the extreme distal-lingual cusp loading scenario were approximately 4 times greater than physiologically normal loading.

The authors concluded that the cusp-supporting substructure design could beneficially influence stress distribution in veneer material upon loading, particularly at the occlusal fissures. Clinical experience has demonstrated veneer chipping may also occur at the cusps, indicating that chipping behavior is not entirely the result of loading-induced stress. Based on these results, carefully designed zirconia, alumina, and gold alloy single crown substructures are necessary.

The diagnosis of acceptable marginal integrity is fundamental to successful dental restorations, essential to the maintenance of healthy oral tissues, and indispensable in quality control during restoration placement. Routine radiographic assessment of interproximal

restorative margins and residual cement has been suggested. In an effort to identify a rationale for the use of imaging methods during restoration placement and to suggest an optimal protocol to diagnose restoration fit, investigators presented an SR of radiographic methods used to diagnose dental restoration misfit.¹⁵⁹

Using general criteria, an extensive MEDLINE database search from 1950 to February 2014 was conducted. The initial search yielded 446 publications on the radiographic assessment of dental restoration fit. Application of the inclusion criteria narrowed the field to 14 in vitro and in vivo publications looking at marginal discrepancies associated with crowns, intracoronar restorations, and implant abutments and crowns.

The publications were subjected to Quality Assessment of Diagnostic Accuracy Studies (QUADAS) criteria.¹⁶⁰ QUADAS is a validated instrument¹⁶¹ used to assess the quality of published studies, especially in the context of systematic literature reviews. The present report used QUADAS to rate selected literature as being of high, moderate, or low quality.

The results indicated that evidence supporting the use of radiographic methods for assessing dental restoration fit is unfortunately limited to low and moderate quality studies. Few studies directly compare the clinical and radiographic examination of marginal discrepancies. The optimal radiographic trajectory requires further investigation, although orthogonal projection appears to be most appropriate for restoration-tooth and abutment-implant interface assessments. Conventional radiography is most often used. The influence of postprocessing on digital radiographs for proximal assessment has not been addressed. The use of tomography for proximal margin evaluation requires investigation.

General implant prosthodontic considerations

Most implant systems incorporate screws to fasten abutments and/or prostheses. Prescribed screw tightening is necessary for implant prosthodontic performance. Investigators sought to measure the accuracy and precision of as-received implant torque wrenches comparing measured to desired (or manufacturer prescribed) values.¹⁶² The null hypotheses indicated that desired wrench torque values are similar measured mean values and that neither wrench design nor wrench designation (universally applicable versus system specific) affect measured mean torque values.

Ten wrenches from 4 manufacturers were investigated. Two manufacturers offer toggle-style wrenches (Salvin Dental Specialities and IMTEC/3M) and 2 offer beam-style wrenches (Straumann USA and Nobel Biocare). All are described as system-specific, except the Salvin wrench that claims universal applicability. Each wrench delivered the desired torque to a calibrated

digital torque-limiting device. The desired values were compared with the 95% CI for mean measured values.

The results indicated that 1 wrench (Nobel Biocare beam-style) demonstrated a desired torque that fell within the 95% CI for the measure mean. For the other wrenches, the desired torque value fell above (Straumann beam-style and IMTEC toggle-style) or below (Salvin toggle-style) its measured mean.

Using 95% confidence limits (CLs) as the objective measure, the authors concluded that only 1 of the wrenches evaluated demonstrated accuracy. The style of torque wrench (beam versus toggle) or its designation (system specific versus universal) per se did not affect the delivery of the desired torque. The reader is cautioned that torque delivered by a wrench is only 1 factor affecting the resultant clamping force within a screw-fastened joint. Other factors include screw design/material, surface/interface technology, and fit. The reader should also consider that the wrenches tested here were new and that aging effects were not considered.

Implant screw fasteners that are inadequately or excessively tightened can have significant clinical consequences. Without knowing otherwise, clinicians are likely placing implant components and prostheses using either lower or higher torque values than required. A potential problem exists that should be better understood and appropriately addressed by clinicians, manufacturers, and independent investigators.

The loosening of implant abutment and prosthetic retaining screws over time is a concern. Fastening abutment screws approximates microscopic machining irregularities at screw-implant interfacial contact points. The plastic deformation of these irregular point contacts after the application of prescribed screw tightening can result in an unintended reduction of the preload, referred to as settling or relaxation. Manually retightening retaining screws can reestablish the intended preload and improve screw joint stability. The investigators studied the influence of an intentional screw retightening technique and screw material on joint stability in fixed implant-supported prostheses with different levels of fit accuracy after 1 year of simulated masticatory function.¹⁶³

Mandibular implant-supported fixed complete dentures (metal frameworks with acrylic resin bases/teeth) were fabricated and used to create 20 edentulous mandibular models (10 providing accurate prosthesis fit and 10 providing intentional misfit). Experimental prostheses were fastened to models using 4 protocols: as-placed titanium screws, as-placed gold screws, retightened titanium screws, and retightened gold screws. For the "as-placed" groups, the screws were tightened to 10 Ncm. For the "retightened" groups, the screws were tightened to 10 Ncm and retightened to 10 Ncm after 10 minutes. The fastened prostheses were dynamically

loaded in a moist environment to simulate 1 year of clinical function. Screw joint stability was measured with a digital torque meter. New screws were used for each experimental run.

The results revealed that prosthesis misfit significantly decreased joint stability. Additionally, the screw retightening protocol produced significantly improved joint stability independent of prostheses fit level or screw material. The authors indicated that for the implant restorations evaluated in this study, all screw tightening techniques resulted in reduced loosening torque values after extended dynamic loading. This was particularly true for inaccurately fitting prostheses. In addition, joint stability was significantly improved when a screw retightening protocol was used.

Although the present study represented an *in vitro* simulation of clinical conditions, reasonably strong evidence supports a retightening protocol for implant prosthetic screw placement. The results also support the advantages of accurately fitting implant restorations.

While healthy periodontal ligaments possess extremely sensitive tactile receptors, osseointegrated implants may not. Centrally directed oral function is modulated, in part, by periodontally derived peripheral input. Attenuated peripheral sensory input resulting from the replacement of missing natural teeth and periodontal structures must be understood in order to optimize prosthetic conditions (load transfer to implants, occlusal contact design). With this in mind, Higaki et al¹⁶⁴ conducted an SR to survey the evidence of sensation differences between natural teeth and osseointegrated dental implants.

A systematic search of articles (January 1980 to May 2012) was conducted in MEDLINE, Cochrane Library, and Scientific Citation Index databases. This search produced 90 articles. An initial screening, consideration of inclusion criteria, and a full text review reduced the pool to 6 articles on oral sensation for inclusion in the metaanalysis: 4 on tactile sensibility (minimum perceivable applied load) and 2 on thickness discrimination (minimum perceivable interocclusal thickness).

All included studies on tactile sensibility revealed threshold levels for implant restorations to be significantly greater (approximately $\times 4$ to $\times 20$) than for natural teeth. Additionally, metaanalysis indicated threshold levels for implant restoration thickness discrimination to be significantly greater (approximately $\times 1.2$ to $\times 2.3$) than for natural teeth.

This SR and metaanalysis confirms that sensation differences between dental implants and natural teeth do exist. The results indicate that natural healthy teeth can sense significantly lower force applications (greater tactile sensibility) and significantly thinner interocclusal materials (improved thickness discrimination). However, the data entered into this metaanalysis were drawn from

only a few qualified reports, and research heterogeneity was a significant concern. Further investigation should involve well-designed randomized clinical trials to clarify differences between natural teeth and dental implants. Additionally, the physiologic impact of sensation differences on oral function (mastication and occlusion) and parafunction (bruxism and clenching) should also be explored.

Implant removable prosthodontics

In general, the available literature indicates that patients wearing mandibular 2-implant overdentures are more satisfied and report better quality of life than patients with conventional complete dentures. However, these conclusions may be influenced by the ideal “controlled clinical trial” nature of associated reports (ideal patient selection, homogeneous cohorts, financially managed therapy, random treatment assignment). To investigate the “real world” effects on oral health-related quality of life (OHRQoL), investigators conducted an international multisite prospective study comparing the mandibular 2-implant overdentures and conventional complete dentures in participants with edentulism under pragmatic therapeutic conditions.¹⁶⁵

This study enrolled a total of 209 participants with edentulism (mean 68.8 years of age) who chose to receive either new conventional complete dentures or maxillary complete dentures opposed by mandibular 2-implant overdentures. The participants came from 8 sites in North America, South America, and Europe. The practitioners presented a full range of treatment options to the participants, and decisions were made accordingly. Additionally, the participants paid for the treatment selected. No additional inclusion/exclusion criteria were applied. Sociodemographic data (age, sex, marital status, education level, and income) were collected. Standard treatment practices were used. At baseline and 6 months after prosthesis placement, the participants completed the OHRQoL questionnaire (the 20-item Oral Health Impact Profile – OHIP-20).

The findings demonstrated that more individuals with implant overdentures reported improved quality of life than conventional complete denture wearers. Differences in the interpretation of the impact of implant overdentures were observed in North America, South America, and Europe. The highest percentage of participants with implants reporting improvements in all OHIP-20 domains were in North America. A significantly higher percentage of participants with implants in North America reported improvement in both the psychological and the handicap domains compared with those receiving conventional complete dentures. In South America, all participants with implants reported less physical pain compared with 66% of the conventional complete denture wearers.

The authors concluded that although mandibular 2-implant overdentures improve OHRQoL for patients with edentulism more than conventional complete dentures, international and cultural differences might affect the responses to quality of life questionnaires. When comparing OHRQoL findings from different studies, this multicultural effect should be considered. In general, the results support the notion that a 2-implant mandibular overdenture should be considered the first choice treatment for edentulous patients in a real-world setting.

RPDs represent the standard treatment for partial edentulism despite reports of shortcomings. Most shortcomings are likely related to inappropriate design, inaccurate fit, and the inadequate management of hard and soft supporting tissues. Improved RPD performance can be achieved by supplementing the prosthetic foundation with osseointegrated dental implants. This approach facilitates prosthesis support and stability, contributes to the maintenance of edentulous alveolar bone, and improves esthetics. The researchers conducted a prospective, within subject, time series study to evaluate patient-based outcomes (Oral Health Related Quality of Life—OHRQoL) for RPDs compared with implant-supported removable partial dentures (ISRPDs).¹⁶⁶

Seventeen partially edentulous participants (12 women, 5 men, mean age 62 years) seeking new mandibular distal extension base RPDs received one 4-mm (wide) by 6-mm (long) dental implant in 1 or both posterior edentulous areas. After healing, conventional RPDs were fabricated and placed. Twelve weeks later, the implants were exposed, ball abutments inserted, and attachments incorporated into the existing prosthesis for conversion to ISRPDs. The 49-item Oral Health Impact Profile (OHIP-49) questionnaire, initially administered to all participants upon enrollment (baseline), was readministered at 6 and 12 weeks after RPD delivery and at 6 and 12 weeks after ISRPD conversion.

The results revealed that 29 of 30 implants survived in the 17 participants. The single early implant failure was replaced without complication. Prosthodontic complications included 1 abutment loosening, 1 attachment replacement, and limited other minor issues. The mean OHIP-49 score reduced significantly (41 units) over the course of the trial, with the most significant reductions occurring 6 weeks after RPD placement (23.7 units) and 6 weeks after ISRPD placement (11.8 units). Only 1 of the 7 OHIP-49 domains demonstrated significant improvement in the transfer from RPD to ISRPD conditions, with that being physical disability.

In this study, participants with partial edentulism reported significant quality of life improvement after wearing an optimized RPD and again after conversion to an ISRPD. The results indicated that the use of short implants (4×6 mm) to support ISRPD may be considered.

However, long-term results are needed to draw definitive conclusion in this regard. With proper treatment planning, surgical execution, prosthesis fabrication, and follow-up care, complications associated with ISRPD maintenance appear minimal and manageable.

If not carefully designed and accurately fabricated, extension base RPDs can transfer harmful loads to abutments during the rotational movement of the prosthesis under functional loading. Strategically placed dental implants may be used to counteract these rotational movements, thus sparing the abutments harm. Patient satisfaction related to ISRPDs requires investigation. Investigators evaluated outcomes (patient satisfaction) for distal extension base conventional RPDs and ISRPDs.¹⁶⁷

The study enrolled 12 participants (mean age 63 years) who received new Kennedy Class 1 mandibular RPDs and conventional maxillary complete dentures. Bilateral balanced occlusion was established. After 2 months of RPD wear, the participants completed a 13-question survey assessing satisfaction (comfort, retention, masticatory capacity, appearance, ease of cleaning, and speech). Single dental implants were then placed bilaterally in each mandibular posterior edentulous region. After 4 months, ball abutments were installed and attachments picked up in the existing RPD bases. After 2 months of ISRPD wear, the patient satisfaction survey was readministered.

Patient examinations after ISRPD wear found stable periodontal and periimplant conditions with no radiographic indications of bone loss. A comparison of satisfaction surveys identified statistically significant increases in perceived overall patient satisfaction, prosthesis retention, comfort, and masticatory capacity for both the maxillary conventional complete denture and the mandibular ISRPD. No significant differences were observed with respect to perceived appearance, ease of cleaning, or speech.

It was concluded that the ISRPDs evaluated in the trial favorably impacted patient satisfaction, improved perceived prosthesis retention and stability, and minimized rotational movements resulting in improved comfort. The authors also mentioned that ISRPDs might be preferred as a less expensive alternative to implant-supported partial fixed dental prostheses. Notwithstanding study limitations (small number of participants and limited follow-up period), these findings seem to support the effectiveness and viability of ISRPDs.

Despite improved oral function and satisfaction, implant-supported mandibular overdentures are not without biologic complications, including periimplant mucositis (soft tissue inflammation) and periimplantitis (inflammation with osseous affects). The incidence of these biologic implant complications in edentulous patients is not well understood. Investigators assessed

participants from 2 independent clinical trials to determine the incidence of periimplant mucositis and periimplantitis in edentulous patients restored with mandibular implant overdentures during a 10-year follow-up period.¹⁶⁸

Participants for this subanalysis came from 2 independent prospective clinical trials. All 150 participants selected received conventional maxillary complete dentures and 2-implant mandibular overdentures. The implants were located in the mandibular canine regions and used to support bar and clip attachments. Aggressive implant hygiene instruction was provided to the participants and reinforced at all recall examinations. Clinical and radiographic parameters were assessed at 5 and 10 years of function. PDs and bleeding index were monitored.

The results indicated that the incidence of periimplant mucositis (patient level) was 51.9% after 5 years of evaluation and 57% after 10 years. The incidence of periimplantitis (patient level) was 16.9% after 5 years of evaluation and 29.7% after 10 years.

The authors concluded that periimplant mucositis and periimplantitis occur to a significant level in edentulous patients wearing overdentures. Dentists must be aware of these biologic complications and the potential impact on their edentulous patients, reinforce optimal personal and professional hygiene, and be prepared with management strategies when complications are identified.

Implant fixed prosthodontics

The ability to generate sufficient force is an important element of effective mastication. A number of factors can influence masticatory force, one of which is dental status. Currently, the literature is insufficient to compare the masticatory force potential of implant-supported FPDs with natural dentitions. Researchers carried out a clinical trial to assess the maximum occlusal force (MOF) for patients with an implant-supported FPD on 1 side of the dental arch and natural dentition on the opposite side.¹⁶⁹ The trial was also designed to determine the relationships between MOF and sex, age, and BMI.

Forty participants (20 men, 20 women, mean age 43 years) with an implant-supported FPD on 1 side and natural dentition on the other side were recruited into this study. FPDs replacing the second premolar to second molar were supported by 2 implants and opposing healthy natural teeth, and were without complication for at least 3 months before data collection. The MOF was measured bilaterally (same participant) at the first molar region with a force transducer. Recordings were repeated 3 times (45-second intervals) for each side, with the highest value designated MOF.

The results indicated that the MOF was slightly but significantly greater on the dentate side. A mean MOF of 595.1 N was recorded on the dentate side (men, 651.5 N,

significantly greater than women, 538.7 N). A mean MOF of 577.9 N was recorded on the implant-supported FPDs (men, 629.3 N, significantly greater than women, 526.4 N). Men and taller, heavier individuals had higher MOF values. However, BMI was not significantly related to MOF.

The authors concluded that, in the same participants, the MOF values on the dentate sides were slightly (approximately 3%) higher, but significantly greater than the MOF on implant-supported FPDs. The authors recommended that additional research on larger and more varied populations was necessary to identify the impact of race, sex, diet, and other physical characteristics on MOF recordings. Clinical trials involving a variety of conventional and implant-supported prostheses should also be accomplished.

Cementing implant restorations involves the risk of irretrievable excess subgingival cement and subsequent periimplant disease. During routine therapy at a single dental facility, soft tissue complications were observed related to implant crowns placed with a methacrylate cement (Premier Implant Cement; Premier Dental Products Co). Upon removal of restorations and abutments, residual excessive cement was visually identified. To ascertain the extent of this problem on the facility's patient population, the researchers reported on the retrospective clinical observation of all similarly placed restorations.¹⁷⁰

To safely manage other patients at the same facility, all patients treated from April 2009 to February 2010 with implant restorations placed using the methacrylate cement were recalled. A total of 126 implants, supporting single crowns and FPDs, were examined in 71 patients. The crown margins had been located at the gingival crest along the palatal aspect and not more than 1.5 mm into the periimplant sulcus on the mesial, distal, and facial aspects. Each restoration was originally placed by prosthodontists using a calibrated implant cementation routine. In all restorations at recall, the implant sulci were probed at 6 sites, the restorations removed, and the abutments retrieved. Excess cement was recorded and removed. Periimplant tissues were rinsed with 0.12% chlorhexidine. The abutments were replaced, restorations recemented with eugenol-based interim cement, excess cement removed, and follow-up examinations scheduled.

The data collected during recall management revealed residual cement related to 59.5% of the implants examined. BOP was associated with 80% of the implants with excess cement and suppuration with 21.3% of the implants. After removal of the excess cement and replacement of the restorations, a 76.9% reduction in BOP and the total elimination of suppuration was found at follow-up.

The authors indicated that, despite a careful cementation protocol, excess cement remaining in contact with

periimplant tissues resulted in BOP in most patients and suppuration in some. A limited application of cement to the restoration and the complete removal of excess cement after placement must be given a high priority. The low viscosity of the methacrylate-based cement was cited as a possible reason for the high number of restorations displaying excess cement in this patient population. Additionally, methacrylate-based materials have been shown to favor biofilm formation. Finally, the authors suggested that whenever esthetics are not a consideration, restoration margins should be placed at accessible levels to facilitate the removal of excess cement. If deep subgingival crown margins are unavoidable, screw-retained restorative options should be considered.

Shortened dental arch (SDA) describes a condition in which posterior teeth are missing and a treatment philosophy of not replacing missing posterior teeth. The basis of this philosophy is that occlusal changes and functional compromise related to missing posterior teeth are self-limiting. However, some dentists consider replacing missing posterior teeth with implant-supported restorations beneficial. Investigators reported on a clinical trial designed to assess changes in MOF and masticatory efficiency in participants with SDA who were rehabilitated with an implant-supported restoration up to the first mandibular molar.¹⁷¹

Ten participants with SDA (18 to 45 years) with bilaterally missing mandibular molars and having an approximately full complement of maxillary teeth (experimental group) were recruited. In each participant, 1 implant was placed bilaterally in the first mandibular molar region and restored with a single crown. Ten matched dentate participants served as controls. Masticatory efficiency was evaluated objectively by measuring released naturally occurring dye (β -carotene) from masticated raw carrots before and 3 months after restoration placement. The MOF was recorded with a force measuring device (piezoelectric quartz sensor positioned in the premolar-molar area) before restoration placement and at 6 weeks and 3 months after restoration.

The results revealed that, compared to dentate controls, the SDA experimental group showed significantly less mean MOF before and 6 weeks after restoration. At 3 months after restoration placement, the mean MOF was statistically similar for the experimental and control groups. Participants in both groups demonstrated approximately equal occlusal force on the left and right sides. The masticatory efficiency of the SDA groups was statistically lower than that of the dental controls before restoration placement. However, 3 months after restoration placement, the masticatory efficiency of the experimental and control participants was similar.

Within the study limitations, the authors concluded that restoring participants with SDA to mandibular first

molar occlusion improved both masticatory efficiency and occlusal force. The results suggested that approximately 3 months of functional adaptation to the newly restored condition was required for the masticatory efficiency and occlusal force to achieve levels comparable with those of the matched dentate participants. The authors indicated that the benefits gained by replacing the first molars in patients with SDA may contribute favorably to oral health-related quality of life.

Early experience with endosseous implant therapy for edentulous patients was dominated by screw-retained restorations. As the implant management of partially edentulous patients gained popularity, the use of cement-retained restoration became common. The similarities between cemented crowns on implants and natural teeth provided the profession with several attractive advantages. Although published information evaluating the placement of screw-retained and cement-retained restorations is abundant, the systematic assessment of clinical outcomes is lacking. Researchers systematically reviewed existing evidence to assess the clinical outcomes specifically related to screw-retained versus cement-retained implant restorations.¹⁷²

Electronic databases were searched for publications between 1966 and 2007 related to screw-retained and cement-retained implant restorations in partially edentulous healthy individuals with follow-up periods of at least 12 months. The major outcomes of interest were implant or crown loss, abutment failure, or esthetic failure. The minor outcome variables included screw loosening, decementation, porcelain fracture, bone loss, strain, and marginal discrepancies. An initial search produced 577 publications. Screening and full text evaluation yielded 23 articles for this review (3084 total implants, 1 RCT, 8 prospective trials, 9 retrospective studies, 5 in vitro investigations). Random effects Poisson models were used to analyze the failure and complication rates.

The results indicated that, overall, the major outcome failure rate was 0.81 per 100 years, with no statistically significant difference between screw and cement retention. Additionally, no statistically significant differences were found between the groups for the minor outcomes of screw loosening (3.66 per 100 years) and decementation (2.54 per 100 years). Porcelain fracture (0.46 per 100 years) was statistically similar for both cohorts.

This SR of the available literature revealed no significant difference between cement-retained and screw-retained restorations with respect to major (implant survival or restoration loss) and minor clinical outcomes. This is important information for clinical practice. While cement retention may be more popular and supported by a variety of claims, screw retention appears equally suitable for the restoration of implants in patients with partial edentulism. The authors suggested that clinical and microbiologic enhancement of both restorative

approaches should be the focus of future clinical inquiry and scientific investigation.

Prosthetic materials

The recent introduction of zirconia-based ceramics for complete-coverage dental restorations has generated considerable interest. High fracture strength and reasonable esthetics contribute to its popularity. Careful finishing of the ceramic surface is important to prevent wear of opposing enamel. Investigators evaluated the 3-body wear of enamel opposing different ceramics after different surface finishing procedures.¹⁷³ The null hypothesis was that no difference would be found in the wear of enamel opposing smooth, rough, or glazed surfaces of feldspathic porcelain, lithium disilicate, or dental zirconia.

The ceramic materials investigated included dense sintered yttrium-stabilized zirconia (Crystal Zirconia; Dental Laboratory Milling Supplies), lithium disilicate (IPS e-max CAD; Ivoclar Vivadent), and conventional low-fusing feldspathic porcelain (VITA VMK Master, VITA Zahnfabrik). Twenty-four specimens of each material (N=72) were prepared. The zirconia and lithium disilicate specimens were sectioned from CAD/CAM blocks into rectangular specimens. Feldspathic porcelain was formed into disks. Specimens of the 3 ceramic materials were allocated to 3 groups: rough surface finish (diamond disk prep), smooth surface finish (abrasive paper and silicon polisher), and glazed surface finish (superficial applied glaze). A total of 9 groups with 8 specimens each were placed in a 3-body wear simulator in the presence of a food-like slurry, with standardized enamel specimens (n=72) serving as the substrate. Enamel wear was evaluated after 50 000 cycles.

The results demonstrated that among surface treatments, most enamel wear was caused by glazed ceramic surfaces: zirconia ($5.58 \pm 0.66 \text{ mm}^2$), lithium disilicate ($3.29 \pm 1.29 \text{ mm}^2$), and porcelain ($4.2 \pm 1.27 \text{ mm}^2$). No statistically significant difference in enamel wear was found between rough and smooth surface treatments. From a material perspective, the least enamel wear was caused by lithium disilicate ceramic, with feldspathic porcelain and zirconia causing statistically more.

The authors concluded that within the limitations of this in vitro study, the material causing the least enamel wear was lithium disilicate, while zirconia and feldspathic porcelain demonstrated similar wear of the opposing enamel. In general, polished ceramic surfaces demonstrated less wear of the antagonist enamel specimens than glazed surfaces. Careful clinical management of ceramic occlusal surfaces is important in preserving opposing natural tooth structure and maintaining long-term occlusal stability.

Recently, clinical observations related to the chipping of bilayered ceramic restorations have stimulated interest

in monolithic high-strength alternatives, including zirconia and lithium disilicate. Current evidence indicates relatively favorable enamel wear against these materials unless they are adjusted. However, a significant clinical concern involves opposing enamel wear after the simulated occlusal adjustment of the ceramic. Using an *in vitro* protocol, investigators compared the wear of enamel against adjusted, adjusted-polished, and adjusted-glazed zirconia and lithium disilicate. For reference, the wear of enamel opposing polished porcelain and natural enamel was also measured.¹⁷⁴

The materials investigated included zirconia (LAVA; 3M ESPE), lithium disilicate (IPS e.max Press; Ivoclar Vivadent), veneering porcelain (Ceramco 3; Caulk Dentsply), and enamel (control). Three different lithium disilicate and zirconia surface preparations were used: an adjusted surface (high speed fine diamond rotary instrument), an adjusted-polished surface (fine diamond + polishing points and paste), and an adjusted-glazed surface (fine diamond + fired overglaze). Porcelain specimens presented an overglaze surface. *In vitro* wear was conducted in a mastication simulator (10-N vertical load, 2-mm slide, 20-cycles/min) with lubricant (33% glycerin) for 400 000 cycles. Individual cusps of extracted molars served as antagonists.

With respect to ceramic wear, the results revealed no detectable wear on adjusted and adjusted-polished zirconia. Porcelain demonstrated the most wear (1.29 mm³), and all other ceramics showed significantly less wear than porcelain, similar to enamel-to-enamel wear. With respect to enamel wear, the results indicated that the greatest enamel wear was produced by porcelain (2.15 mm³). Adjusted-polished lithium disilicate, adjusted-glazed lithium disilicate, and adjusted-polished zirconia produced the least statistically similar enamel wear (0.36 mm³, 0.47 mm³, and 0.39 mm³ respectively).

The authors concluded that zirconia was more wear resistant than lithium disilicate. For zirconia, a polished surface produced the least enamel wear. For lithium disilicate, adjusted-polished and adjusted-glazed surfaces produced the most favorable enamel wear. Veneering of zirconia and lithium disilicate with porcelain should be avoided in areas of occlusal contact to prevent excessive enamel wear. In general, it appears that dentists must be prepared to polish these monolithic, high-strength ceramics appropriately after occlusal adjustment to achieve favorable clinical results.

To further study the characteristics of occlusal wear in dentistry, investigators compared the friction and wear behavior of human enamel opposing 2 indirect restorative materials: lithium disilicate glass ceramic (IPS e.max Press; Ivoclar Vivadent) and Type III gold.¹⁷⁵

Friction-wear tests on human enamel (n=5) specimens opposing lithium disilicate (n=5) and Type III gold (n=5) specimens were conducted using a ball-on-flat

configuration (rounded enamel versus flat ceramic/gold specimens) with a reciprocating wear testing apparatus in a fluid environment (distilled water). Wear pairs were subjected to a normal load of 9.8 N, reciprocating amplitude of 200 μm, and reciprocating frequency of 1.6 Hz for up to 1100 cycles. The frictional force of each cycle was recorded, and the corresponding friction coefficient for different wear pairs was calculated. After wear testing, the wear produced on the enamel specimens was examined under a scanning electron microscope.

The results indicated that Type III gold had a significantly lower steady-state friction coefficient and caused less wear damage to enamel than lithium disilicate. Enamel that opposed lithium disilicate exhibited surface flaws and surface loss indicative of abrasive wear as the dominant wear mechanism. In comparison, the worn enamel surfaces that opposed Type III gold had small patches of adherent gold smear on the surface, indicating a predominantly adhesive wear mechanism.

A lower friction coefficient and better wear resistance were observed when human enamel was opposed by Type III gold, as compared with lithium disilicate glass ceramic. Abrasive mechanics characterized ceramic-to-enamel wear in this investigation, while adhesive mechanics were seen in gold-to-enamel wear. The authors pointed out that a longer testing period (more wear cycles) would better evaluate the long-term effects of the materials tested. Additionally, the absence of important physiologic factors (artificial saliva and food simulation slurry) and the lack of restorative material surface characterization may have limited the clinical relevance.

Concluding this section on prosthodontics materials is another occlusal wear study that has better clinical relevance. Using an *in vivo* protocol, investigators evaluated the wear between enamel and opposing monolithic zirconia crowns, as compared with enamel wear occurring between contralateral natural tooth antagonists.¹⁷⁶

A total of 20 participants were enrolled in the study (10 women, 10 men, mean age 43 years). Each participant possessed a healthy natural dentition requiring a single molar crown, which was milled in zirconia (Zenostar Zr Translucent; Wieland Dental). At the clinical evaluation, necessary occlusal adjustments were made with fine diamond rotary instruments followed by thorough polishing of the entire occlusal surface with diamond-impregnated polishers. The crowns were placed with a glass ionomer cement. Conventional polyvinyl siloxane dental impressions of both jaws were made and poured in Type IV dental stone after crown cementation (baseline) and at 6-month follow-up. The occlusal contact wear was assessed using a 3D laser scanning method.

The results indicated that the mean vertical loss (and maximum vertical loss) in the occlusal contact areas was 10 μm (43 μm) for zirconia crowns, 33 μm (112 μm) on

enamel opposing zirconia, and 10 μm (58 μm) for contralateral natural tooth antagonists. Both mean and maximum vertical enamel loss were significantly greater for enamel-zirconia contact areas than with contralateral enamel-enamel contact areas.

The authors concluded that the monolithic zirconia crowns used in this investigation were associated with the greater wear of opposing enamel than occurred between natural, unrestored teeth. However, the clinical use of monolithic zirconia crowns may be justifiable, since the amount of antagonistic enamel wear after 6 months may be comparable with, or even lower than, that caused by other available ceramic materials not included in this study. The present protocol was hindered by a small sample size, short observation period, and limited inclusion of commonly used restorative materials. Additionally, the replication limits of polyvinyl siloxane impression material and Type IV dental gypsum may have affected the results. Further clinical evaluation of wear induced by zirconia and other high-strength ceramics over an extended period is necessary to confidently qualify the best materials and practices.

OCCLUSION AND TEMPOROMANDIBULAR DISORDERS

Occlusion and temporomandibular joint disorders (TMD) continued to generate a great deal of interest in the dental literature in 2014. One study evaluated the psychological aspects of TMD.¹⁷⁷ The study attempted to verify clinical symptoms and jaw functionality in college students with TMD according to the anxiety/depression (A/D) level and to evaluate the correlation between A/D and functionality, maximum mouth opening (MMO), pain, and muscle activity. Nineteen students diagnosed with TMD according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) underwent 2 assessments during an academic semester. The evaluations were based on questionnaires (MFIQ—Mandibular Function Impairment Questionnaire; HADS—Hospital Anxiety and Depression Scale), clinical measurements (MMO without pain, MMO, and assisted MMO; palpation of joint and masticatory muscles), and electromyography. The HADS scores obtained in the 2 assessments were used to classify all data as either “high” or “low” A/D. Data normality, differences, and correlations were tested with the Shapiro-Wilk test, Student *t* test (or the Wilcoxon test), and Spearman test, respectively ($\alpha=.05$). None of the clinical variables were significantly different when low and high A/D data were compared. In low A/D, a significant correlation was found between the HADS score and the MFIQ ($P=.005$, $r=0.61$) and MMO without pain ($P=.01$, $r=-0.55$). The conclusion from the study was that variations in A/D level did not change clinical symptoms or jaw functionality in college students with TMD. While the study has

significant limitations in terms of the size and non-homogeneity of the population diagnosed with “TMD,” it reinforces the concept that anxiety and depression may not influence patients with TMD as previously assumed.

Several authors have discussed TM joint imaging from a structural perspective as opposed to a behavioral perspective. One group of authors wrote a thorough update article on imaging the TM joint.¹⁷⁸ The article begins by explaining that the temporomandibular joint (TMJ) is one of the last diarthrodial joints to appear in utero and does not emerge in the craniofacial region until the 8th week of gestation. The maxilla, mandible, muscles of mastication, and biconcave disk develop embryologically from the first branchial arch through the 14th week of gestation. The TMJ is considerably underdeveloped at birth compared with other diarthrodial joints, making it susceptible to perinatal and postnatal insults. The joint continues to develop in the early childhood years as the jaw is used for sucking motions and eventually chewing. The TMJ is a ginglymoarthrodial synovial joint that allows both backward and forward translation as well as a gliding motion. Similar to the other synovial joints in the body, the TMJ has a disk, articular surfaces, fibrous capsule, synovial fluid, synovial membrane, and ligaments. What makes this joint unique is that the articular surfaces are covered by fibrocartilage instead of hyaline cartilage.

Conventional radiographs have a limited role in evaluating the TMJ. They can be used to evaluate the bony elements of the TMJ but give no useful information when it comes to the nonbony elements such as cartilage or adjacent soft tissues. They also do not give useful information concerning joint effusions, which are commonly associated with pain and disk displacements. CT is useful for evaluating the bony elements of the TMJ and the adjacent soft tissues, and is ideal for evaluating fractures, degenerative changes, erosions, infection, invasion by tumor, and congenital anomalies. Clinical evaluation of the TMJ can be nonspecific because the symptoms of internal derangement (ID) and myofascial pain dysfunction overlap. Magnetic resonance imaging (MRI) should be part of the standard evaluation when an internal structural joint abnormality is suspected because it provides high resolution and great tissue contrast. This allows for a detailed evaluation of the anatomy and the biomechanics of the joint through open and closed mouth imaging. For optimal imaging of the TMJ, small bilateral surface coils with small fields of view are used to achieve a higher signal-to-noise ratio and simultaneous bilateral acquisition. MRI is the imaging modality of choice for the diagnosis of ID with an accuracy of 95% in assessing the disk position and form, and 93% accuracy in assessing the osseous changes.

The exact mechanism of a disk displacement is unknown, although trauma with injury to the posterior disk

attachment is considered the most likely cause. Unenhanced MRI is the imaging modality of choice for evaluating ID. During the early stage of ID, the disk retains its normal shape, but over time it becomes deformed by the thickening of the posterior band and thinning of the anterior band. This produces a biconvex, teardrop-shaped or rounded disk. The disk maintains a normal biconcave shape as long as it remains on top of the condyle during mouth opening. As a result, the presence of an irregular and rounded disk almost always indicates disk disease. Other MRI findings that suggest disk disease include disk flattening, a decrease in the normal intermediate to high signal intensity of the disk, and the presence of tears or perforations in the chronic stage. Joint effusion represents an abnormally large accumulation of intraarticular fluid and is commonly seen in symptomatic patients. A small amount of joint fluid can be seen in asymptomatic patients. An effusion is more prevalent in painful than in nonpainful joints. Osteochondritis dissecans (OCD) and avascular necrosis (AVN) of the mandibular condyle are similar pathologic entities that likely represent points on a spectrum of the same pathophysiology. Common clinical features of OCD/AVN of the mandibular condyle include pain and joint disability. Pain is commonly over the joint and along the third division of the trigeminal nerve. Other symptoms include ipsilateral headache, earache, and spasm of the masticator muscles. These can occur with or without limitation of the joint movements. MRI is the modality of choice for assessing OCD/AVN of the mandibular condyle. Adenocarcinoma is the most common metastatic tumor of the jaw, making up about 70% of tumors. Reported metastasis to the TMJ includes breast, renal, lung, colon, prostate, thyroid, and testicular primary tumors. Osteochondroma is the second most common neoplastic lesion affecting the TMJ. Osteochondroma, osteoma, and condylar hyperplasia are often difficult to differentiate both clinically and on imaging. MRI and CT may delineate the exact extent of the tumor and its relationship to anatomic structures within the TMJ.

TMJ imaging should be performed on a patient by patient basis depending upon clinical signs and symptoms. MRI is the diagnostic study of choice for evaluating the disk position and ID of the joint. A CT scan to evaluate the TMJ is indicated when bony involvement is suspected but should be used judiciously because of the risk of radiation. Understanding the TMJ anatomy, the biomechanics, and the imaging manifestations of diseases is important in recognizing and managing these various pathologies accurately.

A CT study evaluated which parts of the articular surface of the mandibular condyle are involved in osteoarthritic (OA) change (the occurring pattern) and the relationship of these patterns to clinical signs and symptoms.¹⁷⁹ The CT images and clinical records of

patients with OA involvement of 1 or both TMJs were reviewed (OA changes confirmed by CT; 684 TMJs included). The condylar articular surface was divided into 9 imaginary sections on the CT images: anteromedial (AM), antero-central (AC), anterolateral (AL), centrimedial (CM), centricentral (CC), centrilateral (CL), posteromedial (PM), posterocentral (PC), and posterolateral (PL) sections. The occurring patterns were classified with hierarchical cluster analysis based on the distribution of the sections involved in OA changes. OA changes were observed most frequently on the AC (62.4%) followed by the AM (55.0%), CC (48.2%), AL (43.0%), CL (43.3%), CM (33.3%), PC (28.9%), PL (25.3%), and PM (23.1%). The occurring patterns were classified into 3 types, in which subjective joint pain ($P < .001$) and noise ($P < .05$) were more frequently reported in the type with OA changes in the entire joint, followed by the lateromedial and anteromedial types in descending order. No significant differences for age, sex, side, pain on palpation, clicking, crepitus, mouth opening range, or craniomandibular index were observed. OA changes were more likely to occur on the anterior than the posterior and on the medial than the lateral surface of the mandibular condyle, while subjective joint pain and noise were more frequently reported with OA changes involving the lateral or entire part. Pain on palpation, noise, and mouth opening range were not related to the occurring pattern of OA changes.

The results showed that the anterior part of the condylar head was involved more frequently in the OA changes than the posterior part, which might be expected from the results of previous studies showing that the anterior part bears more of the load. The second highest incidence was for the AM section; the higher incidence (65.1%) occurred with the anteromedial involvement than with the lateral (24.1%) involvement of OA changes. In addition, recent studies based on the 3D modeling of the TMJ from the MR images in combination with an optical jaw tracking system have reported that the stress field changes mediolaterally in the TMJ during opening and closing and is related to the morphology of the TMJ. The direction of such mediolateral translation is not in accordance with the anisotropic orientation of collagen fibrils in the fibrous layer of the condylar cartilage, which is more durable to the sheering stress in the anteroposterior direction. Because of this, the plowing force exerted by such mediolateral translation during jaw movement may well be related to the damage in the articular cartilage and subchondral bone when the functional load to the joint increases because of various contributing factors related to TMD pathophysiology.

Another article discussed the validity of panoramic radiographs in the diagnosis of osteoarthritis of the TM joint.¹⁸⁰ The study used the clinical and imaging criteria (MRI) of the RDC/ TMD as the gold standard in 1 group

of participants with TMJ disease. The study population was recruited from among patients seen for TMJ disease between September 2008 and December 2012. A total of 654 participants were studied during this period. The clinical exploration and diagnosis were carried out (when possible) according to the axis I guidelines of the RDC/TMD. In all patients, a panoramic radiograph study was performed as part of routine exploration, and 125 participants underwent an MRI study of both TMJs. The criteria used to request static and dynamic MRI assessment of the TMJs were unilateral or bilateral joint crepitus, gradual worsening of symptoms, appearance of sudden occlusal alterations, severe and persistent limitation of oral opening, and manifest dissociation between symptoms and clinical signs. The final study sample consisted of 84 participants (168 joints) (76 women [90.5%] and 8 men [9.5%]; mean age 48.6 years). Osteoarthritis was clinically diagnosed based on the RDC/TMD (coarse crepitus) in 46 participants (54.8%) and by MRI in 59 participants (70.2%). The validity indicators of panoramic radiographs were poor using both the MRI and clinical criteria (RDC/TMD) as gold standards (sensitivity 56.6%/39.1% and specificity 32.2%/32.4%). These results limit the usefulness of panoramic radiographs in diagnosing OA of the TMJ. Panoramic radiographs have little validity for the diagnosis of degenerative disorders of the TMJ when MRI or the clinical criteria of the RDC/TMD are taken as the gold standard.

The relationship between disk position and degenerative changes in the TMJs of young participants with TMD was studied in an MRI investigation.¹⁸¹ The ID of the TMJ is one of the most common types of TMD. The term refers to an abnormal position of the articular disk in relation to the mandible condyle and the articular eminence of the temporal bone. The term *disk displacement* has generally been accepted as a synonym. Disk displacement is subdivided into 2 main groups: disk displacement with reduction and disk displacement without reduction, both referring to the functional disk performance. This disorder has been associated with characteristic clinical findings such as pain, clicks, articular dysfunction, and closing or opening locks.

ID is diagnosed by means of clinical examinations combined with imaging methods such as MRI. MRI can provide essential information about disk position, signal intensity, morphology, and structure. In patients with ID, a variety of morphologic changes in the bone structure of the mandible condyle and temporal eminence may occur, such as flattening of the condyle and temporal functional surfaces, osteophytes, erosion, idiopathic condyle resorption, subchondral cysts, and intraarticular loose bodies. A relationship has been reported between ID and the morphologic changes of the condyle and articular eminence associated with the secondary remodeling and

degenerative bone changes (OA) observed on CT scan images. Common ID signs and symptoms such as clicking, locking, pain tenderness, restricted ranges of mandibular motion, and crepitation are associated with the detectable structural changes that have been observed 3 dimensionally thanks to the introduction of CT and MRI.

One transversal imaging study was aimed at establishing the frequency and possible relationship between the disk position (disk without displacement [DWD], disk displacement with reduction [DDR], and disk displacement without reduction [DDWR]) and the degenerative bone changes of the TMJ in children and adolescents with ID before orthodontic treatment. The hypothesis proposed supported the relationship between degenerative bone changes and disk displacement without reduction in children and adolescents with ID of the TMJ.

The blinded study was based on the MRI observations of 88 consecutive patients of both sexes evaluated before orthodontic treatment. The inclusion criteria considered symptomatic patients who had been clinically diagnosed with ID in at least 1 TMJ during their first visit and who had received no previous treatment for their condition. The exclusion criteria were age older than 18 years, ongoing orthodontic treatment, systemic diseases such as gout, generalized osteoarthritis, joint hyperlaxity, congenital TMJ deformity, cysts, and tumors, and previous history of TMJ surgery.

The study population consisted of more women (n=65; 73.1%) than men (n=23; 26.9%), and the average age was 14.7 years. MRI assessment of the 176 TMJs revealed 171 displaced disks (97.1%) with a DDR frequency of 50.6% (n=89), a DDWR frequency of 42.6% (n=75), and a DWD frequency of 6.8% (n=12) in the surveyed participants. Healthy TMJ bone structures (no signs of OA) were found in 106 of the 176 TMJs (60.2%), and degenerative bone changes were found in 70 TMJs (39.8%) in the overall population studied. The most frequent degenerative bone changes found were flattening of the condyle anterior surface (n=55), followed by joint surface erosion and irregularities (n=32), flattening of the temporal eminence functional surface (n=36), subchondral cysts (n=7), osteophytes (n=2), and idiopathic condyle resorption (n=1).

The results of this study showed a strong relationship between degenerative bone changes and disk displacement without reduction ($P < .01$) in the TMJs of young participants with TMD. However, disk displacement with reduction was not associated with degenerative bone changes ($P < .01$). In general, these results may be explained by the fact that DDWR involves an enduring displaced disk position, where no disk tissue is positioned between the temporal eminence and the jaw condyle surface either during functional or resting positions. Cartilage changes and changes in the synovial membrane

give rise to a vicious sequence of cartilage break down, together with episodes of attempts at repair. When the degenerative process exceeds its repair response, OA could progress into clinical or image detectable phases.

From the 176 TMJs studied, 66 (53%) presented degenerative bone changes and 37 of 62 participants had bilateral compromise (60%). These individuals were in their growth stage, meaning their articulations were supposed to tolerate stress because of their potential for remodeling. The severity of the alterations found is notable, in that the most frequent association corresponded to 2 or more OA signs in the same TMJ. In the present study, osteophytes, subchondral cysts, and idiopathic condylar resorption never appeared as the only imaged sign present; they were always found in concomitance with flattening of the condyle anterior surface and/or temporal eminence articular surface and other types of erosion and irregularities. They showed chronic articular alteration, which can affect individuals for a lifetime.

MRI studies provide more reliable image information of studied structures than does conventional radiographic imaging. MRI offers soft tissue contrast to observe the articular disk. It is the gold standard for diagnosing the ID of the TMJ because it is a useful method of determining the position, configuration, and shape of the TMJ disk structure. In the present study, MRI properly detected all disk shapes, positions and reductions if present, and condyle morphology. This study is considered reliable and valid for visualizing articular soft structures with respect to osseous components.

Pediatric dentists and orthodontists may be the first health practitioners to examine children's craniofacial characteristics, and, if a child is under treatment, the professional will be present in most of the child's growth stages. The prevalence of TMD averages 30% in children, showing the importance of TMD assessment when morphologic changes associated with growth and craniofacial development prevail. Thus, a joint diagnosis is key to the early identification of TMD. While RDC/TMD represent a standardized protocol for research and guidelines for the assessment and management of patients with TMD, a simplified protocol for specialists and for general dentists should be developed in order to identify TMD early in childhood and adolescence.

The observations in this study show the importance of an early diagnosis and support prompt treatment in young patients with ID to prevent an increase in a pathologic TMJ condition. Treatment should be aimed at preventing disk displacement with reduction from developing into disk displacement without reduction because of the significant probability of early bone damage.

A similarly themed investigation examined the prevalence of disk displacement of various severities in a

young pre-orthodontic population through the use of MRI.¹⁸² Studies have demonstrated the presence of disk displacement in both children and adults. A study involving pre-orthodontic adolescents showed that disk displacement was not a rare condition, but rather a common phenomenon—the reported frequency of disk displacement, including its early stages, was 85% in girls and 60% in boys. Not only has disk displacement been shown to cause TMD, but animal studies have also demonstrated that disk displacement negatively influences mandibular growth. The prevention of disk displacement is important for all areas of dentistry so that the resultant joint instability that would complicate dental treatment can be avoided. However, many children with disk displacement are asymptomatic, and disk displacement is difficult to detect clinically. With the advent of MRI (a diagnostic tool allowing the objective evaluation of disk status), disk displacement has been found to be common in both children and adults seeking orthodontic treatment. This finding has been brought to the attention of dentists relatively recently. Studies suggest that disk displacement is not a congenital condition but rather is commonly acquired during adolescence.

The study sample was derived from a population of 199 consecutive pre-orthodontic patients aged 15 years or younger visiting a private orthodontic clinic for initial examination and record-taking between March 2005 and September 2008. Of those, 153 patients (59 boys, 94 girls) who showed signs and symptoms of TMD during the initial examination underwent MRI of their TMJs to evaluate the disk position. The patients ranged in age from 6 to 15 years with a mean age of 11.1 years. These patients were consecutively selected from the orthodontic clinic. Of the 153 patients imaged, 4 TMJs in 2 patients were excluded because of poor image quality as a result of motion artifacts, making the final sample size 302 TMJs from 151 patients. The patients were divided into group 1 (6 to 9 years old), group 2 (10 to 12 years old), and group 3 (13 to 15 years old).

Of the evaluable TMJs of 151 patients, 3 patients had normal disk position bilaterally, and the remaining 148 patients showed disk displacement, accounting for 74.4% (148 of 199) of the young pre-orthodontic patient population in the private orthodontic office. While disk displacement was found to be common in all 3 age groups, the proportions of more advanced disk displacements increased with age.

Moving away from imaging, another study was designed to find specific factors that are mathematically distinct between the mastication timings, movement pattern shapes, variability, and movement velocities of normal asymptomatic participants and a group of participants with verified TMJ IDs.¹⁸³ Left-sided and right-sided chewing movement recordings of 28 participants were randomly selected from a large database of patients

exhibiting verified unilateral or bilateral TMJ IDs. The masticatory movements of an age- and sex-matched control group of 20 asymptomatic participants (32 ± 11.6 years, $P > .6$) with verified normal TMJ function were also recorded. The means and standard deviations of the opening, closing, turning point, terminal chewing position, and velocity patterns were calculated. A 2-tailed Student *t* test with unequal variances was used to compare the parameters between the 2 groups ($\alpha = .05$).

The dysfunctional group functioned significantly more slowly and with greater variability than the control group. The vertical dimension was consistently smaller in the dysfunctional group ($P < .001$). The terminal chewing position was significantly less precise in the dysfunctional group (vertical: $P = .002$ and lateral: $P = .037$). The maximum lateral width was significantly less ($P = .007$), and the peak and the average velocities were significantly lower ($P < .001$ for both) in the dysfunctional group. The group of dysfunctional participants exhibited significantly slower, smaller, and more variable chewing patterns than the control group. The functional pattern of mastication appears to be significantly altered in the presence of an ID of the TMJ.

An article discussing the role of the otolaryngologist in the diagnosis and management of TM joint and chronic oral, head, and facial pain disorders was published in 2014.¹⁸⁴ The authors discussed 3 common pitfalls in the diagnosis of TM joint and chronic oral, head, and facial pain disorders. The first was the complex regional anatomy of the head and neck, often resulting in disparity between the site and the source of pain. The second was that symptoms of pain, limitation of mandibular movement, joint noise, tinnitus, and altered occlusion are not specific to the pathologic condition. Thus, these symptoms can be caused by local otologic and TMDs or infectious, neoplastic, neurologic, and systemic conditions. The third was that chronic tissue damage from trauma and/or multiple surgical procedures can lead to the central sensitization of sensory nerve pathways, leading to neuropathic pain, allodynia (pain response to nonpainful stimuli), and hyperalgesia (excessive pain response to mildly painful stimuli). The presence of neuropathic pain can make accurate diagnosis extremely difficult because the clinician can easily be misled into believing that the source of the pain is localized when, in fact, there is a central nervous system-mediated component.

Unfortunately, this article repeats some common misconceptions in the field of TMD. The first is that the authors view IDs as a flaw in joint biomechanics as opposed to structural damage in the TMJs. The second is the erroneous claim that a progressive opening of the occlusion on 1 side is often the major symptom associated with a slowly expanding neoplasm in this region as opposed to a loss of joint dimension on the ipsilateral

side. The third is the statement that the clinical significance of joint noise is questionable. The fourth is that advanced diagnostic imaging should be performed when patients do not respond to conservative treatment as opposed to obtaining TMJ imaging for diagnosis. On a positive note, the authors emphasized that pain management is a necessary component of patient management. Failure to control pain levels, along with chronic tissue injury, may lead to central sensitization of the ascending nerve pathways that transmit pain, causing chronic neuropathic pain. This pain leads to symptoms of allodynia, in which nonnoxious stimuli such as light touch activate pain pathways leading to the cerebral cortex. An important goal in the management of these patients is to prevent the onset of chronic central neuropathic pain. With the onset of chronic neuropathic pain, local treatment of the diseased joint and a reduction in the activity of the central pain pathways is needed. However, successful management of the patient in whom chronic neuropathic pain has developed is much more difficult, because multiple surgical procedures and repeated trauma to tissues tend to exacerbate central sensitization of the ascending pain pathways.

The purpose of 1 study was to analyze the long-term effects of the Herbst treatment on tooth position and occlusion.¹⁸⁵ 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 the 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), a minor relapse occurred; during the late posttreatment period (T3-T4), the molar and canine relationships remained, on average, unchanged. The horizontal and vertical incisor overlaps were reduced to normal values in all participants during treatment (T1-T2). After treatment (T2-T4), the horizontal overlap remained, on average, unchanged, but the vertical overlap increased insignificantly. The conclusions were that 32 years after Herbst therapy, overall, acceptable long-term results were seen. Stability was found in 64% of the patients for sagittal molar relationships, in 14% for sagittal canine relationships, in 86% for overjet, and in 86% for overbite. A Class II relapse seemed to be caused by an unstable intercuspation 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 the maxillary and mandibular dental arch perimeters and widths and in mandibular incisor irregularity seemed to be independent of treatment and a result of physiologic dentoskeletal changes throughout adulthood. The Class II relapse and the increased horizontal overlap could be explained by changes in the TMJ that necessitated the use of the appliance.

A flawed article discussed the correlations between mandibular asymmetries and TMDs.¹⁸⁶ Mandibular asymmetries are the source of many debates among orthodontists and oral and maxillofacial surgeons. The interest is even greater when facial asymmetries are correlated with the development of TMJ symptoms and TMD. The purpose of this study was to investigate how mandibular asymmetries constitute etiologic or predisposing factors for the development of TMD. When patients with mandibular asymmetries associated with TMD were treated with orthodontic or surgical-orthodontic treatment, their TMJ symptoms were relieved. Thus, mandibular asymmetries represent a major risk factor for the development of TMD. A sample of 16 participants aged between 14 and 36 years (11 women and 5 men) with mandibular asymmetries (81% structural asymmetry, 19% functional asymmetry) were studied. These participants presented skeletal and dental malocclusions combined with several TMDs, mostly due to muscle tension. All the patients received orthodontic treatment. Pretreatment and posttreatment posteroanterior cephalometric analyses were compared to evaluate asymmetry resolution.

The article ignored the voluminous amount of literature correlating mandibular asymmetries with structural changes in the TMJs. The lack of 3D imaging is a significant flaw in the design of the study. Lastly, the claim that "treating a group of patients with mandibular asymmetry and TMD with orthodontic or surgical-orthodontic therapy can resolve all TMJ symptoms and TMD" is unrealistic and not supported by clinical evidence.

An investigator studied the changes in myofascial pain and range of motion of the TMJ when Kinesio taping is applied to patients with latent myofascial trigger points of the sternocleidomastoid muscle.¹⁸⁷ The participants were 42 individuals aged 20 to 30 years (17 men, 25 women). They were randomly divided into the control group and the experimental group, which would receive Kinesio taping. Kinesio taping was applied to the sternocleidomastoid muscle 3 times per week for 2 weeks. The pain which was triggered when the taut band or nodule was palpated was measured. Pain intensity was measured using the visual analog scale (VAS) and pressure pain threshold (PPT). The range of motion of the TMJ was measured. In all participants, VAS, PPT, and the range of motion of the TMJ were measured before and

after the intervention. In the experimental group, pain in the sternocleidomastoid muscle (SCM) was relieved as the VAS and PPT scores decreased significantly and the range of motion of the TMJ increased significantly. In a comparison of the groups, significant differences were shown in the VAS and PPT scores and in the range of motion of the TMJ. Kinesio taping is thought to be an intervention method that can be applied to latent myofascial trigger points.

One investigation studied 30 patients with diagnosed rheumatoid arthritis (RA) and 30 test participants without RA (control group).¹⁸⁸ The objective of the study was to examine both groups for the presence of TMD and for morphologic changes of the TMJ. All individuals were examined using a systematic detailed clinical TMD examination and MRI. The clinical TMD examination yielded significant differences between the patients with RA and the control group in crepitus of the TMJ, palpation tenderness of the masticatory muscles, and unassisted mandibular opening. The evaluation of the MR images for the RA group showed significantly more frequent deformations of the condyle, osteophyte formations, and erosions in the condylar compacta and degenerative changes in the spongiosa. Increased intraarticular accumulation of synovial liquid and signs of inflammatory changes of the spongiosa were only found in the RA group. Statistical analysis showed a significant correlation between crepitus and specific osteoarthritic changes and between crepitus and a complete anterior disk displacement without reduction. A patient with RA may develop signs and symptoms of TMD in the course of time. A timely TMD examination is considered necessary, in that the present study shows no correlation between the duration of the RA disease and the dysfunction. When RA is mentioned in a patient's history, a timely diagnosis based on clinical examination and MRI should be performed to recognize pathologic conditions of the TMJ and treat them appropriately.

An SR described the prevalence of whiplash trauma in patients with TMDs and the clinical signs and symptoms in comorbid TMD/whiplash compared with TMD localized to the facial region.¹⁸⁹ A systematic literature search of the PubMed, Cochrane Library, and Bandolier databases was carried out for articles published from January 1, 1966, to December 31, 2012. The systematic search identified 129 articles. After the initial screening of abstracts, the full texts of 32 articles were reviewed, applying the inclusion and exclusion criteria. Six studies on the prevalence of neck trauma in patients with TMD met the inclusion criteria and were included in the review. Two of the authors evaluated the methodologic quality of the included studies. The reported prevalence of whiplash trauma ranged from 8.4% to 70% (median 35%) in TMD populations, compared with 1.7% to 13% in the non-TMD control groups.

Compared with patients with TMD localized to the facial region, patients with TMD with a history of whiplash trauma reported more TMD symptoms, such as limited jaw opening and more TMD pain and also more headaches and stress symptoms. In conclusion, the prevalence of whiplash trauma was higher in patients with TMD compared with the non-TMD controls. Furthermore, patients with comorbid TMD/whiplash presented with more jaw pain and more severe jaw dysfunction compared with TMD patients without a history of head-neck trauma. These results suggest that whiplash trauma might be an initiating and/or aggravating factor as well as a comorbid condition for TMD.

A review article discussed tissue engineering in dentistry.¹⁹⁰ In terms of the TMJs, the TMJ is one of the most difficult to treat because of the limited blood supply and hence a limited capacity for self-repair. Patients suffering from TMDs often experience pain during normal activities such as eating and speaking and, as a result, have a low quality of life. The articular cartilage of the TMJ has a surface layer of fibrocartilaginous and a deep layer of hyaline-like hypertrophic zone with a thin intermediate proliferative zone. When regeneration of this unique cartilage is required, cell therapy comes first and injectable smart hydrogels could be employed to transfer cells. As is known, autogenic cells are the gold standard for cells used to regenerate tissue, but harvesting cells from the diseased TMJ would be difficult. Finding another cell source would be essential in such a regeneration. For example, human umbilical cord derived mesenchymal-like stem cells, primary costal chondrocytes, or hyaline cartilage cells from anywhere in the body may be an alternative to those from TMJ condylar cartilage. Because bone and cartilage require different competing conditions for regeneration, growing a biphasic osteochondral construct in vitro is challenging. Ultrarapid tissue engineering techniques coupled with gradient based scaffolding and a single cell population provide a promising approach for future biologic joint replacement. In such conditions, hyperhydrated collagen gels are used. The gels are seeded with human mesenchymal stem cells preconditioned in an osteogenic medium at 1 end and preconditioned in a chondrogenic medium at the other end. The development of distinct bone-like and cartilage-like areas and the mimicking of a primordial joint-like structure have been demonstrated after 7 days of in vitro culture. The same concept of fabricating gradient-based scaffolding was also applied to poly (D,L-lactic-co-glycolic acid) microspheres. The gradation in such cases was obtained by having growth factors instead of cells with different potentials, for example, cartilage-promoting transforming growth factor-1 (TGF-1) at the cartilaginous end but bone-promoting bone morphogenetic protein-2 (BMP-2) growth factors at the bony end of the construct. A newly

formed osteochondral tissue was observed in a small mandibular condyle osteochondral defect in New Zealand rabbits weeks after implantation.

Regarding the TMJ disk, an acellular porcine-derived extracellular matrix was effective as an inductive template for the reconstruction of a TMJ disk when implanted in vivo for 6 months. Regarding the cellular component, adipose stem cells could be a cell source for TMJ engineering. Furthermore, platelet-derived growth factor (PDGF) could be effective for engineering the TMJ disk. PDGF in an optimal concentration of ≥ 5 ng/mL significantly increased the proliferation rate of the TMJ-disk derived cells, collagen, and hyaluronic acid synthesis. It also upregulated the RNA levels of type I and II collagens, MMPs, and tissue inhibitors of metalloproteinases. Basic fibroblast growth factor, transforming growth factor- $\beta 1$, and insulin-like growth factor-1 have also been investigated for application in TMJ disk regeneration. All these growth factors have been shown to induce bone marrow mesenchymal stem cell differentiation into fibroblast-like cells, which could synthesize TMJ disk matrix of GAG and type I collagen.

The approaches used to overcome the challenge of TMJ engineering have varied from cell injection therapy to the use of synthetic or natural scaffolds as well as relying to some extent on biologic modulators. The critical outcome of success with engineered TMJ replacements will not only be measured by the restoration of function but also by the prevention of fibrous or ossified adhesions. These adhesions are the main complications of many surgical interventions and must be key to success in clinical applications. In designing TMJ replacements, incorporating signaling molecules that allow for rapid and convenient tissue replacement but also prevent adhesions or ossification of the replaced tissue is challenging. Furthermore, engineering the osteochondral interface, with its complex structure and its cartilaginous component with its zones of different structures and organization, is also challenging.

An evidence-based review studied the link between sleep bruxism (SB), sleep disordered breathing (SDB), and TMDs.¹⁹¹ A relationship between SB and SDB has been previously suggested. However, whether both entities are coincidental, causally related, linked to some arousal reactivity, or under some physiologic state that involves the triggering of 1 or the other is yet to be demonstrated. Currently, no evidence supports the association or causality of SB and obstructive sleep apnea (OSA). However, there do appear to be clinical commonalities between SB and OSA, and SB and SDB often coexist. Both entities appear to share common risk factors, with intersecting prevalences across the life span and clinical features that influence their clinical presentation. This may challenge the clinical decision making for diagnosis, comorbidities, and management of SB and

SDB. The clinician must be cautious in assuming causality just because the treatment of SDB improves SB in some patients. Individual differences in the era of personalized medicine prevent us from extrapolating cause and effect relationships to the whole population.

Vulnerability or predisposition to SDB and SB needs to be identified, because indirect evidence is now emerging that SB may serve as a “reactive or protective mechanism” against upper airway obstruction. When patients with SB and/or painful TMD complain about insomnia, snoring and/or cessation of breathing during sleep, sleepiness of unidentified causes, or uncontrolled blood pressure (BP), screening for the presence of SDB is prudent. The screening is done in collaboration with sleep medicine specialists using either sleep laboratory or home recording systems with electromyography analysis of masseter/temporal muscle activity. In patients with confirmed SB and concomitant SDB and after nasal examination to exclude obstruction, either a maxillomandibular advancement (MMA) or continuous positive airway pressure (CPAP) device may be prescribed. The same is also suggested for patients with TMD and SDB. Dentists need to be aware that current standard maxillary oral appliances (occlusal splints) to protect teeth from attrition may not be appropriate in the presence of SDB. In some patients, occlusal splints may aggravate the underlying SDB. In others, MAA may initiate or aggravate preexisting painful TMD in patients with SDB. Further prospective studies looking at the relationship between SB and SDB and painful TMD and SDB are warranted before the research findings may be translated into clinical guidelines and standards of practice.

An animal study hypothesized that mastication would influence condylar cartilage responses and the subsequent growth of the mandible.¹⁹² Forty-eight 21-day-old male CD-1 mice were used. The mice were randomly divided into 6 groups to receive (ad libitum) diets of varying hardness and durations: control (3 animals), hard diet (HD)/1 week (9 animals), HD/4 weeks (9 animals), SD (soft diet)/1 week (9 animals), SD/4 weeks (9 animals), and hard soft diet (HSD)/4 weeks (9 animals). Three mice were sacrificed at 21 days of age. The remaining mice were randomly divided into 5 groups of 9 when weaned: 18 mice were fed the SD, with 9 sacrificed at 4 weeks and 9 sacrificed at 7 weeks; 18 mice were fed the HD, with 9 sacrificed at 4 weeks and 9 sacrificed at 7 weeks; and 9 mice were fed the HSD every other week and then sacrificed at 7 weeks. The HD group received an ordinary laboratory diet in a hard pellet form for mice. The SD group received the ordinary diet after it was ground and mixed with water in standardized proportions (2 parts food to 5 parts water). No significant differences in weight were identified among the mice in any of the groups, either at randomization or when they

were sacrificed. To further understand the associations between mastication and mandibular condylar cartilage growth, the histology and proliferative ability of the mandibular condylar cartilage were compared among the 3 groups. Histologic analysis showed that the hypertrophic chondrocyte zone in the central region of the mandibular condylar cartilage was significantly thicker in the HD group than in the SD group after feeding the mice the different diets for 1 week (4 weeks of age). Similarly, the hypertrophic chondrocyte zone was thicker in the HD group than in the SD group after feeding the mice the respective diets for 4 weeks (7 weeks of age), suggesting that the hard diet induced terminal differentiation of the mandibular condylar chondrocytes. This finding is consistent with the results of a previous report. The results of this study suggest that neural crest-derived cells might be responsible for the high adaptive ability of the mandibular condylar cartilage. The findings suggest that mastication markedly affects mandibular condylar cartilage growth in rodents.

SLEEP-DISORDERED BREATHING

Oral appliance therapy

A parallel controlled trial explored the effects of mandibular advancement devices (MADs) on inflammatory and hemostatic markers in a patient population with mild to moderate OSA.¹⁹³ Twenty-two patients with OSA were followed, as were 16 control participants. Baseline measurements were made and then again at 3 months and 6 months for the patients; the values for CRP, interleukin-1 β , interleukin-10, interleukin-6, P-selectin, FIB, D-dimer, plasminogen activator inhibitor-1 (PAI-1), thrombin-antithrombin (TAT) complex, activated thrombin-activatable fibrinolysis inhibitor (TAFIa), 6-keto-PGF1 α , glucose, and fibrin clot lysis time (CLT) were acquired for all individuals. Compared with controls, patients with OSA had substantially higher baseline mean levels of FIB, TAFIa, 6-keto-PGF1 α , and glucose. Along with a reduction in the AHI, MAD therapy markedly improved levels of IL-1 β , D-dimer, TAFIa, and CLT. The treatment outcome led to mostly similar inflammatory and hemostatic markers compared with the control group. To our knowledge, despite a small sample size, this is the first study that measures the impact of mandibular advancement therapy on hemostasis, including improved fibrinolysis.

A Swedish group sought to evaluate oral appliance therapy as a viable option for older patients with sleep apnea.¹⁹⁴ Extracting data from 2 previous studies, the overall patient pool contained 630 people; 56 were older than 65 years and 80% (45) continued treatment at the 1-year follow-up. Of the remaining 574 individuals younger than 65 years of age, 74% (426) continued treatment at the 1-year follow-up. Thirty-four older

participants and 243 younger participants were reexamined with the oral appliance in situ. Both groups demonstrated a similar reduction in the mean apnea-hypopnea index (AHI) (20.9 to 7.2 in the younger group; 22.3 to 10.1 in the older group). It was concluded that oral appliance therapy is an effective option for patients with OSA who are older than 65 years, as long as they have adequate dental health to support an oral appliance and sufficient dexterity to maintain the oral hygiene and use of the device.

A different trial included 52 patients with OSA to explore the effects of oral appliance therapy by using cardiopulmonary coupling (CPC).¹⁹⁵ The participants ranged in age from 33 to 74 years, with a mean of 53.7 years; 90.4% of the group were men. Baseline AHI as determined by in-laboratory full-night polysomnography (PSG) was 33.6 ± 17.0 . Subsequent PSG was performed after 3 months of MAD use. The CPC is derived from electrocardiogram measures during the laboratory testing. It analyzes measures of heart rate variability (HRV) and respiration based on the position of a single lead that assesses transthoracic impedance during expiration and inspiration. All respiratory indices improved with use of the appliance; the CPC measures showed a substantial improvement as well. Low-frequency coupling (a measure of sympathetic nervous system activity) significantly decreased, while high-frequency coupling and very low-frequency coupling (measures of parasympathetic nervous system activity) significantly increased. The AHI change was related to the CPC parameters: as the AHI dropped, the high-frequency coupling increased while the low-frequency changes decreased. This claims to be the first study to use CPC as a measure for MAD therapy for OSA.

A Japanese group evaluated videoendoscopy as a method of determining the response to oral appliance therapy in individuals with severe OSA.¹⁹⁶ They examined 36 patients (27 men and 9 women) who had received a diagnosis of severe OSA after laboratory PSG. They used a nasoendoscope while each person was horizontal and breathing through their nose; alterations in the airway at the level of the velopharynx and oro/hypopharynx were noted with mandibular advancement. The MADs increased the oro/hypopharynx in all patients; the velopharynx widened in 29 of 36 individuals. Those with an improved velopharynx had an AHI reduction of 79.8% with oral appliance therapy versus a 40.6% decrease in AHI in those without velopharyngeal changes. The researchers noted 2 types of widening in the velopharynx: the "all-round" type, which is circumferential improvement in the anteroposterior-lateral directions and the "lateral dominant" type, with changes mainly in the lateral aspects. No appreciable difference in the AHI reduction was found between the 2 types. Therefore, in patients

with severe apnea, using an endoscopy procedure may help visualize the impact of mandibular advancement in the retropalatal airway space.

Another study explored a novel device for intraoral use to assist with the monitoring of compliance in patients using an MAD.¹⁹⁷ Ten participants were fitted for an MAD with an embedded compliance monitor. The sensor was comprised of 5 components: a microprocessor with built-in thermocouple, a nonvolatile flash memory, a battery; crystal oscillator for timekeeping, and a magnetic reed relay, which is the actual sensor. When the oral appliance was connected intraorally in the correct orientation and proximity, the magnet's field engaged the monitor's reed relay, which triggered the microprocessor to activate and increase the temperature measurement rate. The data were stored on the flash memory, and a full history of the appliance use was recorded. The patients were instructed to use the MAD for 7 nights and to record their usage and any adverse events in a treatment diary. Data were downloaded via radio frequency identification technology and compared with the information in the journals. The mean objective usage time as read by the compliance monitor was 6.6 ± 1.6 hours/night. The mean subjective wearing time as reported in the participants' journals was 6.5 ± 1.5 hours/night. Adverse outcomes as reported by the participants in the diaries were consistent with common events in the literature and were transient in nature. This trial demonstrated a very high linear correlation between objective and subjective data, validating the approach for use in future research.

A different group sought to compare mandibular advancement therapy to CPAP therapy for OSA in relation to BP, oxidative stress, and HRV in a randomized, crossover, single-blind, controlled study.¹⁹⁸ Twenty-nine adults with moderate to severe OSA underwent CPAP, MAD, and placebo oral appliance therapy (POA; mandibular arch appliance only), with a 1-month treatment time for each modality and a 1-week wash out period in between each type. PSG, the Epworth sleepiness scale, 24-hour ambulatory BP monitoring, oxidative stress measures (including malondialdehyde; catalase; superoxide dismutase; vitamins C, E, B₆, B₁₂, and folate; homocysteine; and uric acid), and HRV were measured at baseline and after 1 month of each treatment modality. Journals were used to assess compliance with the oral appliances and a pressure-time meter for CPAP. Both active treatments resulted in decreases in AHI and the Epworth sleepiness scale, with positive airway pressure having a greater effect. The frequency of diastolic BP dipping was high in the MAD group compared with the CPAP group. Catalase activity was markedly decreased compared with baseline in the active oral appliance group. HRV measurements showed a substantial decrease in total power at night (corresponding to decreased sympathetic activity) for both CPAP and MAD

compared with the placebo and a decrease in the index of sleep autonomic variation with oral appliance therapy compared with baseline. Compliance rates were greater with MAD than with CPAP. CPAP therapy was shown to be more effective at attenuating OSA; however, the higher compliance with the MAD promoted reduction of an oxidative stress enzyme, better autonomic control during sleep, and increased BP dipping.

Pathophysiology and medical implications

Given that obesity is a major risk factor for OSA, another study set out to explore the morphology of upper airways in overweight habitual snorers and in patients with mild OSA.¹⁹⁹ They also established a 1-year, randomized, controlled follow-up study to examine the links between weight loss, the parapharyngeal fat pad area, and OSA after lifestyle changes with weight reduction as a course of treatment. Thirty-six overweight adult patients with OSA with an AHI of 5 to 15 and 24 weight-matched habitual snorers with an AHI less than 5 were followed. Baseline measurements included nocturnal cardiorespiratory recordings and multislice CT of the parapharyngeal fat pad area; the smallest diameter and area of the nasopharynx, oropharynx, and hypopharynx; the smallest diameter and area of the whole upper airway; the distance from the hyoid bone to the mandibular plane and cervical tangent; and the distance between the mandibular symphysis and cervical spine. Patients with OSA were further divided into either an active 1-year lifestyle intervention with an early weight loss regimen or routine lifestyle counseling. The laboratory PSG recordings and CT scans were repeated at 1 year. They found that in individuals with OSA, the pharyngeal fat pad area was markedly larger and the distance from the hyoid bone to the cervical spine was longer than in habitual snorers. The group receiving the targeted weight loss intervention over the course of the year demonstrated a reduction in the pharyngeal fat pad area and a significant drop in the AHI.

Another trial sought to investigate the metabolic activity of the genioglossus and control upper airway control muscles (masseter and pterygoids) in obese patients with OSA compared with an obese control group.²⁰⁰ Thirty obese control participants with an AHI of 4.7 ± 3.1 and 72 obese individuals with an AHI of 43.5 ± 28 events per hour as determined by overnight laboratory PSG were included. Participants also underwent positron emission tomography scanning with ^{18}F -2-fluoro-2-deoxy-D-glucose and noncontrast CT or MRI. Glucose uptake was quantified with upper airway tissues following standardized uptake values. The investigators found that glucose uptake in the genioglossus muscles was significantly decreased in patients with OSA compared with the obese normal controls; this finding was independent of age, BMI, sex, and race. No

differences in glucose uptake were noted in the control muscles and subcutaneous fat deposits in the neck and submental region between the 2 groups. The investigators attribute the reduced glucose uptake in the genioglossus to alterations in tongue muscle fiber type or as a result of chronic denervation.

The same group also examined whether tongue fat is increased in obese patients with sleep apnea compared with obese normal participants.²⁰¹ They evaluated 31 obese controls with an AHI of 4.1 ± 2.7 and 90 obese apneics with an AHI of 43.2 ± 27.3 events per hour. They then subdivided the population into 18 sex-, age-, and BMI-matched case control pairs for reanalysis. All individuals underwent MRI with 3-point Dixon magnetic resonance imaging. They applied volumetric reconstruction algorithms to study the size and distribution of upper airway fat deposition in the tongue and masseter muscles for each group. After controlling for age, BMI, sex, and ethnicity, the tongue in patients with OSA was substantially larger and had an increased amount of fat compared with controls; the results were similar in the matched evaluation. The investigators also noted that larger fat deposits occurred at the base of the tongue in the individuals with sleep apnea compared with normal participants.

Obesity and hyoid position were explored as factors affecting passive pharyngeal critical closing pressure (Pcrit).²⁰² Thirty-four Japanese-Brazilian men aged between 21 and 70 years were examined; they all underwent overnight PSG, CT scans of the upper airway, and Pcrit measurements. The average BMI was $28 \pm 4 \text{ kg/m}^2$ and the average AHI was 29. Factor analysis extracted obesity from BMI, neck, and WC and the hyoid position from the mandibular plane to hyoid angle (MPH), pharyngeal length, tongue length, tongue volume, and upper airway volume. Both obesity and hyoid position correlated with critical closing pressure; also, tongue length and volume, pharyngeal length, and MPH correlated with waist and neck circumference. These results demonstrate that airway collapse can be due to the complex interplay of multiple factors.

A different study investigated the effects of cortisol on cognition in patients with OSA.²⁰³ Fifty-five individuals with an average AHI of 30.3 were tested over 2 days. Within a 24-hour period, blood specimens were drawn every 2 hours to examine cortisol levels. The participants were given a series of neurocognitive tests to evaluate 7 cognitive domains. OSA as measured by the oxygen desaturation index (ODI) was associated with 24-hour cortisol levels. AHI, ODI, and nighttime cortisol levels were associated with global deficit scores in cognitive functioning, especially related to learning, memory, and working memory. Hierarchical linear regression analysis showed that nighttime cortisol was responsible for 9% to 16% of variance in learning, memory, and working

memory; apnea severity did not contribute to any additional variance. Cortisol is therefore implicated in the alterations in neuropsychologic function above and beyond that which can be attributed to apnea severity.

Another group examined whether subjective sleep quality and sleep duration impacts the association between age and telomere length (TL).²⁰⁴ One hundred fifty-four adults aged 45 to 77 years were included; participants were disqualified if they were receiving immunosuppressive treatment and/or had a disease with an obvious immunologic component such as cancer. Subjective sleep quality and sleep duration were assessed with the Pittsburgh Sleep Quality Index (PSQI) and the TL was measured using peripheral blood mononuclear cells. A substantial first-order negative association was demonstrated between age and telomere length; age was also negatively linked with the self-reported sleep quality and sleep duration portion of the PSQI. It was shown that age was more strongly related to TL among poor sleepers, while good sleep quality attenuated the association between age and telomere length. Among older adults, better subjective sleep quality was related to the extent of cellular aging; therefore, sleep may be a modifiable behavior linked with the aging process.

Deoxyribonucleic acid (DNA) damage in the peripheral blood cells of patients with OSA was explored in another trial.²⁰⁵ Because OSA induces oxidative stress as a result of intermittent hypoxia, DNA can be affected via chromosome aberrations and micronuclei. Thirty patients with obstructive sleep apnea hypopnea syndrome (OSAHS) were diagnosed with PSG; 28 normal volunteers were evaluated using the Epworth sleepiness scale (ESS). The degree of DNA damage was assessed through cytokinesis-blocked micronucleus assay. In the group with OSAHS, the average frequency of binucleated cells with micronuclei was substantially higher than in the control participants; the frequency of micronuclei increased significantly with the increasing severity of the disease. Micronuclei result from chromosomal fragments or lagging chromosomes during cell division and exist in the cytoplasm outside the main nucleus; they are considered a main biologic marker of chromosome instability. Treatment for the sleep-disordered breathing decreased the number of cells with micronuclei.

Sleep fragmentation is a hallmark of OSA. One study explored its effects on tumor growth and progression by way of proinflammatory toll-like receptor 4 (TLR4) signaling.²⁰⁶ Mice that were exposed to sleep fragmentation 1 week before the implantation of synergistic TC1 or LL3 tumor cells underwent tumor analysis 4 weeks later. Mice that were genetically deficient in TLR4 or its effector molecules, myeloid differentiation primary response gene 88 (MYD88) and TIR-domain-containing adapter-inducing interferon- β (TRIF), were used as a comparison. The investigators found that fragmented

sleep enhanced tumor size and weight and also increased the extent of invasiveness, with the tumors showing penetration of the capsule into surrounding tissues, including muscle. Tumor-associated macrophages (TAMs) were more numerous in sleep fragmentation tumors, being distributed in closer proximity to the tumor capsule than in the control group. Tumors were found to be typically smaller in both MYD88-negative and TRIF-negative hosts, but the more aggressive features due to fragmented sleep were evident. The effects of sleep fragmentation were eradicated in TLR4-negative mice. Sleep disturbance can contribute to tumor growth and invasiveness via TAM recruitment and TLR4 signaling routes.

A metaanalysis was conducted to evaluate the association between sleep-disordered breathing during pregnancy and perinatal outcomes.²⁰⁷ PubMed, Springer Link, and EMBASE were searched to identify all eligible studies published before August 2013. A total of 24 articles met the inclusion criteria for the metaanalysis. Summary ORs and 95% CIs were derived using a fixed or random effects model. The results, based on all studies but not gestational age and birth weight, illustrated that moderate to severe SDB during pregnancy was associated with gestational diabetes mellitus (OR 1.78, 95% CI 1.63-3.47), preeclampsia (OR 2.19, 95% CI 1.71-2.80), preterm delivery (OR 1.98, 95% CI 1.59-2.48), low birth weight (OR 1.75, 95% CI 1.33-2.32), neonatal intensive care unit admission (OR 2.43, 95% CI 1.61-3.68), intrauterine growth restriction (OR 1.44, 95% CI 1.22-1.71), and an Apgar score less than 7 at 1 minute (OR 1.78, 95% CI 1.10-2.91). Pregnant women and their unborn and newborn infants can be at increased risk for adverse events in the presence of moderate to severe sleep-disordered breathing.

Temporomandibular disorders and sleep bruxism

The Orofacial Pain Prospective Evaluation and Risk Assessment cohort set out to evaluate whether OSA signs and symptoms are associated with the occurrence of TMD.²⁰⁸ The prospective cohort study enrolled 2604 adults aged 18 to 44 years at the outset; the case-control studies enrolled 1716 participants. In both studies, TMD was determined by an examiner according to established research diagnostic criteria. Individuals were considered to have high likelihood of OSA if they reported a history of sleep apnea or 2 or more hallmarks of OSA: loud snoring, daytime sleepiness, witnessed apnea, and hypertension. Cox proportional hazards regression was used to estimate hazard ratios (HRs) and 95% CL for first-onset TMD. Logistic regression was used to estimate ORs and 95% CL for chronic TMD. Two hundred forty-eight people developed first-onset TMD during the median 2.8-year follow-up in the cohort. A high likelihood of OSA was associated with a greater incidence of

first-onset TMD (adjusted HR 1.73; 95% CL, 1.14-2.62). The case-control study demonstrated that a high likelihood of OSA was associated with higher odds of chronic TMD (adjusted OR 3.63; 95% CL 2.03-6.52). Both studies supported a substantial association of OSA symptoms and TMD, with prospective cohort evidence finding that OSA symptoms preceded first-onset TMD.

Another study sought to evaluate objectively measures of sleep and respiratory disturbance in a large representative sample of individuals with TMD in comparison with matched controls.²⁰⁹ Sleep, respiration, and limb movements were recorded using a 2-night laboratory polysomnogram protocol in 170 women, 124 individuals with TMD and myofascial pain, and 46 demographically matched controls. The second night data were compared between the groups using ANCOVAs. For those with TMD, the relationship between pain ratings and sleep parameters was evaluated using multiple regressions. The investigators found that in comparison with healthy controls, the participants with TMD showed a significant increase in stage N1 sleep (12.2% \pm 7.6% versus 9.2% \pm 5.0%, $P=.03$), which was only mild relative to normative values. Participants with TMD also showed mild but substantial elevations in arousals associated with all types of respiratory events (6/hour \pm 6.1 versus 3.5/hour \pm 3.3, $P=.02$) and in respiratory effort-related arousals (RERAs, 4.3/hour \pm 4.3 versus 2.6/hour \pm 2.7, $P=.02$). Myofascial pain predicted lower sleep efficiency ($P=.01$), more frequent awakenings ($P=.04$), and a higher RERA index ($P=.04$) among the patients with TMD.

A pilot study was performed to evaluate the diagnostic accuracy of scoring sleep bruxism (SB) during portable polysomnographic testing in the absence of audio-video (AV) recordings.²¹⁰ Current PSG research diagnostic criteria dictates that SB be diagnosed when more than 2 rhythmic masticatory muscle activity (RMMA) events per hour of sleep are recorded on the masseter and/or temporalis muscles. Ten individuals with a mean age of 24.7 \pm 2.2 years and a clinical diagnosis of SB underwent 1 night of testing in a sleep laboratory. PSG was performed with a type 2 portable monitor while AV recording was obtained. The same examiner scored each test 3 times: without, with, and without AV; this assessed the intrascoring and intraexaminer reliability for RMMA scoring. The rhythmic masticatory muscle activity event-by-event concordance rate between rating without AV and with AV was 68.3%. The RMMA index was overestimated by 23.8% without AV. They did show that the intraclass correlation coefficient (ICC) between scorings with and without AV was good (ICC=0.91; $P<.001$); the intraexaminer reliability was high (ICC=0.97; $P<.001$). The clinical diagnosis of SB was confirmed in 6 of 10 patients using AV and in 8 of 10 individuals without using AV. The researchers concluded that the diagnostic accuracy of portable PSG testing is adequate for the

detection of RMMA episodes in both research and clinical settings; the lack of AV may lead to an overestimation of events.

A different group set out to explore the effect of SB on sleep architecture and investigate the relationship between SB and sleep respiratory events in patients with OSA syndrome.²¹¹ Sixty-seven individuals with an AHI greater than 5 were evaluated and compared with 16 healthy volunteers in the control group. Data were gathered using standard overnight PSG sleep tests in a quiet, dark room. The frequency of SB events was higher in the sleep apnea group than in normals; the risk of SB was substantially higher in the OSA group compared with the controls (OR 3.96; 95% CI 1.03-15.20; $P<.05$). Those with SB demonstrated significantly more apnea, hypopnea, and desaturation events than those without SB. Phasic type SB exhibited a positive correlation with obstructive apneas, microarousal, and oxygen desaturation. Microarousals due to apnea-hypopnea episodes showed an elevated frequency of SB in the OSAS group compared with the healthy participants. These results suggest that successful treatment for OSAS syndrome might prevent sleep bruxism events.

OSA is strongly associated with gastroesophageal reflux disease (GERD), and GERD is associated with nocturnal bruxism. One study sought to evaluate the associations between, and symptoms associated with, nocturnal GERD and SB in patients with OSA and to explore the influence of sex and ethnicity.²¹² A retrospective patient record survey was performed of individuals diagnosed with OSA at a university sleep center. The participants completed a sleep questionnaire and then underwent PSG. Those with diagnosed OSA were evaluated based on sex and ethnic background. The average BMI of those patients assessed was 41 \pm 9 in men and 45 \pm 9 in women; the average AHI was 52.7 \pm 38.2 for men and 40.9 \pm 36.7 for women, ranging over a wide degree of disease severity. Associations were determined between SB and nocturnal GERD, daytime sleepiness, insomnia, restless leg syndrome, and markers of sleep apnea severity in each group. The researchers found that in the OSA population, the prevalence of nocturnal GERD (35%) and sleep bruxism (26%) was elevated compared with that of the general population. SB was more common in whites than in African Americans or Hispanics; no difference was noted based on sex. Nocturnal GERD was similar among all ethnic groups and sexes. Bruxism was associated with nocturnal GERD in women, restless leg symptoms in all participants, sleepiness in African Americans, and insomnia in Hispanics. Nocturnal GERD was associated with sleepiness in men and African Americans, with insomnia in women, and with restless leg symptoms in women and whites. Sleep professionals should be aware of different

presentations of comorbid bruxism and GERD in patients with OSA across differing ethnic backgrounds and sexes.

IMPLANT DENTISTRY

The use of curved titanium abutments has been proposed to provide additional tissue thickness around single-unit restorations in order to create a more favorable esthetic outcome. Investigators compared conventional straight abutments with experimental curved implants in a split-mouth randomized design.²¹³ The curved abutments were provided with an additional circumferential groove of 0.5 mm in depth, drilled within 1.25 mm above the abutment to the implant junction. The pink esthetic scores, plaque index, bleeding index, width of attached mucosa, radiographic bone levels, and PDs were evaluated at the time of abutment installation and 12 months after definitive crown placement. Bone and implant related variables were also recorded at the time of implant placement. The authors could not find any differences between the 2 abutments used for any of the variables, and no correlation could be associated with any of the possible confounding variables.

A longitudinal comparative study on immediate versus delayed implant loading and with at least 6 years' follow-up found that the cumulative survival rate of both groups of implants was equivalent, but the implants that were immediately loaded had less bone around them.²¹⁴ However, the findings have little validity because of the lack of match between the control and the test group and the lack of randomized allocation to the groups. Participants were allocated to the group based on "their existing maxillary condition and their preference." Therefore, the groups were not matched in number, case selection, or patient data.

Investigators published the results of a comparative multicenter study of single implants immediately loaded into extraction sockets or healed ridges.²¹⁵ Three of 55 (5.4%) implants were lost in the extraction socket group and 1 of 55 (1.7%) in the healed ridge group. All failures were within the first year. Bone levels were similar at 5 years because bone gain was observed along the implants in the socket sites. The esthetic outcomes were also similar.

The consensus statement of group 2 in the 5th ITI Consensus Conference was published in 2014.²¹⁶ This group studied the restorative materials and techniques in implant dentistry to provide a 5-year evaluation.

The investigators reviewed studies with a mean observation period of 5.5-year survival for a total of 2186 abutments.²¹⁷ Two thousand and fifty-two metal and 134 ceramic implant abutments for single fixed prostheses were evaluated. No difference in overall survival rates (97.5% versus 97.6%) or in terms of biologic or technical

complications could be found between ceramic and metal abutments. Finally, no difference in technical or biologic complications were detected between internal and external implant-abutment connections. The incidence of biological events was almost twice as high for ceramic abutments as for metal abutments (10.4% versus 6.1%), but without reaching statistical significance. The rate of biologic complication was also twice as high for external abutment connection as for internal ones, but without reaching statistical significance.

In a systematic analysis of studies representing a mean exposure time of 5.4 years, despite similar overall survival rates, the investigators found that the incidence of technical and biologic complications was higher for cement-retained restorations than for screw-retained ones.²¹⁸ For cemented restorations alone, the metal ceramic restorations presented a lower failure rate than ceramic ones. Screw-retained restorations presented a higher rate of ceramic chipping, while cement-retained restorations had a higher rate of fistula and suppuration.

Of more anecdotal interest, a group of authors attempted to answer the following question by conducting a literature review: "Should occlusal splints be a routine prescription for diagnosed bruxing patients undergoing implant therapy?"²¹⁹ In the results section, the authors admit that they were unable to identify a single clinical trial that compared the use or omission of an occlusal splint in patients with implant-supported prostheses.

Esthetic outcomes

The consensus statement of group 3 on the "Recommended clinical procedures regarding optimizing esthetic outcomes in implant dentistry" for the 5th ITI Consensus Conference was published in 2014.²²⁰ It concluded that the available literature does not show that esthetic outcomes can be improved by the use of surgical templates, the use of implant-retained interim prostheses, the timing of interim implant-retained prostheses, or the mode of prosthesis retention (cement or screw-retained). The use of a ceramic abutment did improve the esthetic outcome in 1 of the reviewed studies; esthetics can also be improved by a horizontal offset at the implant-abutment interface.

A disappointing SR investigating the effectiveness of restorative procedures on esthetic results with dental implants was published in 2014.²²¹ The heterogeneity of the data did not allow metaanalysis. The only concrete finding was that facial malpositioning of the implant resulted in an increased likelihood of mucosal recession.

LOADING PROTOCOLS

Group 4 of the 5th ITI Consensus Conference focused on clinical recommendations for implant loading protocols.²²² The group evaluated loading protocols in

4 subgroups: single implants, patients with partial edentulism, fixed restorations in patients with complete edentulism, and overdentures in patients with complete edentulism. This is a must read for all clinicians providing implant therapy.

An SR and metaanalysis of the results of single-unit implant-supported restorations performed in a delayed versus immediate loading protocol was performed by searching for RCTs comparing both protocols.²²³ In this analysis, most of the 11 trials studied provided less than 5 years of follow-up. The review concluded that both techniques can provide similar results when the initial implant stability is greater than 20 Ncm. However, drawing conclusions in terms of esthetic results is difficult because too few studies observed this parameter.

In a comparison of immediate, early, and conventional loading for partial fixed dental prostheses, 1 review concluded that immediate loading can be successful if strict patient selection is applied.²²⁴ Data were insufficient to evaluate this option in anterior sites. For patients with complete edentulism, an SR and metaanalysis on loading protocols could not demonstrate any differences between immediate, early, or conventional loading.²²⁵

With regard to loading protocols with overdentures, another SR and metaanalysis concluded that immediate loading can provide similar early survival rates but conventional loading protocols are better documented.²²⁶ The immediate loading of single implants in the mandible may not be recommended at this time because of lack of evidence. In the maxilla, at least 4 implants should be used if immediate loading is considered.

A large randomly selected sample from numerous private and public practices was used to evaluate the outcomes of dental implants placed in Sweden in 2003.²²⁷ Because of its size, randomization, and practice base, this type of sample is relevant to practicing dentists. A total of 4716 patients in 2 age groups were randomly selected from a national sample of more than 23 000 patients who had received dental implants in Swedish private practices in the year 2003. The age groups were 45 to 54 years (1716 patients) and 65 to 74 years (3000 patients). A satisfaction questionnaire was sent 6 years after completion of the treatment, to which 81% (3827) of patients responded, accounting for 1325 patients in the younger group and 2502 in the older one. Sixty-four percent of treating clinics were private, 74% of surgeons were specialists, and 76% of restorative dentists were general practitioners.

Interestingly, 94% of patients were satisfied with the overall and esthetic results, 65% considered that implants improved their self-confidence, and 70% were satisfied with their masticatory ability. While 25% of patients had experienced complications rarely, 7% had

experienced them frequently. Overall, more than 95% of patients considered the therapy worth the cost and would do it again. Because of the reimbursement regulations in Sweden in 2003, patients older than 65 years would only need to spend \$1000 USD out-of-pocket.

A subsequent report from the same group provides information relative to the effectiveness data of implant therapy.²²⁸ Files from 2765 patients (more than 800 clinicians) were collected. Five hundred and ninety-six patients were clinically examined 9 years after completion of the restorative treatment. In this group, 4.4% of patients lost 1.5% of all implants before prosthetic rehabilitation (early loss), while 4.2% of patients lost 2% of all implants after prosthetic rehabilitation (late loss). Overall, 7.6% of patients had lost at least one implant. Smokers, patients with an initial diagnosis of periodontitis, implants of less than 10 mm in length, and certain implant brands had a higher OR for early implant losses. However, no explanation can be obtained from the given material for the OR differences among implant types. These last 2 studies provide large real clinical practice feedback, which demonstrates that patient satisfaction is overall very high for implant therapy despite the presence of complications and implant losses.

Conclusion

The purpose of this review of the dental implant literature for the year 2014 was to provide restorative dentists with scientifically sound yet clinically relevant papers. Therefore, an unbiased, systematic search, selection, and review process was performed for the 2185 results yielded in the initial search. Scientific standards are very difficult to meet in restorative dentistry because of the numerous confounding variables and operator dependent procedures. It is clear from these results that our field of expertise combines science, technique, and art.

The 5th ITI Consensus Conference focused on clinical recommendations for implant loading protocols and demonstrated the efficiency of immediate or early loading in numerous clinical situations. These studies were performed by experienced clinicians in well-controlled settings and the less experienced should proceed with caution when performing complex procedures. The report illustrates the difference between efficacy and efficiency. Efficacy refers to the possible outcomes of a procedure in ideal conditions, while efficiency refers to the large-scale implementation of such procedures. The studies by Derks et al^{227,228} exemplify the efficiency type of study, which gives broad and general answers to a large question. The study by Cooper et al,²¹⁵ on the other hand, is an example of a multicentered study performed to compare the efficacy of immediate loading in healed ridges versus extraction sockets.

DENTAL CARIES AND CARIOLOGY

The primary areas addressed in scientific articles on dental caries published in 2014 were the demographics of the disease and risk factor assessment, prevention, genetics/microbiology, and treatment/remineralization.

Demographics and risk factor assessment

Both in the United States²²⁹ and in the rest of the world,²³⁰⁻²³² an increased risk of dental caries is strongly related to lower socioeconomic status. Another study determined that the bacterial saliva profile of individuals with low levels of oral disease is not influenced by diet, while smoking and possibly socioeconomic status seem to affect the bacterial profile of saliva.²³³ The authors, using high throughput techniques, analyzed stimulated saliva specimens from 292 participants with low levels of dental caries and periodontitis. Using the presence and levels of bacterial probes as endpoints (300 different bacterial species were searched), the influence of diet, lifestyle, and socioeconomic status on the bacterial saliva profile was analyzed. The predominant bacterial profile was dominated by taxa/clusters usually related to oral health (from *Streptococcus* and *Veillonella* groups). Specimens also contained putative periodontal pathogens such as *Porphyromonas gingivalis*, *Aggregatibacter actinomycetemcomitans*, and *Prevotella intermedia*. Cariogenic bacteria such as *Streptococcus mutans* and *Lactobacillus* species were found in less than 4% of the specimens. The conclusion of the study was that age, sex, BMI, alcohol consumption, and diet in general had no statistical effect on the presence or levels of any taxon/cluster. Two bacterial taxa (*Streptococcus sobrinus* and *Eubacterium*) were identified at higher levels in smokers than in nonsmokers. Finally, when the high socioeconomic status subgroup was compared with the low socioeconomic status subgroup, highly significant differences were observed, in that 20 bacterial probes differed in frequency between subgroups. An interesting question, which only prospective studies may answer, is whether bacterial profiles of saliva can be used as biomarkers of health and disease.

In another study, place of residence and monthly household income (socioeconomic indicators) and oral hygiene (behavioral factor) influenced the occurrence of early childhood caries.²³⁴ Additionally, to promote children's oral health, the children must be enrolled in oral health programs, adopt healthy habits as early as possible, and follow parental advice.²³⁵ Evidence-based support is also available for the effectiveness of early preventive dental visits (EPDVs), starting in the first year of life. The benefits of EPDVs before the age of 3 years are evident among children at high risk or with existing dental disease. EPDVs may be associated with reduced

restorative dental care visits and related expenditures during the first years of life.²³⁶

Because an individual's socioeconomic status is difficult to control, preventive measures are very important in controlling disease. Cho et al²³⁷ found that water fluoridation could not only lead to a lower prevalence of dental caries but also help reduce the effect of socioeconomic diversity on oral health.

In the general population, type 1 diabetes has been found to increase the risk of developing both dental caries and periodontal disease in 10- to 15-year-old adolescents.²³⁸ However, other studies have found that frequent consumption of snacks, including the cheese and bread often eaten by patients with diabetes, is more effective against caries than the sugar-based snacks habitually consumed by individuals without diabetes.²³⁹

Low salivary rates associated with long-term smoking,²⁴⁰ radiation therapy,²⁴¹ primary diseases,²⁴² and certain medications^{143,243} have always been directly related to increased risk of dental caries. Investigators have found a significant decrease in mean salivary flow rate, salivary pH, and salivary buffer capacity and a significant increase in salivary viscosity among participants with nursing caries compared with caries-free participants and participants with minimal caries.²⁴⁴ These results reemphasize the importance of the various physicochemical properties of saliva, such as salivary flow rate, pH, buffering capacity, and viscosity, all of which act as markers for caries activity. However, as suggested by the authors, in order to extrapolate the findings of this study, studies involving a larger sample size are required.

More than one fourth of adults between the ages of 60 and 79 years have untreated root caries, while more than one third have untreated coronal caries. Lower salivary flow rates play a significant role in both the number of teeth and the number of surfaces developing caries in these adults.²⁴³ Saliva appears to be so critical as a protective factor against dental caries that even the composition of maternal saliva is associated with oral infection among children and predicts the increased occurrence of early childhood caries.²⁴⁵

Enamel hypoplasia in the past years has been investigated as a possible predisposing factor for the development of dental caries. Investigators in a cross-sectional multidisciplinary study found that caries was more common among children who had enamel hypoplasia in their posterior teeth than among those with none, while in anterior teeth, there was no association.²⁴⁶

Obesity is increasingly recognized as a global public health problem because it increases the risk of diseases such as type 2 diabetes, hypertension, atherosclerosis, heart disease, and brain disease. However, whether overweight and obesity are directly associated with the occurrence of dental caries is still a question. Generally speaking, overweight individuals consume more

sugar-containing foods and beverages²⁴⁷ and therefore have a higher risk for development of dental caries.^{248,249} While it is clear that in certain geographic areas this correlation seems to be stronger, there is no certainty that obesity is a predisposing factor per se.²⁵⁰ For example, in a study of 18-year-old adolescents, no direct correlation was found between obesity and caries.²⁵¹ However, an analysis of food intake demonstrated that specific dietary habits (intake of sugar-sweetened drinks, frequency of sugar intake limited to main meals, frequency of food intake between meals) may be considered risk factors common to both dental caries and childhood obesity.²⁴⁹

Interestingly, previous caries experience may predict a risk of becoming overweight and obese. This relationship, however, seems dependent on the socioeconomic position and educational level of the mother; one study suggested that a high caries experience may be a marker for a low future risk of obesity among children and adolescents with well-educated mothers.²⁵² This study shows a direct association between dental caries and obesity, evident from a correlation between the prevalence of dental caries and fat mass percentage.

An original study indicated a strong association of blood lead levels with increasing numbers of carious teeth in children aged 24 to 72 months.²⁵³ These findings support other studies in an innovative analysis evaluating children with no caries. This study demonstrated that even low blood lead levels are associated with the increased extent/severity of dental caries in early life.

Oral health promotion strategies have proven effective in work environments.²⁵⁴ Even the provision of web-delivered education to primary caregivers can be an effective and low cost strategy for promoting maternal and infant oral health, because children with an early caries experience have a high risk of disease progression.²⁵⁵ Oral health promotion and prevention programs should, therefore, target small children and their caregivers.²⁵⁵

Genetics/microbiology

Most of the genetic research on dental caries over the past years has focused on *S. mutans*. The goal of 1 research project was to selectively kill or inactivate this microorganism based on the theory that the initial key role of *S. mutans* in establishing a biofilm is the foremost critical step in caries formation.²⁵⁶ However, other microbial species have also been isolated from carious lesions and have been related to the process of tooth decay, including lactobacilli and bifidobacteria, *Atopobium*, *Prevotella*, *Propionibacterium*, *Scardovia wiggisiae*, and *Veillonella*. Using next generation sequencing methods and 16S ribosomal ribonucleic acid (rRNA)-based analysis, research has shown that thousands of microbial species colonize the oral cavity. However, in recent years, several papers have limited these estimates

to a few hundred. The use of second-generation sequencing and metagenomic techniques has revealed a very diverse ecosystem, where *S. mutans* accounts for only 0.1% of the whole bacterial community in dental plaque and 0.7% to 1.6% in carious lesions. However, these DNA-based studies may quantify dead, transient, or inactive microorganisms that do not contribute to the disease, inflating estimates of diversity and introducing noise in the analysis. Thus, the application of high-throughput sequencing to the RNA extracted from oral specimens finally provides an opportunity to identify the metatranscriptome, that is, the active microbial composition and expressed genetic repertoire underlying disease initiation and progression. Determining the active microbiota in carious lesions may finally unravel the elusive etiology of the disease, paving the way for diagnostic and preventive tools.²⁵⁷ An elegant review on this subject has been published by Simòn-Soro and Mira.²⁵⁸ Although the composition of oral biofilms is well established, the active portion of the bacterial community and the patterns of gene expression in vivo have not been studied. In a study by the same research group from Spain²⁵⁹ using RNA-sequencing technologies, a metatranscriptomic study of human dental plaque was performed in 9 individuals with 2 different approaches: a short-reads, high-coverage approach by Illumina sequencing (a particular molecular biology technique) to characterize the gene activity repertoire of the microbial community during biofilm development; and a long-reads, lower-coverage approach by pyrosequencing to determine the taxonomic identity of the active microbiome before and after food ingestion. The high-coverage approach allowed the authors to analyze more than 398 million reads, revealing that microbial communities are individual-specific and no bacterial species was detected as a key player at any time during biofilm formation. The authors could identify some gene expression patterns characteristic of early and mature oral biofilms. The transcriptomic profile of several adhesion genes was confirmed through qPCR by measuring the expression of fimbriae-associated genes. In addition to the specific set of gene functions overexpressed in early and mature oral biofilms, as detected through the short-reads dataset, the long-reads approach detected specific changes compared with the metatranscriptome of the same individual before and after a meal; this can restrict the list of organisms responsible for acid production and therefore potentially for dental caries. Several important conclusions can be drawn from this article. First, the bacteria changing activity during biofilm formation and after meal ingestion was participant-specific. Second, some individuals showed extreme homeostasis with virtually no alterations in the active bacterial community after food ingestion, suggesting the existence of a microbial community that could be related to dental health.

Studying these participants furthers the understanding of how to obtain a stable and healthy biofilm. In fact, other authors have suggested that the dental plaque of individuals who have never suffered from caries can be a genetic reservoir of new anticaries compounds and probiotics,²⁶⁰ while the presence of manifest caries has been associated with reduced bacterial diversity in the oral environment.²⁶¹ Finally, no evident link was noted between bacterial composition and the biofilm development stage. These results confirm the concept that individual-specific microbial communities are a consequence of host-bacterial co-evolution to maintain host health. Therefore, the host-specific microbiota could be considered as a genetic fingerprint peculiar to every person. Simòn-Soro et al²⁶² in a third paper tried to identify the RNA-based, metabolically active bacterial composition of caries lesions at different stages of disease progression to provide a list of potential etiologic agents of tooth decay. Noncavitated enamel caries lesion and dentin caries lesion specimens were collected from 13 individuals. RNA was extracted and complementary DNA (cDNA) was constructed and used to amplify the 16S rRNA gene. The resulting polymerase chain reaction products were pyrosequenced using titanium-plus chemistry, and the sequences obtained were used to determine the bacterial composition. Estimates of bacterial diversity indicate that the microbiota of cavities is highly complex, each sample containing between 70 and 400 metabolically active species. The composition of these bacterial groups varied among participants and between different caries lesions in the same individuals. Moreover, enamel and dentin lesions had a different bacterial makeup. Lactobacilli were located almost exclusively in dentin cavities. Streptococci accounted for 40% of the total active community in enamel caries, and 20% in dentin caries. However, *S. mutans* represented only 0.02% to 0.73% of the total bacterial community. Enamel caries lesions were the least diverse, with a median of 177.7 bacterial species, whereas the estimates for open dentin cavities were 250.7 and hidden dentin cavities 201.2. The data indicate that the etiology of dental caries is tissue dependent and that the disease has a clear polymicrobial origin. The low proportion of *S. mutans* detected confirms that they are a minority and that their importance as the main etiologic agent of tooth decay is questionable. Future experimental work should be performed to confirm the cariogenicity of the identified bacteria. Based on these studies, identifying which types of microorganisms are really involved in the process of dental caries, from the initial biofilm formation all the way to the progression of the disease, is possible for the first time. With RNA laboratory technology, we can identify, not only which bacteria are present but also if and when they are metabolically active. Looking also at the very small percentage of *S. mutans* involved overall

(0.1% in saliva and 0.7% to 1.6% in carious lesions), the role of *S. mutans* may have been overestimated and could be not as important as initially thought. Also looking at the type of genes active in the different steps of biofilm formation, different bacterial species could perform the same metabolic activity: this means that research targeting a specific bacterial family may be bound to fail. However, none of these new studies have actually demonstrated that other bacteria can play the same role as *S. mutans* in the initial formation of the biofilm. On the other hand, years of research on the selective killing primarily of *S. mutans* are in the final clinical stage, and it will not be too long before clinical data will be available for direct evaluation. Some authors do believe that research will demonstrate that other species will take the place of *S. mutans* in the mechanism of caries formation and development. Future research will have to deal with the process of biofilm formation in general and not with a specific bacterial agent.^{258,263}

An understanding of genetic contributions to caries can be of great interest to dental clinicians as the starting point of host susceptibility. In the future, they may be able to explain to patients that some forms of caries are more strongly associated with inherited risk and that similar behaviors (tooth brushing frequency or dietary habits) may carry different caries risk. Individuals with a higher genetic risk could therefore be monitored more meticulously and treated with more aggressive caries management and prevention programs.²⁶⁴

Although metabolomics and metatranscriptomics research represents the most innovative type of study in the year 2014, still, the majority of papers in the genetics area of dental caries were focused primarily on *S. mutans*. An SR and metaanalysis demonstrated evidence of vertical transmission of *S. mutans* from mother to child.²⁶⁵ The knowledge of the *S. mutans* strains is important because the virulence of the microorganisms varies; also, the virulence affects the evolution rate of dental caries, which can be more or less aggressive.

An interesting study was published by Shang et al²⁶⁶ on the efficacy of an antimicrobial peptide (LK-6) against oral pathogens and *S. mutans* biofilms. This peptide was previously demonstrated to be very effective against *E. coli* and *Staphylococcus aureus*. The results of the study were encouraging and suggested that L-K6 may have clinical applications in treating dental caries by killing many different types of oral pathogens, primarily *S. mutans*. It was also found that this antimicrobial peptide was acting as an antiinflammatory agent in infected tissues.

For *S. mutans* to express its virulence, it must use the carbohydrates present in the oral cavity. Investigators using steady-state continuous culture were able to examine the effects of carbohydrate availability on *S. mutans* in the absence of confounding effects from pH,

growth rate, and other influences known to affect gene expression in this organism.²⁶⁷ The results of this interesting study revealed profound changes in gene expression and the phenotypic properties of *S. mutans* in response to the quantity of carbohydrates available in the environment.

Being able to identify in advance individuals who are more likely to have active caries has always been a goal of research. Zhao et al²⁶⁸ found that the concentration of soluble toll-like receptor-2 (sTLR-2) at the microbial host interface in caries active saliva was significantly higher than that in caries-free saliva. Therefore, sTLR-2 represents a potential biomarker for caries activity.

Another study revealed the differential colonization behavior of bacteria with respect to pH gradient and a lower than expected abundance of lactobacilli and streptococci in established carious lesions.²⁶⁹ The data indicated the numerical importance of relatively unexplored taxa within the lesion of dentinal caries. The gradient nature of pH in the lesion and the different colonization of bacterial taxa examined with reference to pH provides new insight into conservative caries management.

One interesting investigation performed a genome-wide association study of surface-level caries scores in the primary dentition and nominated the KPNA4, ITGAL, and PLUNC family genes as determining caries susceptibility and replicated the associations for MMPED2, AJAP1, and RPS6KA2.²⁷⁰ Replications in additional samples are warranted to confirm the associations of newly nominated genes with dental caries.

Another study evaluated a number of host-derived enzymes and found the abundance of the test enzymes was markedly higher in caries-affected dentin than in intact dentin.²⁷¹ CT-B exhibited the highest percentage of colocalization with collagen, followed by MMP-9, MMP-2, and CT-K. The high expression of CTs and MMPs in caries-affected teeth indicates that those host-derived enzymes are intensely involved with caries progression.

Investigators sequenced coding exons and exon-intron boundaries of the enamel gene (ENAM) in 250 children with a severe caries phenotype and 149 caries-free children.²⁷² Haplotype interaction analysis demonstrated that the presence of 2 specific single-nucleotide polymorphisms increased caries susceptibility 2.66 times. These findings support ENAM as a gene candidate for caries susceptibility in the studied population.

One interesting study demonstrated for the first time the spatial distribution of bacterial taxa in vivo at various stages of the occlusal caries process.²⁷³ The research technique applied a molecular methodology involving the preparation of hard dental tissue slices for fluorescence in situ hybridization and confocal microscopy. The study showed that distinctly different biofilms were involved with various stages of occlusal caries lesions.

The authors concluded that the molecular methodology represents a valuable supplement to previous methods of studying microbial ecology in caries by allowing the analysis of the structural composition of the undisturbed biofilm in carious lesions in vivo.

An interesting review article attempted to establish which characteristics associated with biofilm formation were responsible for the development of dental caries.²⁷⁴ The authors analyzed biofilm formation as a complex process of protein-bacterium interaction and discussed to what extent microorganisms of the cariogenic flora differ in virulence determinants from microorganisms of physiologic flora.

An SR and metaanalysis was conducted to evaluate the possible association of s-IgA levels and dental caries.²⁷⁵ The pooled metaanalysis data demonstrated higher levels of s-IgA in the caries active group than in the control group. Based on these findings, there is evidence to support the presence of increased s-IgA levels in caries-active individuals.

An in vitro study was done to investigate the contribution of sugar substitutes to the cariogenic potential of *S. mutans* biofilms.²⁷⁶ The substitution of sucrose induced a down-regulation of most of the genes involved in sucrose-dependent colonization in biofilm cells. When the ratio between the expression of biofilm and planktonic cells was considered, most of those genes were down-regulated in biofilm cells in the presence of sugars and up-regulated in the presence of sugar substitutes. However, sucralose, but not sorbitol, reduced the cariogenic potential of the diet because it induced the biofilm formation with the lowest biomass, did not change the pH of the medium, and led to the lowest lesion depth.

A cross-sectional, retrospective study was done to determine the prevalence and abundance of 20 key oral bacteria in both health and disease.²⁷⁷ The database was constructed based on the microbiological analyses of specimens from 6308 individuals with gradations of periodontitis. Data concerning the abundance of the 20 oral bacteria and PPD were provided. *Porphyromonas gingivalis*, *Tannerella forsythia*, *Treponema denticola*, *Eubacterium nodatum*, *Porphyromonas micra*, and *Porphyromonas intermedia* showed a clear increase in abundance and prevalence with increasing pocket depth. Correlation matrices illustrated that almost all microorganisms were in one way correlated to other species and most of these correlations were significant. Several beneficial bacteria showed strong correlations with other beneficial bacteria. Knowledge of bacterial correlations may pave the way for new treatments focusing on restoring the shifted balance.

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Noteworthy Abstracts of the Current Literature

Patients' evaluations of complete denture therapy and their association with related variables: A pilot study

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Purpose. Patient satisfaction is an important goal in complete denture therapy, and many factors influence this parameter. This study aimed to evaluate expectations before and satisfaction after therapy with complete dentures. As a secondary objective, other variables that may interfere with patient satisfaction were also evaluated.

Materials and methods. A representative sample of 99 patients assigned visual analog scale (VAS) scores to their expectations before and satisfaction after therapy regarding chewing, esthetics, comfort, and phonetics. Demographic data and answers to a questionnaire concerning the dentists' conduct were recorded. Multiple linear regression was used to evaluate the association among studied variables and patients' expectation and satisfaction with their dentures.

Results. The average VAS scores were high for both expectations and satisfaction, and satisfaction exceeded expectations. Patients' expectations about esthetics and comfort were associated with age and self-reported time of using complete dentures. Patient satisfaction regarding chewing was associated with the number of postdelivery adjustments. Also, patient satisfaction regarding esthetics was associated with gender and esthetic expectations. In regard to phonetic satisfaction, associations were verified among self-reported time of using complete dentures, comfort and phonetics expectations, and dentists' explanations. Comfort satisfaction was associated only with educational level.

Conclusion. Patient satisfaction regarding complete dentures exceeded expectations and an expressive majority of positive evaluations of the dentists was noticed. Many patient-related variables seemed to influence their evaluations of their dentures.

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