Annual Review of selected dental literature: Report of the Committee on Scientific Investigation of the American Academy of Restorative Dentistry

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Dentists have been told for decades that they must be continuous learners to keep up with the changes in materials and techniques that occur over all disciplines of clinical dentistry. This is essential so that they can provide optimal care for their patients. A number of sources of information are available to dentists, including courses and seminars sponsored by different types of providers, information gleaned from newsletters, and articles in trade journals and in the peer-reviewed literature. Much information can be learned from manufacturers, conversations with colleagues, and surfing the Internet. It is increasingly clear that the validity of this information is highly variable, that the information is frequently commercially biased, and that many conclusions are made that are not based on sound scientific evidence.

Even the most avid consumer of continuing dental education is confronted with a considerable amount of misinformation. The peer-review system is far from perfect, and many studies with insufficient sample sizes and inappropriate research protocols find their way into print in the myriad of journals that have proliferated in recent years. Most properly conducted systematic reviews complain about the paucity of properly conducted randomized controlled trials (RCTs) and the poor quality of the available evidence.

However, every year many studies are conducted and published that do provide evidence that helps dentists make intelligent clinical decisions. It is a given that a majority of clinicians have difficulty gaining access to much published information, and even if they have access, most do not have sufficient time available to critically analyze the available data. This review is conducted to assist clinicians in locating pertinent studies in several disciplines so that they can remain current with information generated in the previous year (2012). Some studies are analyzed in depth, and the research methodology may be validated or criticized. Other references are merely provided for interested readers and are not commented on. Readers are advised to read this review 1 section at a time, digest the changes that have occurred over the past year in that discipline, and then gain access to any specific studies that they may want to evaluate in greater depth.

This analysis of the scientific literature for the year 2012 is divided into 7 sections: (1) dental caries and cariology; (2) periodontics; (3) dental materials; (4) occlusion and temporomandibular disorders; (5) prosthodontics; (6) endodontics; and (7) implant dentistry. Obviously, some studies may fall into 2 or more of these groups.

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DENTAL CARIES AND CARIOLOGY

The year 2012 was a good one for written reports on dental caries. These reports indicate marked gains in the understanding of the polymicrobial nature of caries and a nascent, albeit rapidly advancing, understanding of its molecular and genetic components. The latter include the remarkable phenotypic plasticity of oral biofilms and their constituent members. Progress in prevention of the disease and its clinical signs, demineralization, and progression of carious lesions proceeded, with both traditional and molecular genetic research foci. This preventive progress is integrally tied to improving diagnostics, thus allowing clinicians the opportunity to treat the infection and any subsequent demineralization damage nonsurgically when conditions permit.

Understanding the disease

Dental caries with cavitation continues as mankind's most common disease that causes irreversible damage to the human structures.[1] The understanding of caries processes has been evolving over the past century. For more than 10 years, the nature and language of caries research has become more and more erudite as new research tools become available. In 2012 a larger portion of the research work was on "omics." These include an array of molecular microbiologic disciplines, such as genomics, metagenomics, and proteomics. These studies were augmented by metabolomics and other emerging disciplines. There has been a continuation of the emphasis on understanding the nature of both health- and disease-associated structured biofilm communities. Within this body of work there have been new findings in the continued effort to identify noncultivable microorganisms by using polymerase chain reaction (PCR)-based methods such as real-time quantitative PCR augmented by primers designed to be specific for 16S rRNA or other genes.[2,3] Additionally, there was a focus on the biofilm's interaction with the host's genome[4] and on the phenotypic expression of the biofilm's microbial constituents.[5] The interaction of the host's genotype and phenotype with the oral biofilm suggests that personalized dental medicine strategies may have an important place in the treatment and diagnosis of this disease.[6]

This year's efforts confirm that dental caries is a disease associated with "communities" of organisms that differ between caries and noncarious conditions, albeit with new levels of understanding.[7] These reports are reinforced by studies finding that the oral biofilm constituents have remarkable phenotypic plasticity.[8] That is, the genes of the microbes in the oral biofilm are expressed differently under differing environmental conditions. For example, when variations in salivary flow, pH, oxidative stress, or carbohydrate sources and frequency occur, *Streptococcus mutans* can exhibit phenotypic variability, because it has evolved a network of regulators to integrate its cellular response to environmental change.[9]

Identifying potential biofilm participants in the caries process by using next-generation sequencing (NGS) was well reviewed and is an example of how newly established and evolving technologies are helping us to understand the microbial roles in dental caries.[10] NGS is an area to watch because it is less expensive and faster than 16S rRNA cloning, does not involve cloning, and can retrieve millions of partial 16S rRNA sequences in one run. These attributes allow more researchers worldwide to participate. As an example, a previous cross-sectional NGS study in Chinese children with and without caries found 42 000 unique sequences, with the genera of *Streptococcus, Veillonella, Actinomyces, Granulicatella, Leptotrichia,* and *Thiomonas* significantly associated with dental caries.[11] The ability to handle this type of volume of data is evolving in bioinformatic software but is not complete. Interestingly, when NGS was used to compare the salivary microbiota of adults with dental caries with the microbiota of those without caries, the caries-free "healthy" microbiome was less complex or more conserved than the more variable caries microbiome.[12]

These and previous studies make it abundantly clear that dental caries is a polymicrobial disease. However, there has been less focused work on identifying which of the putative pathogens or which combination of suspected pathogens is key to the caries processes. Posing this observation as a question, one asks: Are some potential pathogens more important than others in creating and sustaining a biofilm community that produces demineralization sufficient to damage tooth structures, and if so, is this true for all members of the studied population? The answer to this question is important from prognostic, diagnostic, and therapeutic perspectives. It seems likely that there are lynchpin organisms, or combinations of organisms, that are critical to a biofilm's protective or pathologic nature. If there are key players in most diseased biofilms, then targeted therapeutics designed to eradicate or minimize specific pathogens may be a useful strategy. One group published an analysis on successfully targeting *S mutans*.[13] Knowledge gained from these types of analyses and their derived treatment strategies is rapidly evolving.

Prevention

Prevention of dental caries and subsequent demineralization and cavitation produced articles confirming previous studies in areas such as dental sealants. Preparation of a pit and fissure system to receive sealants was explored in an in vitro study that found that the use of a small round bur to prepare the fissure system produced less subsequent microleakage than did fissure cleaning with a brush, pumice slurry, air polishing, air abrasion, or longer etching times.[14] Whether microleakage per se translates to clinical performance remains questionable.[15] Sealing partially erupted teeth, where moisture control is

problematic, can be difficult. One study found that at 24 months, glass ionomer sealants and resin-based sealants both performed relatively poorly when the evaluation criterion was complete sealant retention. The resin sealants were completely retained at 40.7%, and the glass ionomer sealants at 44.4%.[16]

Fluoride varnishes continued to provide reasonable prevention of carious lesions. A school-based study of 7- to 14-year-old children found a prevented fraction (caries arrested or prevented in the treatment group compared with the control group) of 40% compared with those receiving a placebo varnish.[17] When anticaries strategies using fluoride toothpastes, rinses, and chlorhexidine were administered to adults based on their level of risk in a 2-year trial, there was a 24% reduction in caries increment, although that reduction did not reach statistical significance (P=.101).[18] There was, however, a statistically significant overall reduction in caries risk as assessed by salivary *S mutans*, lactobacilli, and salivary fluoride levels. This draws attention to the multifaceted nature of the disease and the need for continued research on the significance of purported caries risk factors.

Silver diamine fluoride (SDF) was tested for its effectiveness in arresting and preventing caries. In an RCT comparing the effectiveness of twice-per-year application of SDF to that of a flowable glass ionomer, SDF arrested 91% of treated lesions, compared with 82% for flowable glass ionomer.[19] Clinically, an attractive feature of SDF is that SDF does not have the same unintended adhesion issues as flowable glass ionomers have when applied to interproximal sites. SDF's effect on *S mutans* and *Actinomyces naeslundii* (both putative caries pathogens) in dentin-supported biofilms indicated that SDF has antimicrobial activity against both of these species in biofilms and that it retarded the demineralization of dentin.[20] A valuable review of the use of silver compounds in dentistry was published.[21] Such use includes SDF's application in root caries, where it was found to have preventive superiority to oral hygiene instruction (OHI) alone, OHI and application of 1% chlorhexidine varnish every 3 months, and OHI and sodium fluoride varnish every 3 months.[22]

Because SDF is not approved by the US Food and Drug Administration, some clinicians and researchers sought alternative ways of gaining the benefits of silver compounds by using silver-based alternatives that are not restricted.[23] This includes the use of silver nitrate, as suggested by early research giants in dental history such as G.V. Black,[24] W.D. Miller,[25] and Percy Howe.[26] Dr Howe's advocacy of silver nitrate led to the dental community naming silver nitrate solutions "Howe's solution." Dr Black established and reported a protocol for the repeated application of silver nitrate to frank caries until the caries was arrested and the remaining dentin was ebernated. Today's uses and protocols are available for review and use by individual providers of dental care.[23] The dental community awaits further well-designed prospective studies before public and payment policies for the use of these solutions will be adopted. This is problematic for the private research sector given the cost of caries trials and the potential return on investment for any commercial product. For reference, the American Dental Association's Center for Evidence-Based Dentistry provides a review of SDF's effectiveness as an arresting and preventive agent in children.[27] In virtually all caries-treatment uses of silver compounds, dentin staining is an effect that may limit their utility.

A study of caries prevention with xylitol-impregnated oral wipes found that significantly fewer infants in the xylitol-wipe group had new carious lesions at 1 year compared with the placebo-wipe group.[28]

A large multicenter study sponsored by the US National Institute of Dental and Craniofacial Research evaluated chlorhexidine in adults aged 18 to 80; it did not find that a 10% chlorhexidine diacetate coating was superior to the placebo coating for preventing new caries over the 13-month trial period.[29] This study assessed coronal caries and is consistent with previous systematic reviews of chlorhexidine in participants who are not identified as being at high risk of caries progression.[30,31] The authors concluded that similar prospective studies are needed for chlorhexidine and root caries, a context in which existing studies have found preventive efficacy.[32]

A trial examining the effect of casein phosphopeptide amorphous calcium phosphate (CPP-ACP) added to regular tooth brushing with fluoride toothpaste in children 2.5 to 3.5 years old found no significant effect in preventing caries.[33]

For patients who desire to augment caries prevention by using phytotherapeutics (herbal therapy) in the form of food components, a new review found that green tea, apples, red grape seeds, red wine, nutmeg, ajowan caraway, barley coffee, chicory, and specific mushrooms have anticaries activity. In vivo anticaries activity has been found for cranberry, glycyrrhiza root (licorice root), garlic extract, cocoa extracts, and more.[34] Many of these foods and herbal extracts have broad antimicrobial activity. Patients and clinicians should be cautioned that the quality and consistency of these products is not regulated and that the concentrations and purity of the embedded active ingredients can vary greatly.

Along with herbal therapies, probiotic strategies continue to be investigated. An excellent review of oral probiotics was reported by one group of investigators.[35] Studies involving bacterial species native to the oral biofilm, such as lactobacilli and bifidobacteria, have generally found significant reductions in *S mutans* levels.[36] These studies found a change in one of the most commonly cited risk factors for dental caries, *S mutans* levels, but have not yet validated their utility when the formation of carious lesions is the study endpoint. It is disappointing that there are not enough probiotic investigations using the development of

carious lesions as an endpoint to perform definitive reviews at this time.

The status and likelihood of a long-anticipated caries vaccine was reviewed in one article.[37] Progress is being made in incremental steps in various vaccine strategies using proteins, recombinant or synthetic peptides, protein-carbohydrate conjugates, or DNA-based active vaccines. There have been some successes in animal models, but no vaccines are yet commercially available.

Diagnostic/prognostic studies

One of the goals of diagnosing dental caries is to permit the clinician the opportunity to intervene with a strategy appropriate to the clinical and diagnostic presentation. Diagnosis includes the caries infection and the clinical signs of the infection, generally manifested as levels of demineralization. Being able to identify either the infection or early demineralization offers the best current opportunity for arresting or reversing the caries processes. Much of the work in diagnostics in 2012 was aimed at early detection of physical damage. Being able to accurately identify the depth of more extensive carious lesions provides the opportunity to treatment plan whether all caries should be removed in specific situations. This section's emphasis is on identifying and quantifying demineralization damage to teeth, with a small portion devoted to the previously explored microbiologic and "omic" techniques.

The use of laser and transillumination devices to augment visual, tactile, and radiographic data produced interesting outcomes. When examining primary molars for proximal lesions in an in vitro study, visual examination had the highest combined sensitivity and specificity.[38] This study found that transillumination with the Ti-Max P200 light (NSK Oceania Pty Ltd, Waterloo, Australia) had the highest specificity (no demineralization present when the device indicates no demineralization), whereas digital radiography had the highest sensitivity (demineralization present when the device indicates demineralization). However, the highest combined sensitivity and specificity, which are currently the most clinically relevant data, were visual examination followed by digital radiography for both enamel and dentinal lesions. When examining both occlusal and proximal caries in primary molars with a laser device or visual examination, visual examination again had the best combined sensitivity and specificity.[39] When occlusal caries in permanent teeth was the subject of examination, in a comparison among visual examination with recording in the International Caries Detection and Assessment System, a laser fluorescence pen, and a laser fluorescence camera, visual examination was the superior performer and the recommended method.[40]

In a study comparing laser detection of residual caries in prepared cavities with tactile discrimination and a caries detector dye, the laser had a higher fidelity with tactile discrimination than did the dye, whereas the dye identified more residual caries sites.[41] Although all systems may be useful adjuncts for determining when caries removal is optimal, a cost comparison between an explorer and a laser device that has the same diagnostic yield as the explorer suggests that laser systems are not the best choice for this use. The authors of this and other studies[42,43] did not identify which systems were superior at removing affected versus infected dentin.

A prognostic method that accurately discriminated those who will acquire the clinical manifestations of dental caries and those who will not would be a wonderful tool for the dental community. It would allow focusing scarce resources on those who will experience damage from the disease. There have been numerous attempts to provide such tools. A comparison of several modern prognostic systems and their strengths and weaknesses was performed in 2012.[44] As previously noted, research in prognostics is proceeding hand in hand with the work on understanding biofilms and the associated "omics."[7,12,45,46] It is clear that more work, including prospective studies, is needed.

A review of why accurate predictive systems are difficult to develop can be found in the 2012 publication of Nate Silver's book *The Signal and the Noise: Why So Many Predictions Fail—But Some Don't*.[47] This book is educational and is an entertaining read. For reference, Silver is the statistician who correctly predicted the outcomes of the 2012 US elections in all but the North Dakota senatorial race. However, the book is not a political book. Rather, it investigates how one can distinguish the true signal that is germane to what one is trying to predict from a universe of noisy data. The book includes a section on how the Oakland Athletics, a professional baseball team, famously used analytics to select players that increased team performance. The Athletics' system is an evidence-based, sabermetric approach to the selection of players (*sabermetric* refers to a measure of in-game activity derived from the Society for American Baseball Research [SABR]). This approach changed the sport. Other sections of Silver's book, on weather forecasting, stock market predictions, and poker, demonstrate methods of analysis and their strengths and weaknesses. The subject matter is directly applicable to the prediction of who will manifest the signs and symptoms of dental caries, and it will give the reader a better understanding of why this task is difficult and how one might approach the issues to improve caries-prediction/caries-risk models.

Treatment of lesions

Once demineralization has been detected, there are a number of choices on how to manage the lesions. These choices are modulated by the clinician's experience and the patient's clinical presentation. Many patients for whom demineralization has not been sufficient to cause cavitation can be treated with remineralization strategies, whereas the same lesions in a different patient may

dictate surgical invention. This section examines the 2012 work on remineralization of enamel caries and surgical interventions.

Fluoride's role in remineralization was reviewed in one article, and its value in the inhibition of caries was confirmed.[48] This publication reiterates that formation and existence of fluoroapatite only slightly reduces enamel solubility and is not a major contributor to caries inhibition. Rather, the presence of dissolved fluorides from toothpastes, rinses, and other sources contiguous to enamel promotes remineralization and inhibits demineralization. This publication is a useful refresher for updating knowledge of fluoride, providing an updated review of fluoride's mechanisms of action and its recommended uses.

CPP-ACP for augmentation of remineralization yielded mixed results. It had positive results for remineralization in a double-blind, randomized crossover study with sugar-free gum as the delivery vehicle.[49] However, CPP-ACP paste delivered daily in a school system showed no significant benefit over regular tooth brushing with a fluoride toothpaste in the prevention of dental caries in primary teeth.[33]

Restoration of lesions also prompted examination of the use of calcium phosphate. When it was applied in a restorative nanocomposite resin containing a mean nanoparticle size of 116 nm of amorphous calcium phosphate, the enamel mineral loss was approximately 3 times less around the experimental nanocomposite resin than around the control composite resin.[50] There are clear implications for recurrent caries for this type of performance if it is sustainable in the oral cavity. Recurrent or secondary caries continues to be a substantial clinical problem. In 1873 participants with a mean age of 15 years who received 4030 class II restorations, the mean failure rate after 4.6 years was 2.9% for composite resins and 1.6% for amalgams.[51] For composite resins, the most common reason for replacement was secondary caries (73.9%), followed by loss of the restoration (8.0%), fracture (5.3%), and marginal defects (2.4%).

In summary, the reported research in 2012 included steady knowledge gains in understanding dental caries as a disease and in its prevention, prediction, diagnosis, and treatment. This work provides useful insights for both clinicians and researchers that will lead to eventual control of the disease in treated populations and individuals.

PERIODONTICS

This section of the review covers pertinent articles relating to systemic relationships in periodontal diseases, periodontal soft and hard tissue regeneration, mucogingival procedures, and extraction socket healing. Use of biomaterials for bone augmentation is also reviewed.

Cardiovascular disease and periodontal disease

Periodontal disease has been associated with cardiovascular disorders and has been related to the number of a patient's remaining teeth.[52] The objective of 1 study of 1016 participants (mean age, 70 years) was to investigate whether the number of remaining teeth was related to the intima-media thickness and to atherosclerosis. Carotid artery intima-media thickness was evaluated with ultrasound. Results indicated an inverse relationship between the number of remaining teeth and the number of carotid arteries with plaque after adjustment for age, sex, smoking, body mass index, blood glucose, triglycerides, cholesterol, C-reactive protein, leukocyte count, and blood pressure. No relationship to intima-media thickness was seen.

A study reported the status of oral health in a population with coronary artery disease in Pakistan.[53] The study was conducted on 145 test individuals (cases) and 145 control participants. The control participants had an average of 14 teeth. Plaque index and gingival indices were recorded. A significant difference between cases and controls was observed in this study sample with respect to missing teeth ($P=.027$) and the periodontal parameters of plaque index and community periodontal index ($P<.001$). Prevalence of periodontal parameters was observed to be higher in cases than in controls at subgroup-level analysis (by sex and age group). Oral health was significantly associated with coronary artery disease in this study sample matched for sociodemographic characteristics.

Osteoporosis and bisphosphonates

Osteoporosis continues to be of interest when related to periodontal diseases and dental implants. How should low bone mineral density affect periodontal and dental implant treatment decisions?[54] Millions of patients are taking medications for the treatment of osteoporosis, and dental professionals should be aware of the many medications that are frequently prescribed. The most frequently prescribed drugs are the bisphosphonates. Current knowledge on the interrelationships among bisphosphonates, alveolar bone, and bone loss is inconclusive. Data relating to dental implants and bisphosphonates are inconclusive; however, patients should be informed of the possible risks of osteonecrosis.

The purpose of 1 extensive review was to discuss theories about clinical, pathological, and dental management of bisphosphonates and their relationship to osteonecrosis of the jaws.[55] Predisposing risk factors for the development of osteonecrosis of the jaws are discussed. Osteoporosis generally affects the mineral status of cortical and trabecular bone in postmenopausal women. Bisphosphonates are drugs that preserve and increase bone mass. Little is known about the side effects and dangers of the long-term use of therapeutic doses of bisphosphonates. A complication recently reported is osteonecrosis of the jaws. This review provides an update on current knowledge about clinical, pathological, and management aspects of bisphosphonate-related

osteonecrosis of the jaw (BRONJ). Little evidence exists to direct the prosthodontic management of patients with a history of bisphosphonate use. Patients with active osteonecrosis related to bisphosphonate use have reduced tissue tolerance to function with removable prostheses and decreased potential for osseointegration of dental implants. Treatment decisions should be based on clinical judgment tempered by the presenting conditions, medical profile, and patient needs. Until further evidence emerges regarding management of patients with active BRONJ, conservative prosthodontic treatment is reasonable and prudent.

There are many reports about risk factors for the development of BRONJ. In one study,[56] a case series of 14 participants with osteonecrosis of the jaws in association with bisphosphonate therapy and dental implant placement was presented, along with a detailed literature review. Nine of the individuals had underlying malignant disease, and 5 had osteoporosis. In 10 participants, implants were placed in either the posterior mandible or maxilla. The mean interval between implant insertion and disease onset was 20.9 months. Pain (n=12) and signs of infection (n=10) were the most common symptoms. Histologic signs of infection were found in 9 of 11 analyzed participants, with presence of *Actinomyces* in 6 individuals. Two participants had an infiltration of underlying malignant disease. Posteriorly placed implants seem to be at higher risk for development of osteonecrosis of the jaws.

A retrospective chart-review study compared early success rates and the crestal bone changes of dental implants in participants taking oral bisphosphonates at the time of implant placement with those of participants who had never taken bisphosphonates.[57] One hundred women with 153 implants who were taking oral bisphosphonates at the time of implant placement constituted the test group, and 100 women with 132 implants who had never taken bisphosphonates constituted the control group. There was no significant difference between groups in the success rates of dental implants at stage 2 surgery (test 93.5%, control 95.5%). The change in crestal bone height was statistically significant from the time of placement to stage 2 surgery within both groups but was not significantly different between groups. In this study, the use of oral bisphosphonates at the time of implant placement and during healing did not affect early implant success rates or crestal bone changes up to the time of stage 2 surgery.

The purpose of another study was to investigate the association between the use of oral bisphosphonate therapy and dental implant failure.[58] This case-control study involved 337 women, aged 40 years and older, who had 1181 implants placed at the Department of Periodontology and Implant Dentistry at New York University College of Dentistry between January 1997 and December 2004. Cases, defined as cases in women with one or more implant failures, were identified from the departmental database. Controls were then randomly selected for each case. Adjusted odds ratios were estimated by using logistic regression models fitted through generalized estimating equations. After adjusting for selected covariates, the odds of oral bisphosphonate use was 2.69 (95% confidence interval [CI], 1.49-4.86) times higher in women for whom implants failed compared with those for whom implants did not fail. Although no significant interaction was observed (P=.41), the stratified analyses suggest that the association between oral bisphosphonate use and dental implant failure was stronger in the maxilla than in the mandible. Findings from this study suggest that dental clinicians should be aware of the increased risk of implant failure associated with oral bisphosphonate use in the population.

Antibiotics and periodontal therapy

The purpose of an interesting meta-analysis was to assess the effectiveness of full mouth scaling and root planing with amoxicillin and metronidazole compared with scaling and root planing alone.[59] An electronic search of 8 databases and a hand search of 10 international dental journals sought articles published through September 11, 2011. Gain in clinical attachment level, reduction in probing depth, secondary outcomes, and adverse events were analyzed. The findings of the meta-analysis seem to support the effectiveness and the clinical safety of full mouth scaling and root planing together with amoxicillin and metronidazole.

Another study evaluated the effects of metronidazole and amoxicillin as an adjunctive periodontal treatment and compared the added adjunctive effect of chlorhexidine.[60] One hundred eighteen participants received scaling and root planing only or with metronidazole and amoxicillin for 14 days. Half of the participants in each group rinsed with 0.12% chlorhexidine twice a day for 2 months. The 2 antibiotic groups had lower mean number of sites with probing depth $\geq$5 mm and fewer participants exhibiting $\geq$9 of these sites at 1 year posttreatment. The chlorhexidine subgroups had a trend (P>.05) to present fewer residual sites $\geq$5 mm compared with the placebo subgroups at 1 year. Treatment of generalized chronic periodontitis is significantly improved by the adjunctive use of metronidazole plus amoxicillin and of metronidazole. It seems that the previously described antibiotic regimens have a positive influence on clinical probing depth reduction when used to treat chronic periodontitis.

Alveolar ridge preservation

The objective of 1 study was to examine the effect of alveolar ridge preservation (ARP) compared with nongrafted socket healing.[61] A systematic review with electronic and hand search was performed. RCTs, controlled clinical trials, and prospective cohort studies were eligible. Eight RCTs and 6 controlled clinical trials were identified. Average change in clinical

alveolar ridge width varied between −1.0 and −3.5 ±2.7 mm in ARP groups and between −2.5 and −4.6 ±0.3 mm in the controls, resulting in statistically significantly smaller reduction in the ARP groups in 5 out of 7 studies. Mean change in clinical alveolar ridge height varied between +1.3 ±2.0 mm and −0.7 ±1.4 mm in the ARP groups and between −0.8 ±1.6 mm and −3.6 ±1.5 mm in the controls. Height reduction in the ARP groups was statistically significantly less in 6 out of 8 studies. Histologic analysis indicated various degrees of new bone formation in both groups. Some grafts interfered with the healing. Two out of 8 studies reported significantly more trabecular bone formation in the ARP groups. No superiority of one technique for ARP could be identified; however, in certain situations guided bone regeneration was most effective. Statistically, significantly less augmentation at implant placement was needed in the ARP group in 3 out of 4 studies. Postextraction resorption of the alveolar ridge might be reduced but cannot be eliminated by ARP techniques, and at the histologic level they do not always promote new bone formation. RCTs with unassisted socket healing and implant placement in the ARP groups are needed to support clinical decision making.

A subsequent study evaluated the quality and quantity of augmented bone after alveolar ridge reconstruction with titanium mesh and autogenous particulate bone graft for implant placement.[62] Forty-one participants (50 sites) rehabilitated between September 2000 and May 2009 with autogenous particulate intraoral bone or iliac cancellous bone marrow grafts and micro-titanium meshes were enrolled. Bone defects were classified by means of shape as complex horizontal-vertical (HV), horizontal (H), and socket (S) types, and the augmented bone was evaluated based on preoperative computed tomography (CT) data. The postsurgical complications were assessed during the healing period and after implant superstructure placement. The bone defects were successfully augmented by using the titanium mesh technique. The HV-type defect was the most difficult to augment (mean horizontal gain, 3.7 ±2.0 mm; mean vertical gain, 5.4 ±3.4 mm). The mean horizontal gain with the H-type defect was 3.9 ±1.9 mm. The S-type defect achieved the most efficient bone augmentation (mean horizontal gain, 5.7 ±1.4 mm; mean vertical gain, 12.4 ±3.1 mm). The major postsurgical complications were mesh exposure, infection, total or partial bone resorption, and temporary neurologic disturbances. Implant failure was observed in one patient. The HV-type defect had significantly higher bone resorption ($P<.05$) than did the other defect types. Autogenous bone grafting with titanium mesh allows adequate vertical and horizontal alveolar bone reconstruction. However, the clinical outcome of augmentation depends on the type of preoperative bone defect.

The objective of another study was to describe a new radiographic method to map the alveolar bone remodeling after ARP procedures to compare different surgical techniques more accurately.[63] The newly developed measuring method was applied to a case series describing a specific preservation technique. The material and methods were as follows: Fourteen extraction sites (in 14 participants) located in the anterior maxilla were treated with bovine hydroxyapatite (0.25-mm to 1-mm particles) and a saddled connective tissue graft. A radiographic 3-dimensional assessment of the hard tissues was performed at baseline and at 3 months after the procedure. Standardized horizontal measurements were made at 3 coronoapical levels (−2, −5, and −9 mm) and at 3 mesiodistal levels (mesial, center, and distal) in the buccal and palatal aspects. Vertical measurements were also recorded in 9 regions superior to the alveolar crest. The horizontal dimension of the crest decreased by 1.6 mm (20%) in the cervical regions (−2 mm level); decreased moderately, by 1 mm (12%), at the −5 mm level; and decreased very little, 0.5 mm (6%), at the apical (−8 mm) level. The losses were always significantly higher in the buccal than in the palatal aspect. Buccally, the maximal bone remodeling at the cervical level remained below 1 mm. Vertical bone resorption was homogeneous and <1 mm in the 9 measured regions. This new method successfully assessed the ARP technique and can be used to measure other procedures.

Recession and mucogingival treatment

Treatment for gingival recessions offers clinicians the challenge of covering exposed root surfaces. There are multiple procedures to accomplish root coverage, and this section is devoted to exploring a few of the traditional approaches and to comparing the results of these procedures.

The aim of 1 randomized clinical trial was to evaluate the adjunctive benefit of connective tissue graft (CTG) compared with that of coronally advanced flap (CAF) for the treatment of gingival recessions.[64] Twenty-nine participants with one recession were enrolled; 15 participants were randomly assigned to CAF+CTG and 14 were assigned to CAF alone. A blinded evaluator performed all measurements. The main outcome measures included complete root coverage and recession reduction. After 6 months, CAF+CTG resulted in better outcomes in terms of complete root coverage than did CAF alone.

Periimplant plastic surgery includes soft tissue enhancement by connective tissue grafting.[65] The palatal donor site provides periimplant keratinized mucosa and soft tissue height. Platelet-rich plasma (PRP) contains growth factors that may enhance early healing. The present animal study investigated the effect of PRP on wound healing of palatal donor sites after connective tissue harvesting. In 12 mongrel dogs, bilateral palatal connective tissues of 10 × 15 mm were harvested. At the test

site, PRP was applied into the wound, and the contralateral site served as a control. The healing was evaluated clinically and histologically at 1 week, 2 weeks, and 4 weeks after surgeries. Exact binomial probability and Wilcoxon signed rank test were used to compare the clinical and histologic measurements. No statistically significant differences between PRP and control sites were measured with regard to clinical healing and histologic variables, including inflammatory cells, collagen fibers, and granulation tissue at any time interval. The addition of PRP to palatal mucosal wound sites did not accelerate wound healing.

An RCT compared 2 surgical techniques for root coverage with the acellular dermal matrix graft (ADMG) to evaluate which procedure could provide better root coverage and greater amounts of keratinized tissue.[66] Fifteen pairs of bilateral Miller class I or II gingival recessions were treated and assigned randomly to the test group, and the contralateral recessions were assigned to the control group. The ADMG was used in both groups. In the control group, the graft and flap were positioned at the level of the cementoenamel junction (CEJ), and in the test group, the graft was positioned 1 mm apical to the CEJ and the flap 1 mm coronal to the CEJ. The clinical parameters were recorded before the surgeries and after 6 months. There were statistically significant differences favoring the test group for all parameters except for the amount of keratinized tissue at 6 months.

Long-term follow-up of treated patients can provide convincing evidence for the effectiveness of one procedure over another. One study[67] reexamined 9 of the originally treated 17 participants 10 years after the initial study was reported. Results at 1 and 10 years of these 9 participants (9 test and 9 control teeth) were compared with original baseline values. At 10 years, all quantitative parameters except probing depth for both treatment protocols had statistically significant improvements from baseline. At 10 years, there were no statistically significant differences between enamel matrix derivative (EMD) + coronally advanced flap (EMD + CAF) and connective tissue graft + coronally advanced flap (CTG + CAF) for any measured parameter. The only statistically significant finding in this study was the difference in width of keratinized tissue found at 1 year (EMD, 3.00 mm; CTG, 3.89 mm; P=.031). Qualitative parameters at 10 years indicated similar stability. The only major qualitative difference was the marginal tissue contour, which was similar to adjacent tissues at EMD-treated sites but greater than adjacent tissues at all CTG sites except one. Esthetically, both EMD- and CTG-mediated treatments were similar at 10 years. Given the choice, 6 of 9 patients would choose EMD over CTG treatment to avoid a secondary harvesting procedure. This article seems to have overused statistical methods to compare samples that were perhaps too small. Given that the results were similar for both treatment groups, perhaps the results support a conclusion that equal results can be achieved without EMD. The authors are to be commended for reporting this long-term follow-up study.

An 8-year case series study evaluated the results of CAF procedures performed for the treatment of single gingival recessions.[68] Sixty participants with single maxillary gingival recessions ($\geq$2 mm), without loss of interproximal soft and hard tissue, treated with the CAF procedure and evaluated at 6 months (as reported in a previously published article), were followed up for 8 years. Complete root coverage, recession reduction, and amount of keratinized tissue (KT) were analyzed by using descriptive statistics. Three participants dropped out during the course of 8 years. Recession reduction from baseline to 8 years was 2.3 $\pm$1.1 mm. The percentage of sites with complete root coverage decreased from 55% at 6 months to 35% at 8 years. The amount of KT tended to decrease from baseline to 8 years. Recession relapse and reduction of KT occurred during the follow-up period. The baseline width of KT is a predictive factor for recession reduction when using the CAF technique.

Another study compared clinical outcomes of laterally moved, coronally advanced flap (LMCAF) versus bilaminar technique (BT) in the treatment of single gingival recession on molar teeth.[69] Fifty participants with Miller class I and II gingival recessions at first molar teeth were treated; 25 were randomly assigned to the BT group and 25 to the LMCAF group. Participant's postoperative morbidity was assessed 1 week after the surgery; the esthetic and clinical evaluations were made 1 year later. No statistically significant difference was found in terms of recession and probng pocket depth reduction. Statistically greater probability of complete root coverage (odds ratio, 22.1) and greater increase in gingival thickness were observed in the BT group. Greater increase in keratinized tissue was obtained in the LMCAF group. Patient satisfaction with esthetics was high in both treatment groups. Better postoperative course was observed in the LMCAF group, whereas reduced postoperative sensitivity and improved root coverage evaluation were found in individuals treated with BT. Gingival recession at first molar teeth can be successfully treated with LMCAF and BT. Better complete root coverage was achieved with BT, and more comfortable postoperative course was associated with the LMCAF.

Extraction socket healing

The purpose of another study was to assess whether the use of a graft, membrane, or both after tooth extraction improves healing of the site dimensionally, radiographically, or histologically.[70] Medical Literature Analysis and Retrieval System Online (MEDLINE), Embase, and the Cochrane Central Register of Controlled Trials were searched for articles published through August 2011. RCTs that included and compared healing after tooth extraction between a control group (no

intervention) and a graft and/or membrane group (test) were selected. Titles and abstracts of 2861 publications were screened. Forty-two articles were selected for full-text reading. Nine articles met the eligibility criteria and were selected for further analysis. Because of the varying graft materials used and the different methods of investigation, as well as the variation in follow-up times, a meta-analysis was not possible. This review found that clinically, there was a range in loss of width in the control sites of 2.46 mm to 4.56 mm, compared with 1.14 mm to 2.5 mm in the test sites. The range in loss of height in control sites was 0.9 mm to 3.6 mm, compared with a gain of 1.3 mm to a loss of 0.62 mm in test sites. Radiographically, a range of change in bone height of between 0.51 mm and 1.17 mm was noted in control sites, compared with a change of between 0.02 mm and 1 mm in test sites. Data are limited regarding the effectiveness of alveolar ridge preservation therapies when compared with controls. Overall the socket intervention therapies did reduce alveolar ridge dimensional changes postextraction but were unable to prevent resorption. Histology found a large proportion of residual graft material that may account for some of the difference in alveolar ridge dimensions at follow-up.

The purpose of 1 study was to describe histologically the undisturbed healing of fresh extraction sockets when compared with immediate implant placement.[71] In 8 beagle dogs, after extraction of the 3P3 and 4P4, implants were inserted into the distal sockets of the premolars, and the mesial sockets were left to heal spontaneously. Each animal provided 4 socket sites (control) and 4 implant sites (test). After 6 weeks, animals were killed and tissue blocks were prepared for ground sectioning. The relative vertical buccal bone resorption in relation to the lingual bone was similar in both test and control groups. At immediate implant sites, however, the absolute buccal bone loss observed was 2.32 mm, which may indicate that although an apical shift of both the buccal and lingual bone crests occurred at the implant sites, this may not happen in naturally healing sockets. This investigation found that after tooth extraction the buccal socket wall underwent bone resorption at both test and control sites. This resorption seemed to be more pronounced at the implant sites, although the limitations of the histologic evaluation method that was used preclude a definite conclusion.

The following study is interesting and may have practical applications. The aim of this immunohistologic investigation was to define and compare the osteogenic potential with the vascularization of the provisional matrix in grafted and ungrafted extraction sockets after 4 and 12 weeks of healing.[72] Thirty-three participants with 65 extraction sites (15 women, 18 men; mean age, 54.4 years; range, 30-73 years) participated in this study. After extraction, sockets were either augmented with Bio-Oss (Geistlich Pharma AG, Wolhusen, Switzerland) or remained nonaugmented. At implant placement after 4 or 12 weeks, bone biopsies were obtained. Within the specimens the osteogenic and endothelial potential of mesenchymal cells was analyzed in the provisional matrix by using immunohistochemical analysis with 3 monoclonal antibodies Cbfa1/Runx2, osteocalcin (OC), and CD31. Of the 65 extraction sockets, 25 (13 nonaugmented, 12 augmented) sites after 4 weeks' healing time and 40 (19 nonaugmented, 21 augmented) sites after 12 weeks' healing time were involved in the study. After 4 weeks, a median amount of 56% of Cbfa1-positive cells and a median amount of 21% of cells expressing OC were measured. A median CD31 score of 5 was observed. After 12 weeks, a median amount of 61% of positive cells expressed by Cbfa1/Runx2 staining and a median amount of 9% of OC-positive cells were measured. The results at 12 weeks revealed a median score of 3 for CD31-positive cells. Osteoblastic activity in the provisional matrix was highest after 4 weeks of healing period. The active zone of bone formation is found in the apical region of the extraction socket during the early healing phase, shifting to the coronal region after 12 weeks. A peak of osteoblastic activity within the first weeks is followed by a reduction in mature osteoblasts, with osteoblasts remaining in an inactive stage. The vascularity changed in a way similar to the maturation of osteoblasts within the observation period. With increasing age, a decreasing endothelial potential was observed not after 4 weeks but rather after 12 weeks, suggesting that angiogenesis is diminished in older patients in the later phase of healing in extraction sockets.

The objective of another study was to elucidate the socket healing process and biodegradation of incorporating synthetic bone fillers followed by grafting of the fresh extraction socket.[73] Third premolars in 4 quadrants of 8 beagle dogs were extracted and randomly treated with hydroxyapatite (HA), biphasic calcium phosphate (BCP), beta-tricalcium phosphate (beta-TCP), or no graft (C). Histologic observations and histomorphometric analysis at 3 zones (apical, middle, and coronal) of the socket were performed. Socket area (S) and the proportions of newly formed bone (%NB), residual biomaterials (%RB), and fibrovascular connective tissue (%FCT) at 2, 4, and 8 weeks were measured. The numbers of osteoclast-like multinucleated cells were also determined at the 3 zones. The %NB was significantly higher in the control group compared with the grafted groups at all healing periods. The % NB of HA and BCP increased with time, whereas %RB showed different patterns that decreased in BCP, unlike the minimal change observed in HA. The %NB of beta-TCP showed the smallest portion compared with other grafted groups at 2 and 4 weeks; however, it was significantly increased at 8 weeks. The %RB of beta-TCP was less than that of HA and BCP at all healing periods. Numbers of multinucleated cells were greater in BCP and beta-TCP, followed by HA, and they were smallest in the control group. Within the

limitations of this study, bone formation of the extraction socket was found to be delayed in the sockets grafted with synthetic bone fillers, and different healing processes were found according to the biodegradation patterns.

Another study questions the use of slowly resorbable cow bone grafts in extraction sockets. The results may have negative clinical consequences. Conflicting data exist on the outcome of placing Bio-Oss (Geistlich Pharma AG) into extraction sockets.[74] It is relevant to study whether the incorporation of Bio-Oss into extraction sockets would influence bone-healing outcome at the extraction sites. The aim of this study was to assess periimplant bone changes when implants were placed in fresh extraction sockets and the remaining defects were filled with Bio-Oss particles in the canine mandible model. Six mongrel dogs were used in the study. In 1 jaw quadrant of each animal, the fourth mandibular premolars were extracted with an elevation of the mucoperiosteal flap; implants were then placed in the fresh extraction sockets and the remaining defects were filled with Bio-Oss particles. After 4 months of healing, micro-CT at the implant sites was performed. Osseointegration was calculated as the percent of implant surface in contact with bone. In addition, bone height was measured in the periimplant bone. The results found average osseointegration to be 28.5% (range, 14.8%-34.2%). The mean crestal bone loss was 4.7 ±2.1 mm on the buccal aspect, 0.4 ±0.5 mm on the mesial aspect, 0.4 ±0.3 mm on the distal aspect, and 0.3 ±0.4 mm on the lingual aspect. The findings indicated that placement of implants and Bio-Oss particles into fresh extraction sockets resulted in significant buccal bone loss with low osseointegration.

Another study determined whether the additional application of plasma rich in growth factors (PRGF) to an extraction socket might influence the early bone deposition, as assessed by micro-CT as well as by histomorphometric markers.[75] Twenty-eight participants (age range, 34-74 years) contributing 36 extraction sockets were included in the study. Sockets were either treated with PRGF (PRGF group; 18 sites in 11 participants) or left to spontaneous healing (control group; 18 sites in 17 participants). Radiographic and histomorphometric analysis was performed on bone cores trephined from each healing socket after 4 to 6 (T1) or 7 to 10 (T2) weeks of healing. Plasma-rich protein in the PRGF group did not yield any enhancement in early (4 and 8 weeks) bone deposition compared with control group.

DENTAL MATERIALS

Restoration repair and materials used for repairs

In the dental materials literature, 2012 could be considered the year of repair and replacement. A host of articles were published that examined aspects of restoration repair ranging from the teaching practices in dental schools to patient satisfaction with repaired restorations. A series of 3 articles described the teaching of restoration repair in dental schools located in Canada, the United States, Scandinavia, the United Kingdom, and Ireland.[76-78] A combined survey was done of 67 dental schools in the United States and Canada with a response rate of 48 (72%) schools. Department chairs or senior faculty members were asked to complete an online survey including questions regarding whether repair techniques were taught, how they were taught, the indications taught for repair versus replacement, and opinions on the perceived longevity of repaired restorations. Questions were limited to the repair of resin-based restorations, and respondents were also asked to describe the techniques taught for repair. Of the 48 Canadian and US schools responding, 42 (88%) indicated that they taught the repair of resin-based restorations and 33 (69%) included both didactic and clinical teaching of repair techniques. When questioned on the evidence used to support this teaching, all 48 schools reported that the decision was based on clinical experience with repaired restorations, 34 (81%) said it was based on existing evidence, and 11 (26%) said it was based on case reports. Of the 6 schools not teaching repair techniques, 2 cited poor experience with repaired restorations, 2 cited lack of evidence, 1 cited a lack of clinical experience, and 1 did not respond. The most common consideration in deciding on repair was preservation of tooth substance (100%). The most common restoration-related failure reasons were marginal defects (100%) and marginal discoloration (90%). The most common techniques taught were mechanical roughening of the existing restoration surface (100%) followed by phosphoric acid etching (100%), adhesive bonding (100%), and hybrid composite resin repair (100%). When asked what would be considered acceptable repair longevity, 4 said less than 3 years, 10 said 3 to 5 years, and 13 said 5 to 10 years. Nearly all reported that patients were willing to accept repairs as an alternative to restoration replacement. Results from the articles describing teaching of restoration repair in Scandinavia, the United Kingdom, and Ireland were similar.

Two articles published on research coming from the Dental Practice-Based Research Network (DPBRN) described the reasons for failure of amalgam and composite resin restorations, the decision reasons for repairing or replacing these restorations, and the materials chosen for both repairs and replacements.[79,80] Both articles described prospective results from data collected on 9484 restorations from 7502 participants in 197 practices. Overall, 75% of the defective restorations were replaced and 25% were repaired. Most of the restorations repaired or replaced were amalgam (56%), and composite resin was the most frequently used repair and replacement material (56%). Composite resin was 5 times more likely to be used as the replacement material for replacing failed amalgam restorations than was amalgam to replace a defective composite resin restoration.

This change from amalgam to composite resin was most likely when the decision was to replace, the tooth was anterior to the first molars, the tooth was in the maxillary arch, and the original restoration was single surface. Secondary caries was cited as the highest reason for failure at 43% of all failed restorations, with 30% of these receiving repairs because of this diagnosis. Bulk fracture or loss was the second-highest reason for failure at 35% of all failed restorations, with 23% of these receiving repairs. Interestingly, only 1% of restorations failed owing to pain or sensitivity, and 95% of these were replaced. Other reasons for failure were discoloration (3%) and ditching (8%) of margins, patient request for change (2%), and other unspecified reasons (7%). Failed gold restorations made up a small portion of the overall (2.2%), of which more than half (55%) were repaired rather than replaced. Dentist characteristics that were significantly associated with a higher likelihood of repair over replacement included fewer years since graduation, practicing in a group practice setting, and having been the dentist that placed the original restoration. Molars were more likely to be repaired than were premolars or anterior teeth, and single-surface restorations more likely than multiple-surface ones. These studies were consistent with other published studies in that secondary caries was the most common reason for repair or replacement and in that repair was more likely with this diagnosis than with any other. The fact that more recent graduates are more likely to repair may reflect the changes in teaching previously cited in this report.

Another study reported an RCT in which margin defects on class I and II composite and amalgam restorations were sealed with a resin-based sealant (Clinpro Sealant; 3M ESPE, St Paul, Minn) and followed up for 5 years.[81] The sealed group was compared with restorations that were randomly assigned to complete replacement and with teeth that were randomly assigned to no intervention. All restoration repairs and replacements were done under rubber dam, and participants received a caries risk assessment before group assignment. Twenty-three participants with 53 amalgam and 37 composite resin restorations were assigned to one of the 3 groups. After 5 years the repair group had a significant improvement in margin adaptation but some degradation in surface roughness and margin staining. No change was evident in sensitivity or recurrent caries. The replacement group had a significant improvement in margin adaptation, a reduction in secondary caries, and no change in margin staining, roughness, or sensitivity. The no-treatment group had a significant downgrade in margin adaptation, roughness, and staining, with no changes in sensitivity or secondary caries. When groups after 5 years were compared, the sealing of defective margins resulted in similar margin adaptation to that found with replacement and a significant improvement over no treatment. Although there was some degradation of the sealant, both amalgam- and composite-resin-repaired restorations had acceptable performance over the 5-year observation period with this minimally invasive technique.

Two articles dealt with the longevity of repaired and replaced restorations, comparing performance of both the repair materials and the replacement materials.[82,83] The first was a retrospective study of large class II restorations placed in a general practice in the Netherlands. This study tracked 1202 amalgam and 747 composite resin restorations, of which 407 (293 amalgam and 114 composite resin) failed over an observation period of up to 24 years. Of the failed restorations, 161 were replaced and 246 were repaired with composite resin. Composite resin repairs were done by using acid-etch adhesive techniques. Success was defined as the restoration being in place without intervention, and survival was defined as the repaired restoration still functioning without further intervention. Of the 133 repaired amalgam restorations, 57% were due to fracture of the tooth, whereas 62% of the 113 repaired composite resin restorations were due to caries. Of these repairs, 151 (61%) were still in service after a mean observation time of 4.8 years. The most common reasons for failure of the repaired restorations were tooth fracture and caries. Restorations repaired owing to fracture had a lower survival than restorations repaired owing to caries. After 4 years, the annual failure rate for repaired amalgam restorations was 9.3%, whereas that for repaired composite resin restorations was 5.7%. Repairs of composite resins were significantly better in performance than repairs of amalgam. The overall annual failure rate for all 1202 successful amalgam restorations was 3.0% at 12 years, whereas the annual failure rate for all amalgams including those with a first repair was 2.5% at 12 years. Similarly, the annual failure rate of all successful composite resin restorations was 1.8% at 12 years, whereas the annual failure rate including repaired composite resin restorations was 0.7% at 12 years. An interesting finding was that women had a higher risk for repair failure than did men; the authors speculated that this may be due to a greater propensity to seek early care in the case of a failure. The overall conclusions were that repairs can significantly enhance longevity of both amalgam and composite resin dental restorations and that repairs made owing to caries have a better prognosis than do those made owing to tooth fracture.

The second article dealing with the longevity of repairs came from DPBRN.[83] This prospective cohort study compared the effectiveness of sealing or refinishing restorations with defective margins with that of either replacement or no treatment. The study included 50 participants with 113 defective amalgam restorations that were assigned to 1 of the 4 treatment cohorts. Repairs were made with dispersed phase amalgam or a resin-based sealant. Refinishing was done with carbide finishing burs, and all cohorts were evaluated at 1-, 2-, and 7-year recalls.

Ninety-four restorations were followed up at 7 years for margin adaptation, anatomical form, occlusal and proximal contacts, postoperative sensitivity, and secondary caries by using the US Public Health Service 3-level criteria. Failure was recorded if the tooth had been crowned or the restoration was missing at the time of recall. When prior missing or failed restorations were eliminated, 75 restorations remained, of which 34 (45%) were classified as upgrades or no change, 35 (47%) were classified as downgrades, and 6 (8%) were classified as failures. When compared with the no-treatment cohort with a 48% failure rate, the repair cohort performed significantly better and was not significantly different from the refinishing or replacement cohorts. One interesting finding was that downgrades observed at the 7-year recall generally were already present at the 1- or 2-year recalls and had remained unchanged, indicating that most repair defects happen relatively early. Another interesting finding was that restorations originally diagnosed as being defective in anatomic form or wear had a tendency to be downgraded more often than those diagnosed with ditching or margin stain, but this did not result in higher failure rates.

Another article on restoration repair examined patient satisfaction with repaired restorations placed in the DPBRN.[84] This study reported results of 5879 patient satisfaction surveys completed after restoration repairs or replacements provided by one of 179 DPBRN practices. Factors that were associated with higher satisfaction ratings were the number of years since the dentist's graduation from dental school, a patient's older age, the treating dentist having placed the original restoration, the defective restoration being repaired rather than replaced, the new material being tooth-colored rather than amalgam, and the restored tooth being a premolar or anterior tooth and not a molar.

Overall, the evidence continues to build related to the efficacy of repairing direct restorations. These data seem to support the conservative management of defective restorations and indicate that treatment with adhesive composite resin and sealant techniques can yield acceptable clinical performance and patient satisfaction. Restoration repair has been integrated into nearly all of dental education, and although some evidence supports preference for certain clinical indicators, such as secondary caries and margin staining, additional clinical criteria are needed to determine how best to guide the clinician in choosing repair over replacement or no treatment.

Adhesives

Dentistry has always lacked good long-term clinical data on the performance of dental adhesive systems. One refreshing exception to this was the publication of a 13-year clinical study comparing two 3-step adhesives used to restore noncarious class V defects.[85] Numerous authors have cited the traditional etch-and-rinse 3-step systems as being the gold standard for comparison of performance. This study compared Optibond FL (Kerr Corp, Orange, Calif) and PermaQuick (Ultradent Products Inc, South Jordan, Utah) products, both particle-filled and ethanol-based 3-step systems. The study examined differences in clinical performance between the 2 products and the influence of composite resin stiffness on the performance of the PermaQuick adhesive product. Two dentists placed restorations in pairs on noncarious cervical defects in 71 patients under rubber dam. An enamel bevel was used, and materials were all applied according to the manufacturers' instructions. The 13-year success rate was scored by 2 examiners according to restoration retention, margin integrity, margin discoloration, caries occurrence, postoperative sensitivity, and preservation of tooth vitality. Retention loss, severe margin defects or discoloration requiring restoration replacement, and caries at the margins were considered as clinical failures. The 13-year patient recall rate was 77%, and retention rates remained unchanged from the 7-year recall, being 94% for Optibond, 90% for PermaQuick with a microfill composite resin, and 85% for PermaQuick with a microhybrid composite resin. There was no statistically significant difference in retention between products or composite resin types. Margin integrity did continue to deteriorate with time, resulting in only 10% of all restorations demonstrating perfect adaptation after 13 years. It was noted, however, that most defects were small but clinically acceptable defects at the enamel margin. There were no statistically significant differences between adhesives or composite resins for margin integrity. The percentage of restorations without margin discoloration also continued to decline after 13 years, with approximately 45% of restorations being without discoloration. It was noted that most discoloration was superficial and still considered clinically acceptable, again recalling the theme that most defects were small. Fewer than 7% of restorations required replacement due to discoloration. Only 2 teeth exhibited sensitivity at the 13-year recall, and none of the restored teeth became nonvital or had caries recurrence. The clinical success rate remained nearly unchanged from year 7, being 88% for Optibond, 78% for PermaQuick with a microfill composite resin, and 74% for PermaQuick with a microhybrid composite resin. Some interesting observations were noted regarding covariates and restoration failure. It was noted that there were significantly more failures in restored teeth with wear facets, but no differences were noted in restoration size, shape, degree of dentin sclerosis, or presence of an antagonist tooth.

These results are encouraging when considered within the context of the numerous in vitro studies demonstrating limited adhesive durability. Such results continue to reinforce that laboratory methods provide little more than screening tools for evaluating these materials and that long-term clinical studies are the only valid predictors of performance. The often-investigated question of composite

resin stiffness had no influence on retention rates of restorations, even though there was a more than 2-fold difference in elastic modulus between the 2 materials tested. Margin deterioration can be expected over time and may be a property of both adhesive and composite breakdown, but most defects were still considered clinically acceptable. The fact that wear facets were associated with a higher failure rate supported the concept that functional stresses have an important role in predicting success of class V restorations.

There were several shorter clinical adhesive studies in the 2012 literature that investigated some of the later-generation adhesive systems. One 2-year, randomized, prospective trial compared the effectiveness of a 1-step self-etch adhesive with that of the previously described gold standard Optibond product. The all-in-one adhesive was Clearfil S3 Bond (Kuraray America Inc, New York, NY).[86] A total of 161 noncarious class V lesions were randomly assigned to 1 of the 2 products, and the restorations were tracked for 2 years. Results after 2 years included a rapid degradation of margin quality, with only 6.7% of the Clearfil S3 Bond and 25.3% of the Optibond restorations being defect-free. Defects included both staining and material defects at the enamel margins.

A second similar 2-year trial compared 3 different late-generation adhesives, but no differences were noted in retention rates, margin adaption, or staining at this short service time.[87] Similarly, an 18-month comparison of 2-step and 3-step etch-and-rinse adhesives to 2-step and 1-step self-etching systems resulted in comparable retention, but it was noted that staining at enamel margins was statistically worse for the 2 self-etch adhesives.[88] One meta-analysis was reported comparing self-etch to conventional etch-and-rinse systems for orthodontic bonding.[89] Five RCTs encompassing 1721 orthodontic brackets with acid-etch and 1723 brackets with self-etch techniques were compared, and a higher risk for failure with self-etch adhesives was found (odds ratio, 1.35; 95% CI, 0.99-1.83; P=.06). A small time saving of 23.2 seconds (approximately 8 minutes for full bonding) was also noted for these self-etch systems.

Overall it is encouraging to see some long-term clinical data on adhesive systems. These studies call into question many of the in vitro data related to early degradation of dentin interfaces and also reinforce that clinical trials must run much longer than 2 years to properly evaluate performance. All adhesives have degradation of margins over time, but the self-etch systems seem to result in earlier failures of enamel margins than do the etch-and-rinse systems regarded as a gold standard.

Sealants and infiltration

One noteworthy article in 2012 presented a meta-analysis on the longevity of pit and fissure sealants.[90] This analysis included 110 clinical studies with duration of 2 years or longer, and only molars with complete retention of sealant were included in the lifetime assessment. All studies used either a split-mouth or half-mouth design, and 49 studies had randomized assignment of treatment. Separate results were reported for ultraviolet-light-polymerizing, autopolymerizing, visible-light-polymerizing, fluoride-releasing-resin-based, flowable-composite-resin-based, compomer-based, and glass ionomer sealants. Retention rates were reported for 2 to 7 years on most systems, with auto-polymerizing, visible-light-polymerizing, and fluoride-releasing resin-based sealants achieving 64.7%, 83.8%, and 69.9%, respectively, at 5 years. Ultraviolet-light-polymerizing, compomer-based, and glass ionomer systems achieved 5-year retention rates of 19.3%, 3.8%, and 5.2%, respectively. This analysis clearly supports the current American Dental Association clinical recommendations for using resin-based pit and fissure sealants over glass ionomers.

Another interesting study looked at the possibility of using more moisture-tolerant glass ionomer sealants in situations in which teeth were partially erupted, thus preventing good moisture isolation.[16] This study compared 2-year retention of glass ionomer and resin-based sealants placed on the partially erupted first molars in 39 participants aged 5 through 9. GC Fuji Triage White (GC America Inc, Alsip, Ill) was compared with Delton Plus (Dentsply Professional Division, York, Pa), and teeth were chosen that had at least one-fourth to one-half of the occlusal surface still covered by the operculum. No rubber dam was used, materials were assigned by a coin toss, and untreated first molars served as the control group. Results at 24 months found no statistically significant difference in retention between the 2 materials, with 40.7% of the Delton and 44.4% of the Triage sealant completely retained. Two teeth in the resin-based sealant group experienced caries, whereas none of the teeth in the glass ionomer sealant group experienced subsequent caries, although this difference was not statistically significant. The authors' conclusion that glass ionomer sealants may be preferred because of better retention and lower caries was not supported by the data, and the relatively poor retention at 2 years indicates that neither material may be suitable for sealing of partially erupted molars. The lack of an untreated control group prevented any overall determination of treatment efficacy.

The controversial subject of sealing noncavitated occlusal caries was addressed in a 36-month RCT.[91] In this study 60 teeth with dentinal caries were randomly assigned to either a resin-based pit and fissure sealant or no treatment. Caries progression and sealant loss were monitored by clinical and radiographic examinations. Three teeth exhibited sealant loss and subsequent caries progression at 12 months, with no change at 36 months. At 24 and 36 months, the remaining sealed teeth had no additional sealant loss or caries progression, whereas progression was noted in the untreated control teeth. These results support the existing

American Dental Association recommendations for sealing noncavitated enamel lesions using resin-based sealants.

One clinical article reported 3-year results from a split-mouth, placebo-controlled RCT looking at infiltrating proximal lesions with either a low-viscosity infiltrating resin (ICON; DMG America, Englewood, NJ), a conventional adhesive (Prime & Bond NT; Dentsply Int Inc), or a placebo treatment consisting of a microbrush passed over the demineralized surface.[92] Lesion status was assessed radiographically and clinically. Participants had 3 or more teeth with lesions extending radiographically to the enamel-dentin junction or within the outer third of dentin. In all, 39 individuals with 117 qualifying lesions were included, with only 2 participants lost to follow-up after year 2. No teeth were lost to caries progression, and 3-year progression was found in 32% of infiltrated lesions, 41% of adhesive sealed lesions, and 70% of the placebo control lesions. The progression differences between the 2 treatments and placebo were significant, but there was no statistically significant difference in progression between the infiltration and adhesive treatments. Although the sealed lesions had consistently lower progression than did the controls at years 1 and 2, this difference was not significant until year 3, supporting the concept of relatively slow progression of smooth surface lesions in permanent teeth. In this study, the sealing of early lesions with either the infiltrant or adhesive seemed to be equally effective in stopping or slowing lesion progression.

Composite resin

The search for the Holy Grail of dental materials, the low-shrinkage composite resin, continued with 1 report of an interesting and remarkably practical approach. Much of the historical research into low-shrinkage resin chemistry has focused on entirely new monomer systems, in which gains in shrinkage are often offset by degradation in other properties, such as polymerization times, strength, stiffness, viscosity, and so on. Few approaches have retained the proven backbone of dimethacrylate resin chemistry that has made contemporary composite resins strong, clinically acceptable, and relatively inexpensive. One new approach reported in 2012 retains the basic dimethacrylate-based photopolymerized matrix while reducing shrinkage stress through substitution of a diluent monomer with compound capable of undergoing a phenomenon described as reversible addition-fragmentation chain transfer (RAFT).[93] This reaction constitutes the reversible breaking and reformation of a linkage within a polymer chain during the polymerization process. The result is a relaxation of stress as the polymer network breaks and reforms to accommodate the change in shrinkage volume. The reforming of the network bonds results in little or no reduction in final material properties. In this study the currently used reactive diluent triethylene glycol dimethacrylate (TEGDMA) was replaced with trithiocarbonate dimethacrylate, a reactive dimethacrylate capable of RAFT. The base resin was the commonly used bisphenol A-glycidyl methacrylate (Bis-GMA). Composite resins were formed from resins containing 70% Bis-GMA and 30% of the selected TEGDMA or RAFT diluent, 75% by weight barium glass filler, and conventional photoinitiators. Fracture toughness, elastic modulus, glass transition temperature, methacrylate conversion, and shrinkage stress were compared between the 2 composite resin materials. Methacrylate conversion was equivalent between the 2 materials at about 68%, as was fracture toughness and elastic modulus. The RAFT composite resin had a lower glass transition temperature of 155°C (vs 184°C), and most importantly, the measured shrinkage stress was 0.6 MPa for the RAFT material, compared with 1.7 MPa for the conventional TEGDMA-Bis-GMA composite resin. The reaction kinetics were slightly slower for the RAFT material, but more than 50% conversion was achieved within 2 minutes of the start of polymerization. These results indicate that a significant reduction in shrinkage stress may be achievable without sacrificing mechanical properties or the proven dimethacrylate backbone chemistry of existing dental composite resins. The present authors hope that there will be more development of this material in the future.

Two studies reported clinical results of using low-shrinkage silorane-based dental composite resins (Filtek Silorane; 3M ESPE). Unfortunately, both were 1-year results with relatively few restorations. The first study reported on 25 participants receiving 3 class I restorations, randomly assigned to either Filtek Silorane Restorative System with its corresponding adhesive, Filtek Z250 with Adper Scotchbond I adhesive (etch-and-rinse), or Filtek Z250 with Adper Scotchbond SE adhesive (self-etch).[94] Both molars and premolars were included, and the 1-year results found that the Silorane system and the Z250 used with the etch-and-rinse adhesive were statistically similar in clinical parameters, whereas the Z250 with the self-etch adhesive had increased margin staining. The authors' conclusion was that there was no clinical advantage to the Silorane system after 1 year of observations. A second study compared silorane-based composite resin to conventional dimethacrylate composite resin used as a repair material for defective composite resin restorations.[95] Class I and II restorations with occlusal defects receiving at least a Bravo rating and with no caries were included in the design and were randomly assigned to the repair control with a dimethacrylate-based composite resin (Filtek P60; 3M ESPE) with self-etching adhesive (Adper SE Plus; 3M ESPE) or to the silorane-based composite resin (Filtek P90 Low Shrink Posterior Restorative; 3M ESPE) with self-etching primer (P90 System Adhesive Self-Etch Primer and Bond; 3M ESPE). Rubber dam isolation was used for all restorations, and the main reasons for repairs were margin defects (81%) and loss of anatomic form (19%). At 1-year recall there was no statistically significant difference

between the 2 repair materials in any of 6 clinical parameters. Both of these studies indicate the limited value of short-term results in evaluating the clinical performance of composite resin materials.

One interesting study related the clinical property of composite resin wear to laboratory studies. This clinical trial in a relatively small group of 30 participants tracked the wear of a posterior composite resin restoration over 5 years.[96] All participants were evaluated by using the Leinfelder visual cast comparison method. A subset of 10 participants had cast replicates of restorations and opposing dentition occlusally mapped with a contact profilometer (University of Minnesota contact profiling system). Seven composite resin disks of the same material as the clinical restorations were also subjected to in vitro wear at varying loads and numbers of cycles with the University of Minnesota Artificial Oral Environment. The in vivo wear rates were compared with corresponding in vitro rates for both contact depth and volume loss. The results found a conversion rate that equates 1 year in vivo wear to 3×10^5 cycles in the in vitro system, with no significant differences in depths and volumes between in vivo and in vitro results when using an in vitro load of 30 N. Measurements of volume provided the most consistent results, and this study is evidence that a properly designed in vitro experiment can reasonably replicate clinical performance of composite resin wear.

The New England Children's Amalgam Trial data continue to be evaluated in every conceivable manner.[97] One article compared the psychosocial function of children receiving restorations composed of amalgam, a Bis-GMA-based composite resin, or a urethane dimethacrylate-based composite resin in that trial.[98] The results indicated that in children aged 6 to 10, Bis-GMA-based composite resin exposure was associated with poorer follow-up scores for emotional symptoms, clinical maladjustments, personal adjustment, total problem behaviors, and interpersonal relations. These associations were stronger when there were more posterior occlusal surfaces. No associations were found with exposure to the urethane dimethacrylate compomer or to amalgam. It is important to note that these are associations and not demonstrations of cause and effect. A second article reported on the physical development of these same children as it was associated with the choice of restorative materials.[99] The hypothesis that the type of restorative material would affect children's growth was not supported, as there was no significant difference in any index of growth in either boys or girls assigned to either composite resin or amalgam restorations. Children receiving more treatment with either material on primary teeth had a greater increase in percentage of body fat, and girls assigned to composite resin had a lower rate of menarche during the 5 years of follow-up. A third study from this same population looked at the neuropsychological development in children exposed to composite resin and amalgam restorations.[100] A battery of neuropsychological tests were conducted at 4- to 5-year follow-up examinations, resulting in slightly poorer performances in tests of intelligence, achievement, and memory in the composite resin cohort, but there were no statistically significant associations between any primary measure and either restorative option. It was noted, however, that amalgam was generally associated with improved scores.

A study published in 2012 reported on the clinical exposure to bisphenol A (BPA) after placement of composite resin restorations.[101] This study measured both salivary and urinary concentrations of BPA and several other resin compounds before and at several time points after placement of 264 restorations in 171 participants. The preplacement presence of detectable levels of BPA occurred in less than 10% of participant saliva specimens and in 50% to 60% of participant urine specimens. Participants had an average of 2.6 existing pretreatment composite resin restorations, and there were no associations between the number of existing restorations, restoration location, or restored surface counts and BPA or any of the other study compounds in urine or saliva levels. This indicated that there was no detectable long-term exposure to any of the composite resin study compounds from existing restorations. For newly placed restorations, increases in salivary concentrations of 4 of the 6 study compounds were detected within the first hour, but only 2 compounds, bisphenol A bis(2,3-hydroxyphenyl)ether (BPAHPE) and Bis-GMA, remained detectable at 1 to 8 hours after restoration placement. By 8 to 30 hours after placement, only BPAHPE had a small but significant increase from baseline. Urinary concentrations of 5 of the 6 study compounds were increased within 1 hour of restoration placement. By 8 to 30 hours after placement, only BPA had a small but significant increase over the baseline urinary level. Use of a rubber dam reduced salivary levels of several compounds, but it did not affect the urinary levels. This indicated that a rubber dam would decrease short-term exposure but not the long-term absorption of these compounds. The overall results indicate that placement of composite resin is associated with transient exposure to low levels of BPA and other compounds. The elimination of these compounds from saliva and urine is rapid, with only a small increase in BPA being detectable in urine after 8 to 30 hours.

One larger clinical assessment of reasons for placement and replacement of composite resin restorations was reported from a study population of 2480 participants within a private practice.[102] A total of 3528 restorations were reported, of which 58% were first-time restorations and 42% were replacement restorations. The most common reason for placing first-time composite resin restorations was primary caries (56%), and the most common reason for replacing composite resin restorations was secondary caries (43%). These results are consistent with those of previous reports, and one interesting aspect of this study was that the median longevity for those

restorations requiring replacement was approximately 4 years.

Amalgam

One meta-analysis compared the clinical effectiveness of amalgam versus composite resin in class II restorations.[103] This analysis included only prospective trials of 2 or more years' duration with a minimum of 20 restorations at the latest recall. There were 59 studies that met all the inclusion criteria; however, most of the reported results were related to the performance of different composite resin systems. Overall, the clinical success rate for both amalgam and composite resin restorations was approximately 90% after 10 years, and there was no statistically significant difference between the 2 types of materials. It was noted, however, that restorations with either hybrid or microfilled composite resin in combination with an enamel-etching technique and a rubber dam had the best longevity, which was comparable to that of amalgam.

The most common adverse reaction to dental amalgam is the development of oral lichenoid reactions/lesions (OLLs), and a good review article examined the diagnosis of, recommendations for, and resolution of these lesions.[104] OLLs represent a type IV delayed hypersensitivity reaction that in the case of amalgam can take months to years before it expresses. Because OLLs are considered a contact allergy, diagnosis is usually made by physical appearance of white lichenoid-like lesions taken together with physical approximation to an amalgam restoration. Patch testing can be done to identify individuals with suspected hypersensitivity, but it should be limited to patients expressing oral mucosal lesions, such as lichen planus or treatment-resistant mucositis, and the lesions should be anatomically associated with the amalgam restorations. The tests are not 100% accurate; false positives occur because approximately 3.2% of the general population reacts to skin tests for mercury antigens although true allergy to amalgam is far less. The definitive diagnosis can be made only if the OLL resolves after the offending amalgam restoration is removed. Lesions resolve quickly once the restorations have been replaced with an alternative material.

Another article looked at the quality of life and symptoms in Swedish participants reporting problems related to dental amalgam.[105] A survey was done to determine any changes in health-related quality of life and continued symptoms in a group of 515 participants that had previously removed all their amalgam restorations to resolve their self-perceived subjective health impairments. In spite of having these restorations removed, this population still had a quality of life significantly lower than that of the general population, indicating that replacement alone was not sufficient to improve their health.

Another article reported the dose-dependent relationship between exposure to dental amalgam and urinary mercury levels in the Casa Pia Children's Dental Amalgam Trial,[106] even though these same results were previously reported by the original study authors.

The 3 articles associated with the New England Children's Amalgam Trial that found no association between amalgam and neuropsychological or physical growth development were reported in the section on composite materials.[98-100] Another article reported on prenatal exposure to dental amalgam and its association with neurodevelopmental outcomes in the Seychelles Child Development Study.[107] This study prospectively looked at 300 pregnant women to compare the number of amalgam surfaces present during gestation to the child's mental and psychomotor development. It found that the number of amalgam surfaces was not significantly associated with either mental or psychomotor outcomes. A secondary analysis associating the number of occlusal contact points with mental development measures was suggestive of a reduction in girls at 9 months, but this association was not present at a subsequent evaluation at 30 months. The overall conclusion was that there was no evidence of association between a mother's amalgam surfaces and the child's neurodevelopment.

Mineral trioxide aggregate

Mineral trioxide aggregate (MTA) continues to be studied for various indications including endodontic perforation repairs. One article compared MTA and calcium hydroxide for the apexification of traumatized young permanent incisors.[108] Both materials resulted in formation of an apical barrier, but the time to formation was 4.5 months for MTA versus 7.9 months for the calcium hydroxide. Other than more rapid formation, it was noted that final obturation could be completed earlier with the MTA apexification, but it was not clear if either of these factors had any effect on the tooth survival. One short (12-month) study looking at apical fillings compared MTA to ethoxybenzoic acid (EBA). The materials were equally successful at 12 months, with success rates of 95.6% for MTA and 93.1% for EBA.[109] A longer 5-year assessment of apical root-end fillings compared the same 2 materials.[110] Overall success had dropped to 75.9% at year 5, compared with 83.8% at year 1. The MTA success rate was 86.4% versus 67.3% for the EBA, which was significantly different with an odds ratio of 7.65 (CI, 2.60-25.27). The other factor improving success was a distance of less than 3 mm between the bone level and the cementoenamel junction. MTA was also studied as a vital pulpotomy material in primary molars.[111] A total of 93 children with at least 1 symptom-free restorable and vital primary molar were assigned to either MTA or ferric sulfate pulpotomies and followed up for 12 months. There was no difference in clinical or radiographic success rates between the 2 materials.

Material choices

Several articles published in late 2011 and 2012 relate to the decisions

that clinicians and patients make in choosing a restorative material. The DPBRN published 2 in 2011 that examined the decision made when doing a first restoration on a posterior tooth and the choice of materials for restoring noncarious tooth defects. These are included to round out the entire discussion on material choices, even though they were published in 2011. A study of posterior restorations (molars and premolars) surveyed 182 clinicians placing 5599 posterior restorations on teeth with primary caries.[112] A large variety of tooth, patient, provider, and practice-type characteristics were analyzed to determine how they affected the choice of amalgam and composite resin materials. The highest amalgam use was found in 2 health maintenance organizations (78% and 76%), and the lowest amalgam use was found in private-practice clinicians in the Florida and Georgia area (27%). Male dentists placed a nearly equal number of amalgam and composite resin restorations, whereas female dentists placed 67% amalgam restorations. Older dentists also tended to place more composite resin restorations than did more recent graduates. Male patients were more likely to receive amalgam restorations (59%), and although white and black patients received a nearly equal proportion of amalgam and composite resin, 73% of restoration in patients identifying with other ethnicity (American Indian, Alaskan Native, Asian, Pacific Islander) were amalgam. Insured patients were also more likely to receive amalgam restorations (56%). More than half of the restorations placed in molars and premolars (54%) and 57% of the multiple surface restorations were amalgam. The greater the preoperative estimate of lesion depth was, the more likely it was restored with amalgam. On average, more composite resin restorations were placed in younger patients than in older patients. Only a small percentage (3%) of patients received both amalgam and composite resin restorations. The overall conclusion was that there are many different practice, patient, and lesion characteristics that govern the decision on what material is chosen for restoring primary caries, but amalgam is still a widely practiced choice.

The second DPBRN study examined the choice of materials for restoring noncarious tooth defects.[113] This study collected data from 178 clinicians regarding the placement of 1301 restorations on noncarious defects. No specific criteria were outlined for decisions on when to restore these defects, and dentists based this decision on their own beliefs and experience. Of the restorations placed, 46% were owing to attrition, abfraction, or erosion (AAE), 31% were owing to tooth fracture, 7% were for cosmetic reasons, and 16% were owing to all other reasons. AAE and tooth fracture were the primary reasons for placement in older patients, whereas patients younger than 20 years received restorations mainly for "other" reasons. The majority of amalgam restorations were placed owing to tooth fracture (75% of amalgam restorations), and composite resin was used mostly to restore AAE lesions (54% of all composite resin restorations). Most glass ionomer or resin-improved glass ionomer restorations were placed because of AAE (67% of ionomer restorations). Composite resin was the material of choice for restoring AAE (94% of all AAE lesions), with only 4% being restored with glass ionomers.

Another practice-based network study from the Northwest Practice-Based Research Collaborative in Evidence-Based Dentistry (Northwest PRECEDENT) looked at 1943 randomly assessed participants to see if caries location was associated with the choice of treatment provided.[114] Of the participants selected, 55.4% exhibited recent caries, and 42.8% received treatment in at least 1 permanent tooth. The odds of a molar lesion receiving an amalgam restoration were 2.44 (95% CI, 1.81-3.30) when compared with a premolar. If the restoration included only the occlusal surface, the odds were 0.42 that amalgam would be used, versus 2.49 if the restoration included a mesial or distal surface. This indicates that both tooth location and lesion size play important roles in material choice for restorations.

The question of material choice was also addressed by a study from the United Kingdom, where 662 clinicians were interviewed by questionnaire on their use of different restorative options.[115] Amalgam was the most commonly used material for occlusal-proximal restorations of both molars (75%) and premolars (59%). Deciduous molars were mostly restored with glass ionomers (81%), and glass ionomer cement was the predominant luting material at 67%. Only 18% of respondents reported using a rubber dam for restorative procedures.

OCCLUSION AND TEMPOROMANDIBULAR DISORDERS

As the foundation of the occlusion, the temporomandibular joint (TMJ) continued to generate interest in the literature in 2012. When evaluating the literature on temporomandibular disorders (TMDs), one must keep in mind that it has some shortcomings regarding the amount of knowledge on treatment effectiveness at the individual level, given that studies are often performed on unspecific populations identified by the umbrella term *TMD* or, on the contrary, on unrepresentative samples of selected participants, thus limiting the external validity of the findings.[116] As a result, each clinician has to critically evaluate published articles to recognize these common flaws and to realize that treatment outcomes may vary depending on the condition of both the TMJ and the teeth in each individual patient.

There were several articles published in 2012 related to the anatomy of the TMJ and associated structures. One study evaluated the correlation between disk displacements and degenerative bone changes of the TMJ with magnetic resonance imaging (MRI).[117] The aim of this study was to evaluate correlation between disk displacements and degenerative bone changes and MRI images

(MRIs) of 112 participants of both sexes with signs and symptoms of TMDs. For this purpose, a calibrated examiner evaluated 224 MRIs. Disk displacement was found in 58.43% of the TMJs evaluated. Anterior displacement of the disk with reduction was most common, occurring in 67.18% of joints with disk displacement. Degenerative bone changes were observed in 53.94% of the TMJs analyzed. There was significant correlation between disk displacement with reduction and condylar flattening, between disk displacement without reduction and condylar flattening, and between disk displacement without reduction and associated degenerative bone changes (flattening and erosion, flattening, osteophyte and erosion, flattening, and osteophytes, erosion and sclerosis, flattening and sclerosis, flattening, osteophytes, and flattening and osteophytes). The correlation between advanced disk displacement and the occurrence of degenerative bone changes emphasizes the importance of MRIs for accurate diagnosis and for development of an appropriate treatment plan. TMJ imaging should only be performed after thorough physical examination indicates that more information is needed.

Research into the causes and treatment of TMDs must be based on reliable and valid diagnostic criteria. Imaging the TMJ is one step of the diagnostic sequence in addition to clinical findings. The goals of TMJ imaging are to evaluate the integrity of the structures when disorders are suspected, to confirm the extent and age of progression of disorders, and to evaluate the effects of treatment. To achieve these goals, the assessment of the TMJs should involve both the hard and soft tissues. In some patients, it may be necessary to obtain images of the joint to evaluate the true position of the disk, because the stage of internal derangement at the beginning of the treatment influences the success of the treatment.

One article discussed patients with facial pain and jaw function problems who constitute a large and heterogeneous group.[118] Disk displacement and osteoarthritis are the most common intra-articular abnormalities observed at imaging. As disk displacement is seen frequently in asymptomatic volunteers, it is a challenge to explain why disk displacement sometimes is symptomatic and sometimes is not. This article focuses on abnormalities in the condylar bone marrow and the intra-articular soft tissues accompanying the disk displacement. The findings of the TMJ in asymptomatic volunteers and in participants with TMDs were reviewed. Both bone marrow edema and marrow necrosis were documented with histology and with MRI in participants with TMDs. Intra-articular soft tissue changes, such as synovitis, were additionally documented at arthroscopy. However, there is a controversy concerning which diagnostic imaging information is essential. Although there is no doubt that disk displacement and osteoarthritis may be accompanied by inflammatory alterations in the bone marrow and the intra-articular soft tissues, it has been difficult to consistently relate a specific imaging manifestation (bone edema, joint effusion, and synovitis) to TMJ pain. Longitudinal studies are needed to evaluate the importance of MRI abnormalities in the management of patients with TMDs.

Another article explored the relationship between general joint hypermobility and displacement of the TMJ as evident from MRI.[119] Fifth finger extension and apposition, elbow extension, knee extension, trunk flexion, and ankle dorsiflexion were measured in 66 young female participants with MRI-evidenced TMJ internal derangement and in 30 age-matched female control participants. The Beighton score of each participant was measured to quantify the mobility. The possible association between TMJ internal derangements and the mobility of the single joint were assessed with 1-way ANOVA with Bonferroni correction and χ^2, respectively. A correlation of the mobility of every measured joint was also explored.

Few of the TMJ-internal-derangement-group participants and control participants were diagnosed with general joint hypermobility according to the Beighton score. The Beighton score did not differentiate between participants with and without TMJ internal derangements. The participants with TMJ internal derangement, especially those with MRI-evidenced disk displacement without reduction, seemed to have a stiffer trunk than did control participants, but this may not be of clinically significant relevance. Based on the Beighton score, general joint hypermobility does not seem to be a reliable indicator of the likelihood of TMJ internal derangements. Of note in the MRI findings was that of the 66 participants with TMJ internal derangement, 50 had a disk displacement without reduction and 16 had a disk displacement with reduction.

Two articles discussed the lateral pterygoid muscle. The first provided an update on some aspects of the normal function of the lateral pterygoid muscle and its response to alteration, including mandibular advancement and occlusive changes.[120] A number of recent studies have carried out recordings of joint movement and electromyographic (EMG) activity in the lateral pterygoid muscle, where verification of electrode location has been achieved with CT imaging. In these studies, there is no evidence of background EMG activity within the inferior head of the lateral pterygoid (IHLP) or the superior head of the lateral pterygoid (SHLP) when the jaw is in the clinically determined postural jaw position. There is little evidence or reciprocal reaction in the activity between the SHLP and IHLP, and both SHLP and IHLP play an important role in contralateral, protrusive, and jaw opening movements. There is evidence for independent activation of subcompartments within the lateral pterygoid muscle to allow a range of force factors to be delivered to the condyle. In terms of role of the lateral pterygoid muscle in mandibular advancement and occlusal changes, the lack of studies of these issues, with verified recordings that have been made in the lateral pterygoid muscle, means there is no definitive evidence in

humans for the "lateral pterygoid hypothesis," and there is also little reliable information as to the effect of occlusal variables on the activity of the lateral pterygoid muscle. There is also little information on pain and lateral pterygoid muscle activity, although more recent studies found that the pattern of pain induced changes in the lateral pterygoid muscle. EMG activity is not clear-cut but can vary with the task performed and jaw displacement magnitude.

The second article about the lateral pterygoid muscle evaluated the correlation between the lateral pterygoid muscle attachment type and internal derangement of the TMJ, with an emphasis on MRI findings.[121] Disk displacement is accepted as one of the major findings in TMDs. Correlation between the type of lateral pterygoid muscle attachment to the disk-condyle complex and TMJ dysfunction has rarely been discussed and is not yet clear. The purpose of this study was to assess the prevalence of the types of lateral pterygoid muscle attachment to the disk-condyle complex and to investigate whether these attachment types are linked to MRI findings of internal derangements and TMJ dysfunction in a Turkish population. Ninety-eight TMJs in 49 participants (32 men, 17 women; mean age, 36 years) with TMJ clicking, TMJ locking, restricted movement of the jaw, or pain in the TMJ region were included. According to the clinical findings and data observed from MRI examinations, lateral pterygoid attachments to the condyle-disk complex were categorized into 3 types. Correlation between TMJ dysfunction and type of attachment was evaluated. Of 98 TMJs in 49 participants, 47 TMJs (48%) were evaluated as normal, 35 (35.7%) had a disk displacement with reduction, and 16 (16.3%) had a disk displacement without reduction. Arthritis was seen in 49 TMJs (50%). Lateral pterygoid attachments to the condyle-disk complex were as follows. Type I attachment, in which the fibers of the superior head of the lateral pterygoid were attached to the disk, and those of the inferior head of the lateral pterygoid were attached to the condyle, occurred in 29.6% of the TMJs. Type II attachment, in which the fibers of the lateral head of the lateral pterygoid were attached to the condyle and disk, and the fibers of the inferior head of the lateral pterygoid were attached to the condyle, occurred in 40.8% of the TMJs. Type III attachment, in which the fibers of the superior head of the lateral pterygoid were attached to the disk, and the fibers of the middle part of the lateral pterygoid muscle and of its inferior head were attached to the condyle, occurred in 29.6% of the TMJs. There was no statistically significant difference between the type of muscle attachment and the presence or absence of disk displacement, disk degeneration, or articular surface degeneration.

Whereas several articles examined the anatomy of the system, many articles were written regarding the etiology of TMJ disorders. One group of investigators discussed the hyperdivergent facial profile and how it presents to the orthodontist, the oral surgeon, and the restorative dentist.[122] The authors suggested that in women, there is a strong correlation between the disorder and patients' presenting with TMJ pain and severe mandibular retrognathia. Clinicians should be aware of these findings and should convey this information to patients presenting for dental treatments. The first of the 3 main points was that disk derangements, with or without pain, could affect facial growth and the development of TMDs. Second, animal studies that were previously presented have strongly suggested that the surgical creation of disk derangement can affect the growth and development of several cranial facial structures, including the cranial face, midface, and mandible. Third, disk derangements in children suggest that they are at risk to have at least altered mandibular growth with possible development of retrognathia and an increased lower facial height. Recent studies have suggested a strong relationship between TMDs and severe retrognathia.

In another article, the available evidence was found to indicate that the influence of occlusion on the genesis and development of TMDs is low.[123] It is important to understand that morphologic changes of the TMJs can influence occlusion determinants, including anterior open occlusal relationship, large sinusoidal shifts from a seated joint position to maximum intercuspation, large horizontal overlap, and midline discrepancies. Clinicians may mistakenly perceive that the malocclusion of the teeth caused the TMD, when in fact the TMD caused the malocclusion of the teeth.

Another article discussing sleep bruxism states that many dentists believe that sleep bruxism is the pathogenic factor in myofascial TMDs, but almost all supportive data rely on the participants' self-reports rather than on direct observation.[124] The authors administered a structured self-report interview to determine whether a large and well-characterized sample of participants with myofascial TMDs (124 women) experienced sleep bruxism more often than did matched control participants (46 women). The authors then used data from a 2-night laboratory-based polysomnographic study to determine whether the case participants exhibited more sleep bruxism than the control participants. The independent *t* test found that although self-reported rates of sleep bruxism were significantly higher in case participants (55.3%) than in control participants (15.2%), polysomnograph-based measures showed much lower and statistically similar rates of sleep bruxism in the 2 groups (9.7% and 10.9%, respectively). Grinding noises were common in both case participants (59.7%) and control participants (78.3%). Most case participants did not exhibit sleep bruxism, and the common belief that sleep bruxism is sufficient explanation for myofascial TMDs should be abandoned. Although other reasons to consider treating sleep bruxism may exist, misplaced concerns about sleep bruxism sustaining or exacerbating a chronic myofascial TMD should not be used to justify sleep bruxism treatment.

A systematic review of the literature was conducted to find available

evidence that might answer the question of whether hypoxia-reperfusion injury plays a role in the pathogenesis of joint diseases in general and of osteoarthritis (OA) of the TMJ in particular.[125] Four studies meeting the inclusion criteria investigated 4 aspects of the hypoxia-reperfusion mechanism of joints. All of the studies investigated several arthritides in the knee or shoulder joint and were observational studies, except for 1 section of 1 of the studies, which was an RCT. These studies do not provide any evidence to support or reject the hypothesis that hypoxia-reperfusion occurs in TMJ OA. Positive but weak evidence is provided to support the hypothesis that hypoxia-reperfusion injury occurs in OA of the knee joint. Furthermore, some results of these included studies suggest differences between OA and the other types of arthritis in relation to the hypoxia-reperfusion mechanism.

One useful article provided a guide to help clinicians develop critical appraisal skills for the challenging task of translating research into clinical practice.[126] Reviews are designed to search for, analyze, synthesize, and interpret all of the available evidence that may answer specific clinical questions. But traditional literature reviews are susceptible to bias in terms of the information that is included and how it is interpreted. Systematic reviews have been appearing in the dental literature for the past 20 years, and now as many as 50 are published each month. Because the evidence for any given clinical question may change, systematic reviews are perishable, with a useful lifespan of no more than 2 or 3 years. It is also important to understand that systematic reviews can only review information that has been published. Each clinician must be responsible for determining which clinical procedures offer the best options for treatment. Given the problems with the literature in the TMD/occlusion field, as mentioned at the beginning of this section, it is important to understand that systematic reviews often are reviewing studies that are poorly designed. Clinicians need to understand that this limits the value that the literature can have in determining which treatment options are best for any particular patient. Relatedly, those who contribute to the literature have a responsibility to use rigorous study design and to make sure that what they publish truly adds value to the evidence base.

One well-written article discussed the importance of accurate diagnosis in TMDs.[127] The article stresses the importance of exclusion of malignant tumors as the cause of a TMD; misdiagnosis can occur when a clinician assesses intra-articular or musculoligamental dysfunction without considering malignant tumors as a cause of such complaints. The patient with primary or secondary tumors may present with symptoms simulating those of TMDs and therefore is treated similarly. Neoplastic lesions as a cause of symptoms suggesting TMDs are rare but are well documented in the literature. The most frequent malignant tumors are maxillofacial squamous cell carcinomas and primary nasopharyngeal tumors. Other tumors, such as parotid gland malignant tumors, synovial cell sarcoma, and metastatic tumors have also been reported. A detailed ear, nose, oral, and neurologic evaluation must be performed whenever persistence or worsening of TMD symptoms occur.

Investigators attempted to answer the perennial questions regarding the etiology of noncarious cervical lesions (NCCLs).[128] NCCLs are frequent challenges given the variety of opinions regarding their etiology, diagnosis, and treatment. The purpose of this study was to assess potential relationships between occlusal forces and the occurrence of NCCLs. The particular population consisted of 111 volunteers (30 men and 81 women; mean age, 23.6 years). General personal information was recorded, after which the participants were examined for the presence and location of NCCLs. Gingival recession, fracture line, dental and restorative fractions, presence and location of tooth wear, type of occlusal-guidance scheme in lateral mandibular movements, and existence of occlusal interference (interceptive occlusal contact) were reviewed. The participants were divided according to the presence or absence of NCCLs.

A significant association was found between the presence of NCCLs and age ($P=.008$), gingival recession ($P<.001$), occlusive trauma ($P<.001$), presence ($P<.001$) and location of tooth wear, and group function as occlusal-guidance scheme in lateral excursive movements ($P<.001$). A strong relationship between the presence of NCCLs and the occlusal overload was found. The majority of teeth affected by NCCLs in group function guides in lateral mandibular movements. It has been found that maxillary teeth are most affected by NCCLs, with the greatest number on the buccal surface, although NCCLs also can be located on the lingual surface. The highest concentration of NCCLs was found in first premolars (21.6%), which confirms findings in other studies. This is probably because the premolar possesses less capability than do canines to absorb the lateral weak forces that occur during lateral movements guided by group function. When lateral movements are guided by group function and an increased number of occlusal contacts between the posterior teeth are made, the teeth are also subjected to greater force. This makes the posterior teeth, particularly in women, more susceptible to dental tissue loss in the cervical region.

An interesting article assessed the subjective symptoms of TMDs in 167 young participants.[129] There were 119 girls in the study and 48 boys, with an average age of 14.6 years. The participants used self-reporting forms, with 5 ratings for pain intensity and 6 ratings for difficulty in activities of daily living, to compare TMD symptoms according to sex and 3 age groups. Group 1 comprised 6- to 12-year-olds; group 2 comprised 13- to 15-year-olds; and group 3 comprised 16- to 18-year-olds. No significant sex differences were found in the symptoms among the groups, except for headache and neck pain in group 3 (16- to 18-year-olds).

Late-adolescent participants (those 16 to 18 years old) with TMDs had higher pain intensity in the orofacial region and greater difficulty in the activities of daily living than did the early-adolescent and juvenile participants with TMDs.

Moving to diagnosis, the review turns to an article that addressed TMJ alterations and their orofacial complications in patients with juvenile idiopathic arthritis.[130] Patients with juvenile idiopathic arthritis can have alterations in bone metabolism and skeletal growth, as well as damage to the TMJ. Damage to the TMJ can generate extraoral and intraoral alterations, resulting in craniofacial disorders. Alterations in mandibular growth, caused by dysfunctions in the temporomandibular region, seem highly prevalent in these patients. The alterations most often found are retrognathia, micrognathia, anterior open occlusal relationships, dental crowding, facial asymmetry, and mild opening limitations. Therefore, the rheumatologist becomes a key agent in the early detection of disorders, helping with patient referral to a dentist. TMJ disorders should be treated by a multidisciplinary team, and treatment should include pharmacologic treatment for pain control and dental care through functional appliance, as well as orthodontic therapy, physical therapy, and sometimes speech therapy.

One study evaluated participants with deep vertical overlap.[131] Deep vertical overlaps are a common malocclusion in an orthodontic practice. Severe deep vertical overlaps, those with vertical overlaps of at least 5 mm, were found in nearly 20% of children and 13% of adults in this study, representing about 95% of vertical occlusal problems. Deep vertical overlap malocclusion overlies a multitude of hidden skeletal and dental discrepancies. Accordingly, a deep vertical overlap should not be approached as a disease identity; rather, it is a clinical manifestation of an underlying skeletal or dental discrepancy. Dental and skeletal measurements were made on lateral cephalometric radiographs and diagnostic casts of 124 participants with deep vertical overlaps. These measurements were statistically analyzed. The gonial angle was the highest contributing skeletal factor to a deep vertical overlap, confirming the importance of ramus angulation in a developing deep vertical overlap. A deep curve of Spee was the highest contributing dental factor, confirming the importance of including mandibular incisors in deep vertical overlap treatment. Overeruption of the maxillary incisors was the second-highest contributing dental component. A thorough analysis of all deep vertical overlap components reduces the clinician's bias toward predetermined mechanics in treating these patients, and it allows for more individualized treatment planning and mechanotherapy.

It is important to realize when reviewing this study that a decrease in ramus length is common with dimensional loss in the TMJ. It is prudent in deep vertical overlap malocclusions to evaluate the vertical dimension of the joint, including the soft tissue dimension of the disk and the hard tissue dimension of the condyle, to determine if there have been changes in the vertical dimension from the top of the joint socket to the angle of the mandible.

Another article discussed the distribution of TMJ vibration transfer to the opposite side.[132] A vibration is produced when a displaced temporomandibular disk reduces during opening. The vibration can transfer some of its energy from the ipsilateral joint to the contralateral joint. The objective of this study was to determine what percentage of the ipsilateral vibration is transferred to the contralateral joint. The study included the TMJ vibrations of 144 participants (113 women, 31 men) with reducing displaced disks. Vibrations from 165 joints were recorded bilaterally, and joint vibration analysis was performed. In each situation, any contralateral vibration was analyzed to verify whether it was caused by the ipsilateral joint. The contralateral amplitude was divided by the ipsilateral amplitude and multiplied by 100 to produce a percentage of transfer. The percentage values were used to create a relative frequency histogram with 20 classes (1%-5%, 6%-10%, 11%-15%, and so on). The relative frequency histogram graph revealed a 3-mounded distribution of the percentage of transfer. One mound fell between 5% and 34%, one between 35% and 69%, and the third between 70% and 98%. The appearance of a 3-mounded distribution suggests that there may be 3 different failure modes leading to TMJ internal derangements. Alternatively, it may be that failure of the disk's stabilizing ligaments leads to 3 different internal derangement conditions. The evidence of apparent trimodality in this vibration data distribution suggests that there may be 3 different failure modes of disk displacement with reduction (that is, anterior, anteromedial, and mediolateral disk displacement). If so, identifying them could allow for a more detailed description of disk displacement with reduction.

Historically, the TMJ was heard with a stethoscope, Doppler auscultation, and joint vibration analysis. The purpose of listening to the joint with any of these methods is to try to gain an understanding of the anatomy based on the friction that is generated as the condyle functions against the disk, the retrodiskal tissue, or the eminence. It is not possible to definitively diagnose the condition of the joint through listening to the joint with a stethoscope, Doppler auscultation, or joint vibration analysis. It is possible to definitively diagnose the condition of the joint by using TMJ imaging, including MRI and cone-beam computed tomography (CBCT).

One group of investigators attempted to determine if TMDs and tinnitus are associated.[133] The study aimed to determine the prevalence of TMDs in participants with subjective tinnitus, as compared with controls, and the association between symptoms of TMDs, tinnitus, and chronic pain. Two hundred participants were divided into 2 groups, according to the presence (experimental group) or not (control group) of subjective tinnitus. The pain pressure threshold values of the masseter and

temporalis muscles were recorded bilaterally, and a visual analog scale (VAS) was use to address subjective pain. The most prevalent TMD subgroups in the tinnitus participants ($P<.05$) were myofascial pain with limited opening (39.0%), disk displacement with reduction (44.33%), and arthralgia (53.54%). The severity of tinnitus was significantly associated with the severity of chronic pain ($P<.001$). The pain pressure threshold values were lower ($P>.05$), whereas the VAS values were statistically higher ($P<.001$) for the tinnitus participants. These data suggest that an association exists between TMDs and subjective tinnitus.

One article discussed the concurrency of temporal tendinitis with TMDs.[134] Patients with TMDs often have multiple pain issues. Common complaints are headaches and jaw, ear, and facial pain. TMD has been called a great impostor, because it shares many symptoms with other disorders. TMD symptoms can arise from intracapsular or extracapsular origins. One of these extracapsular disorders is temporal tendinitis, which has the ability to mimic TMJ pain. The pathophysiology of temporal tendinitis has been found to be a degenerative inflammatory process, which arrives in the tendon's attachment where the Sharpey fibers insert into the bone. The pathologic process may begin when jaw movements exceed the physiologic limits, resulting in micro- or macroscopic periosteal tears. As the degenerative changes proceed, normal mechanical stress through the Sharpey fibers can result in tenderness, limitation of motion, and referred pain. These degenerative changes and findings have been confirmed histologically.

Four hundred forty-nine participants diagnosed with TMDs were examined to determine how many of them had temporal tendinitis as a coexisting disease entity. Women were the majority (350 or 77.95%) of the 449 consecutive participants with TMDs. Three hundred fifty-three (78.62%) of the 449 participants had positive findings for concurrent temporal tendinitis disorder. Two hundred ninety-six (83%) had the condition bilaterally. The most commonly referred pain symptoms identified in the 353 temporal tendinitis participants were facial pain (68%), temporal headaches (54%), zygoma pain (49%), eye pain (26%), TMJ pain (26%), ear pain (26%), odontalgia (18%), neck pain (9%), and mandibular pain (7%).

The data on the initiating events from the 449 participants with TMDs showed that 180 had direct trauma to the head or face (40%) from motor vehicle accidents, 145 experienced indirect trauma (32.2%) from motor vehicle accidents, and in 118 (26.3%) the initiating factor was unknown. The results of this study suggest that temporal tendinitis is a frequently coexisting condition in patients who have TMDs.

One author discussed the use of articulators in orthodontics.[135] This is a controversial issue. Articulators can be used with other diagnostic aids (such as cephalometrics and photographs) in diagnosis, treatment planning, and posttreatment analysis of orthodontic therapy. Articulators can be particularly helpful to the clinician in uncovering occlusal problems, particularly those that concern the occlusal vertical dimension of the teeth. The use of an articulator allows for an assessment of the difference in occlusion in the maximum intercuspal position and the seated condylar position. Pretreatment and posttreatment evaluation with articulators can measure change at the condylar level, providing quantitative assessment of the treatment outcome at that level. Another diagnostic use of the articulator can be the creation of diagnostic arrangements. These may include orthodontic arrangements, surgical arrangements, restorative arrangements, or any combination of those procedures. Such use allows the clinician, before treatment, to determine the posttreatment relationship of the occlusion and the TMJs. In this manner, the roles of the restorative dentist, surgeon, periodontist, and orthodontist in the treatment can be determined before treatment begins.

One systematic review evaluated the role of EMG in diagnosing TMDs.[136] Although EMG has been used extensively in dentistry to assess masticatory muscle impairments in several conditions, especially TMDs, many investigators have questioned its psychometric properties and accuracy in diagnosing TMDs. The authors conducted a systematic review to analyze the literature critically and determine the accuracy of EMG in diagnosing TMDs. They conducted an electronic search of MEDLINE, Embase, all Evidence-Based Medicine Reviews, Allied and Complementary Medicine, Ovid HealthSTAR, and SciVerse Scopus. The authors selected abstracts that fulfilled the inclusion criteria, retrieved the original articles, verified the inclusion criteria and hand-searched the articles' references. They used a methodologic tool (Quality Assessment of Diagnostic Accuracy Studies) to evaluate the quality of the selected articles.

The electronic database search resulted in 130 articles. The authors selected 8 articles as potentially meeting eligibility for review. Of these 8 articles, only 2 fulfilled the study inclusion criteria, and the authors analyzed them. Investigators in both studies reported low sensitivity (values ranged from 0.15 to 0.40 in one study and had a mean of 0.69 in the second study). In addition, investigators in the 2 studies reported contradictory levels of specificity (values ranged from 0.95 to 0.98 in one study, and the mean value in the second study was 0.67). The likelihood ratios and predictive values were not helpful in diagnosing TMDs by means of EMG. The quality of the 2 studies was poor on the basis of the Quality Assessment of Diagnostic Accuracy Studies checklist.

The scientific literature available to date does not provide evidence to support the use of EMG for TMD screening or diagnosis. There is no substitute for comprehensive medical history and physical examination, which are low in cost and available to the general population. In addition, the use of various imaging modalities

(CBCT, MRI, or both) is appropriate in selected patients for diagnostic and treatment purposes.

Another article discussed the use of kinesiographic (KG) recordings of jaw movements to diagnose TMJ effusion and disk displacement.[137] In the field of TMDs, a clinical assessment of signs and symptoms is considered to be the gold standard for diagnostic assessment of new patients. Therefore, the main internationally recognized diagnostic and classification guidelines are based on the evaluation of the jaw muscles and the TMJs. Beyond that, imaging-based approaches may be needed to more thoroughly assess these disorders in selected patients involving structural problems or pathosis of the TMJ. Among these, MRI has become the standard of reference for the assessment of soft tissues, because it can depict TMJ disk position and the presence of joint effusion.

There are some clinicians who argue for more technologic devices in the diagnosis of TMDs. In the clinical setting, instruments for making EMG and KG recordings have been proposed as diagnostic aids for TMJ and jaw muscle disorders on the basis of their claimed usefulness to detect dysfunctions of the stomatognathic system. In using such instruments, the ultimate TMD diagnosis is based on abnormal EMG activity of the jaw muscles or peculiar features of jaw movements. However, recent studies have questioned the validity and reliability of those diagnostic instruments.

The study population comprised 31 participants seeking treatment (87% women; overall mean age, 43.1 years). KG recordings were obtained with a device used by clinicians, and the correlation of the findings with those of MRI was assessed. MRI is considered to be the standard of reference for the evaluation of soft tissues, and thus for the depiction of disk position abnormalities and intraarticular effusion. KG parameters, which were claimed to be useful for diagnosing intracapsular disorders, were chosen on the basis of their supposed relevance regarding the MRI assessments. Based on this premise, deviations and deflections from the sagittal midline during jaw opening were included in the analysis for their potential relationship with the presence of disk displacement with and without reduction, respectively.

None of the KG variables were found to correlate with any of the MRI findings, thus limiting all attempts to define multiple variable models to predict MRI-based diagnoses. As a consequence of the poor correlation with imaging signs, the accuracy of jaw KG findings to predict MRI diagnoses was not acceptable and too low to support the use of KG in clinical settings. Therefore, clinicians proposing TMD diagnostic and treatment approaches based on the analysis of jaw movements are strongly encouraged to reconsider their claims in the light of evidence-based findings suggesting that those instruments' accuracy to diagnose disease is poor. Data from this investigation do not support the usefulness of jaw-tracking devices to detect TMJ disk displacement and effusion.

There were several imaging articles published in 2012 devoted to the increasing ability to understand anatomy with various types of imaging. One interesting article discussed disk and joint morphology variations on coronal and sagittal TMJ dysfunction.[138] The article studied 74 TMJs from 37 patients with positive TMD symptoms by using MRI scanning to assess disk position, disk morphology, sagittal and coronal condyle position, joint effusion, joint space, and coronal condyle angulation. Disk displacement was present with reduction in 36.48% and without reduction in 21.62% of TMJs. Disk displacement was anterior in 35.1%, anteromedial in 13.5%, and anterolateral in 9.45%. A growing demand for 3-dimensional imaging techniques in diagnosing TMJ pathosis has been reported. MRI is considered the primary imaging of choice for assessing soft tissue components of the TMJ, owing to its excellent soft tissue contrast resolution. MRI has the advantages of being noninvasive and having a minimal risk potential when compared with other imaging techniques. Lately, MRI has made substantial contributions in understanding TMJ pathology, and it is known that MRI is the gold standard for diagnosing TMJ disk displacements.

This prospective study examined 74 TMJs from 37 participants. Twenty-nine (78.4%) were women with a mean age of 31.9 years and 8 (21.6%) were men with a mean age of 30.8 years. All MRI images were obtained by using a 1.5 T system with head coil. All participants were placed into the standard head coil with fixation device on both sides. The MRI protocol included T1-weighted coronal plain images, proton-density fast-spin echo sagittal oblique images in the closed and open mouth positions, and T2 passed in echo sagittal oblique images with closed mouth position. All MRI images were evaluated independently by 2 observers with experience in maximal patient diagnosis on the same monitor and under equal examining conditions after mutual calibration. The acquired images were used to determine the following qualitative data on sagittal slices: disk position, disk shape, joint effusion, and condylar position.

The disk position was described according to MRI imaging criteria for the TMJ. Disk positions were defined as normal, anterior disk displacement with reduction, and anterior disk displacement without reduction. The condyle position was evaluated as being concentric, anterior, or posterior, and it was evaluated in the sagittal images with the closed mouth position. The disk dimension and the maximal thickness of the anterior band, posterior band, and intermediate zone were measured.

Forty-three TMJs (58.1%) of the total 74 joints had a disk displacement on the MRI. Twenty-seven joints (36.5%) exhibited disk displacement with reduction, and 16 joints (21.6%) presented with disk displacement without reduction. The study found that disk displacements are significantly associated with changes of disk shape, malposition, and joint effusion.

Another study examined posteroanterior cephalometric changes in structures found with TMDs.[139] Posterior cephalograms of 61 participants (age range, 16-36.6 years) were used to determine cephalometric differences. Forty-seven participants were women (77%) and 14 were men (23%). Nineteen participants had unilateral TMDs and 16 participants had bilateral TMDs. For assessing facial asymmetry, the asymmetry index for bilateral measurements was calculated between the right and left side. TMJ disk displacement is positively associated with mandibular asymmetry. In a growing person, mandibular displacement can influence the modeling process of the TMJ, leading to asymmetry. Disk displacement might induce skeletal changes in facial morphology. The posteroanterior cephalogram is the first-choice method for diagnosing facial asymmetry.

Skeletal mandibular asymmetry results from many factors. Previous studies have found that disk displacement may be an important determinant in horizontal and vertical ramus deficiency on lateral cephalograms. Additionally, TMDs may cause growth disturbances, which may result in mandibular asymmetry. This study suggests that unilateral TMD is associated with changes in posteroanterior cephalometric measurements. Assessment of facial asymmetry should be associated with clinical examination of the TMJ in patients with internal derangement to ensure an accurate diagnosis and treatment plan.

In an article related to the use of CBCT, the American Dental Association's Council on Scientific Affairs released advisory statements.[140] Emergence of CBCT has expanded the field of oral and maxillofacial radiology. CBCT imaging provides 3-dimensional biometric wave constructions of dental and associated maxillary facial structures with isotropic resolution and high dimensional accuracy.

The American Dental Association's Council on Scientific Affairs recommends adherence to the following principles for safe and appropriate use of CBCT in clinical practice: as with other radiographic modalities, CBCT imaging should be used only after review of the patient's past medical and imaging history and completion of a thorough clinical examination. In accordance with the National Council on Radiation Protection and Measurements, and standard selection criteria for dental radiographs, clinicians should perform radiographic imaging, including CBCT, only after professional justification that the potential clinical benefits will outweigh the risks associated with exposure to ionizing radiation. The clinician should prescribe traditional dental radiographs and CBCT scans only when he or she expects that the diagnostic yield will benefit patient care, enhance patient safety, or significantly improve clinical outcome.

A systematic review of CBCT application in orthodontics was conducted; it evaluated the level of evidence to determine whether the use of CBCT is justified in orthodontics.[141] The authors identified articles by searching the Cochrane, MEDLINE, Embase, SciVerse Scopus, and Cumulative Index to Nursing and Allied Health Literature databases. They searched articles and references manually for additional articles and had no language limitations. Inclusion criteria were CBCT use in orthodontics and the effectiveness in treatment. The lowest level of evidence accepted for the inclusion was a case series with 5 or more participants. The authors evaluated the studies' methodologic quality according to 13 criteria related to study design, measurements, and statistical analysis.

The authors identified 550 articles, and 50 met the inclusion criteria. Study topics included provisional anchorage devices, cephalometry, combined orthodontic and surgical treatment, angle measurements, resorption and teeth infection, and cleft lip and palate. Readers interested in this topic should carefully analyze this study to determine when the use of CBCT scans is legitimately indicated in orthodontic treatment.

Several articles addressed treatment options. One article addressed the treatment of sleep apnea with mandibular advancement devices (MADs) and stated that sleep appliances may be associated with the development of symptoms of TMD.[142] The clinician needs to determine whether the problem was caused by the MAD or the problem appeared coincidentally with the use of the device. The use of the MAD may cause transient TMD symptoms when the device is first worn, but usually symptoms resolve within a few days. For those problems that have become persistent, treatment of the symptoms should be focused.

The presence of joint noises, such as clicking or crepitus, should also be closely evaluated during the initial examination. Joint crepitus (rubbing sound heard during jaw opening and closing) is often indication of articular surface remodeling. If the joint is tender to palpation, joint imaging, preferably CBCT, should be obtained to determine if degenerative changes have occurred. If the TMJs are painful at the time of the initial examination, the joint situation should be treated before the placement of a MAD, because the sleep appliance can aggravate the condition. A MAD should be placed only if the condyles are stable as determined on examination and by palpation and radiograph.

Another article discussed how to investigate and treat migraine in patients with TMDs.[143] Migraine and TMDs are highly prevalent conditions, and they frequently coexist in the same patient. The relationship between migraine and TMDs is complex. Migraineurs often have pain in the TMJ area, and patients with TMDs often experience headaches in addition to the pain in the jaw. Finally, migraine and TMDs are often comorbid, and the phenotype of patients with comorbidity may represent the aggregated contribution of both.

In patients who have facial pain and headaches, standard criteria should be applied for a precise differential diagnosis, because comorbidity of TMDs

and migraine is frequent, as is an overlapping of their signs and symptoms. When TMDs and migraine are simultaneously present, better outcomes are achieved by concomitant treatments.

A systematic review evaluated the efficacy of topical nonsteroidal antiinflammatory drugs (NSAIDs) to relieve TMJ pain.[144] Clinical trials concerning topical NSAIDs with either placebo or an alternative active treatment to treat TMJ degenerative joint disorder were identified. Outcomes evaluated were pain reduction/pain control and incidence of side effects. A single study (a double-blind, placebo-controlled RCT) with 20 participants was identified that evaluated the efficacy of a topically prepared NSAID over a 12-week duration, measuring functional pain intensity, voluntary and assisted mouth opening, pain disability index, and a brief pain inventory analysis. This study found a pain intensity decrease within treatment groups but no significant difference between treatment groups. Presently, there is insufficient evidence to support the use of topically applied NSAIDs to palliate TMJ pain.

One study, an RCT, compared the short-term effectiveness of botulinum toxin injections with that of facial manipulation techniques to treat myofascial pain in jaw muscles.[145] Thirty participants (28 women, 8 men; age range, 23-69 years) meeting research diagnostic criteria for TMD diagnosis of myofascial pain were randomized to receive either single-session botulinum toxin injections or multiple-session facial manipulation. Maximum pain levels and jaw range of motion in millimeters (maximum mouth opening, protrusion, right and left laterotrusion) were provided at baseline, at the end of treatment, and at a 3-year follow-up. Both treatments provided significant improvement over time for pain symptoms. The 2 treatments seemed to be almost equally effective, facial manipulation being slightly superior to reduce subjective pain perception, and botulinum toxin injections being slightly superior to increase jaw range of motion. Differences between the 2 treatments as to changes in the outcomes parameters at the 3-month follow-up were not relevant clinically. Findings from this investigation are in line with the literature data supporting the effectiveness of the wide spectrum of conservative treatment approaches to myofascial pain of the jaw muscles. Future studies with larger samples and longer follow-up are needed to identify tailored treatment strategies.

The effectiveness of splint therapy in patients with TMD disorders was evaluated in a systematic review that studied published RCTs in which the investigators compared the effectiveness of splint therapy with that of minimal or no treatment.[146] The authors searched MEDLINE, Embase, and the Cochrane Central Register of Controlled Trials for studies published from the inception of each database through August 2011. In eligible studies, investigators enrolled adult participants with TMDs and assigned them randomly to splint therapy or to a control group receiving minimal or no treatment. Of the 1567 potentially eligible studies, 11 proved eligible and were included. Moderate-quality evidence suggests that splint therapy reduces pain in the TMJ area. Low- to very-low-quality evidence contained no significant differences between splint therapy and control groups in terms of quality of life or depression.

Although overall results were promising for the reduction of pain, establishing the role of splints for patients with TMDs will require large trials with stronger safeguards against bias. To determine which splint design may be effective for each individual patient, it is necessary to have a more specific diagnosis including an assessment of the structural integrity of the structures in the TMJ.

Another article regarding occlusal splint therapy was also published in 2012.[147] The authors conducted a clinical trial to compare the effectiveness of an education program with that of an occlusal splint in treating myofascial pain of the jaw muscles across a short period. The authors assigned 44 participants randomly to 2 treatment groups; 41 participants completed the study. The first group (4 men, 19 women; mean age, 31.4 years) received information regarding the nature of TMDs and self-care measures, whereas the second group (5 men, 13 women; mean age, 31.1 years) received an occlusal splint. One of the authors evaluated each participant every 3 weeks during a 3-month treatment period. Treatment outcomes included pain-free maximal mouth opening, spontaneous muscle pain, pain during chewing, and headache.

After 3 months, changes in spontaneous muscle pain differed significantly between the education and occlusal splint groups. Changes in pain-free maximal mouth opening did not differ significantly between groups. Changes of headache and pain on mastication did not differ significantly between groups. The authors found that during the short period, education was slightly more effective than an occlusal splint in treating spontaneous muscle pain. The treatments did not have significantly different effects in terms of pain-free mouth opening, headache, and pain during chewing. Therefore, the findings indicate that for successful management of myofascial pain, education of patients regarding self-care as well as effective communication between the patient and doctor may be more effective than an occlusal appliance. Regrettably, this article continues the long tradition in TMD/occlusion literature by ignoring the anatomy when discussing the use of occlusal splints. The clinician must be aware that the conclusions from this study may have been different if the patient population had been clearly diagnosed before beginning occlusal splint therapy.

Another systematic review evaluated the efficacy of occlusal adjustment associated with periodontal therapy.[148] Occlusal adjustment as a part of periodontal therapy has been controversial for years, mostly because the literature does not provide enough evidence regarding the influence of trauma from

occlusion on periodontitis. The need for occlusal adjustment in periodontal therapy is considered uncertain and requires investigation. The purpose of this systematic review was to identify and analyze those studies that investigated the effects of occlusal adjustment, associated with periodontal therapy, on periodontal parameters. A protocol was developed that included all aspects of a systematic review: search strategy, selection criteria, selection methods, data collection, and data extraction. Three reviewers screened the titles and abstracts of articles according to the established criteria.

Although the selected studies suggest an association between occlusal adjustment and an improvement in periodontal parameters, their methodologic issues suggest the need for new trials of a higher quality. There is insufficient evidence to presume that occlusal adjustment is necessary to reduce the progression of periodontal disease. Although it is not possible to determine the role of occlusal adjustment in periodontal treatment, adverse effects have not been related to occlusal adjustment. This means that the decision made by clinicians on whether or not to use occlusal adjustment in conjunction with periodontal therapy hinges on clinical evaluation, patient comfort, and tooth function.

One study addressed the muscle activity of the masseter and temporalis related to the development of anterior guidance.[149] The purpose of the study was to determine if a statistically significant reduction in muscle activity ($P<.05$) occurs when prolonged disclusion time (>0.4 seconds per excursion) is shortened to less than 0.4 seconds per excursion with the Immediate Complete Anterior Guidance Development (ICAGD) enameloplasty. Forty-five symptomatic and fully informed participants (29 women, 16 men) had their right and left disclusion times recorded with T-Scan III (Tekscan Inc, South Boston, Mass) while the bilateral masseter and anterior temporalis muscle activity was simultaneously recorded with EMG. This recording was done twice, once pretreatment and once posttreatment on the same day after undergoing the ICAGD enameloplasty without changing electrodes. Highly significant reductions were found in all 4 muscle activities after shortening the pretreatment prolonged disclusion time to less than 0.4 seconds. When properly performed, such that the posttreatment disclusion time is less than 0.4 seconds per excursion, the ICAGD enameloplasty predictably reduces the excursive muscle activity level in the bilateral anterior temporalis and masseter muscle. Excursive muscle hyperactivity can be a source of rapid acid accumulation, muscular ischemia, and chronic myalgic TMJ dysfunction symptoms. The ICAGD enameloplasty significantly reduced excursive muscle contraction after completion of the first session.

Another investigation studied the relationship between a dentofacial structure and a TMJ structure in orthognathic surgery.[150] Skeletal and occlusal patterns may be associated with the TMJ morphology, including the disk position. In orthognathic surgery, some surgeons state that alterations in the condylar position from surgery can lead to malocclusion associated with the risk of early relapse and can also favor the development of TMDs. For these reasons, several positioning devices have been proposed and applied, but there is no scientific evidence to support the use of condylar positioning devices. There are some reasons why scientific evidence cannot be obtained; however, there is also the question of whether the preoperative position of the condyle is the desired postoperative position. The purpose of this study was to verify the desired condylar position in orthognathic surgery, based on literature on the postoperative condylar position in such surgery. From the studies reviewed, it was suggested that the preoperative position of the condyle was not the desired postoperative position.

One investigative group discussed progressive condylar resorption after mandibular advancements.[151] Progressive condylar resorption is an irreversible complication and a factor in the development of late skeletal relapse after orthognathic surgery. The authors evaluated cephalometric characteristics, signs and symptoms in the TMJ, and surgical factors in 6 individuals (1 man and 5 women) who developed condylar resorption after orthognathic surgery. The findings in preoperative cephalograms indicated that the individuals had clockwise rotation of the mandible and retrognathism because of a small sella-nasion-B-point angle, right mandibular plane angle, and minus value for the inclination of the ramus. There were erosions or deformities of the condyles, or both, on 3-dimensional CT before treatment. The mean anterior movement of the mandible at operation was 3.9 mm, and the main relapse was 3.5 mm. The main change in posterior facial height was 2.1 mm at operation, and the mean relapse was 1.8 mm. Two individuals had clicking or pain or both preoperatively. The click disappeared in 1 individual postoperatively, but one who had been symptom-free developed crepitus postoperatively. In the classified resorption pattern, posterior-superior bone loss was seen in 3 individuals, anterior-superior bone loss in 2, and superior bone loss in one. Progressive condylar resorption after orthognathic surgery is multifactorial, and some of the risk factors are interrelated. Patients with clockwise rotation of the mandible and retrognathism in preoperative cephalograms and with erosion or deformity of the condyle, or both, on preoperative CT seem to be at risk, as do those with wide mandibular advancement and counterclockwise rotation of the mandibular proximal segment at operation. The mandible should therefore be advanced only when the condyles are stable on radiographs, and careful attention should be paid to the postoperative mechanical loading in the TMJ in patients at high risk. As discussed in other articles, the need for mandibular advancement may be the result of structural changes in the TMJs. Therefore, it is imperative to thoroughly evaluate the condition of the TMJs before any type of mandibular advancement.

One group investigated outcomes from using an alternative technique as opposed to the traditional orthognathic surgical technique of bilateral sagittal split osteotomy (BSSO).[152] With the traditional technique there is a risk of damaging the inferior alveolar nerve. Fifty consecutive participants who had a high oblique sagittal split osteotomy (HSSO) as an alternative to avoid damaging the nerve were studied. The participants were evaluated for sensory alterations and function of the TMJ. Healing of both wound and bone was complete and uneventful in all 50 participants. Mean sagittal movement of the mandible was 2.9 mm, and mean length of the osteotomy line was 3.1 mm. No participant had either temporary or permanent alteration in sensitivity. No disorders of the TMJ developed. HSSO seems to be a suitable alternative to BSSO, because it avoids injury to the inferior alveolar nerve without compromising the TMJ. Ossification was uneventful, although bony attachment was less than with the classic BSSO.

One study assessed whether arthroscopic lysis and lavage or operative arthroscopy is more effective for the treatment of TMJ internal derangement at any stage of involvement.[153] Arthroscopy was performed in 458 participants (611 joints) with internal derangement of the TMJ classified as Wilkes stages II, III, or IV. Pain, measured with VAS, was assessed at 1, 3, 6, 9, 12, and 24 months after surgery. Arthroscopic lysis and lavage was performed in 308 of 610 arthroscopies (50.4%), and operative arthroscopy was performed in 303 arthroscopies (49.6%). The significant decrease in pain ($P<.001$) was observed for all participants at any time during the follow-up period from the first month postoperatively to the end of the 2-year follow-up period. A significant increase in mouth opening greater than 13 mm was observed in the group of participants classified as Wilkes stage IV from the first month postoperatively. When the arthroscopic lysis and lavage versus the operative arthroscopy among Wilkes stages were compared, no significant differences in terms of pain were observed during the entire follow-up period.

A different surgical approach to TMJ problems was discussed in 1 article.[154] The author stated that the essential life functions of mastication, speech, airway support, and deglutition are supported by the TMJ function and form. Over a lifetime, this may put the TMJ complex under more cyclical loading and unloading than any other joint. Therefore, there is a need for TMJ total joint replacement devices. The primary goal of TMJ total joint replacement is the restoration of mandibular function and form. Outcomes data confirm that any pain relief attained must be considered of only secondary benefit. In spite of persistent but reduced chronic pain, increased mandibular function and form improvement have been reported, resulting in quality-of-life improvement for 85% of custom TMJ total joint replacement patients studied in the long term. Based on the literature and the orthopedic criteria for the development and use of successful total joint replacement devices, this article presents a rationale for the use of custom TMJ total joint replacement devices as management options for end-stage TMJ disorders. The status criteria for successful custom alloplastic TMJ replacement devices are (1) that the components of any such devices must be stable in situ at implantation; (2) that the materials from which the devices are manufactured must be biocompatible and able to withstand the forces of mandibular function; (3) that the devices must be designed to withstand the loads delivered over the full range of the function of the joint to be replaced; and (4) that the implantation surgery must be performed with the proper indications and aseptically. Based on the available literature to date, custom TMJ total joint replacement devices, by their nature, designs, and biomaterial composition, seem to provide stable, improved long-term outcomes over stock devices.

One group designed a study to evaluate pain pressure threshold and oral-health-related quality of life in patients undergoing alloplastic total joint replacement.[155] Participants requiring total joint replacement were enrolled in the study. The pain pressure threshold and the oral-health-related quality of life were measured preoperatively and at 2, 6, and 12 months postoperatively. The primary predictor variable was postoperative time and the oral-health-related quality of life. The primary outcome variables were the pain-pressure threshold and the oral-health-related quality of life. The 17 participants who completed treatment required 12 months of follow-up. There was no difference in the pain pressure threshold at any time point. There was a significant improvement in the oral-health-related quality of life domain of psychological discomfort ($P=.04$) at 12 months. Facial pain intensity, TMJ pain, mandibular function, and diet were also significantly improved at 12 months ($P=.001$). Alloplastic total joint replacement seems to decrease pain, improve function and diet, and decrease psychological discomfort.

Another group evaluated the applicability of pedicled buccal fat pad grafting for the reconstruction of defects surgically created during oral surgery.[156] A buccal fat pad graft was applied in 23 participants (5 men, 18 women; mean age, 68.3 years). The graft was used to cover surgical defects of the palate, maxilla, maxillary gingiva, buccal mucosa, mandibular gingiva, oral floor, and TMJ region. The size of the surgical defects ranged from 15 × 12 mm to 30 × 40 mm. A pedicled buccal fat pad was prepared by incising the maxillary vestibule after primary surgery, and the surrounding connective tissue was preserved to supply nutrition to the pedicle during surgery. The buccal fat pad was placed on the raw surface of soft tissue or bone surface and sutured to the surrounding tissue of the defect. Complete epithelialization was observed within 4 hours postoperatively. There were no

complications or functional disorders during follow-up. Buccal fat pad grafting seems to be feasible for the reconstruction of surgically induced defects, and it can be extended to the palate, mandible, mouth angle, and TMJ region.

In the TMJ region, the graft was used to repair the postoperative defect left by a synovial chondromatosis resected from the left condylar head in a 58-year-old woman. The size of the defect was 20 × 25 mm, and the size of the fat graft was 30 × 30 mm. The fat graft was prepared intraorally from the TMJ region. Complete epithelialization of the fat graft occurred within 4 weeks. There was no contraction of soft tissues or functional disorder of the TMJ during follow-up, which ranged from 4 weeks to 8 years, 10 months.

There were several interesting animal studies published in 2012. In 1 investigation, the effect of estrogen deficiency and altered TMJ loading on the condylar cartilage was studied.[157] Thirty-six female rats were divided into 4 groups: ovariectomized rats on a normal diet, non-ovariectomized control rats on a normal diet, ovariectomized rats on a soft diet, and non-ovariectomized control rats on a soft diet. Ovariectomy was performed at the age of 60 days. The condylar cartilage in the ovariectomized normal diet group had a significantly higher number of cells than did that of the non-ovariectomized control rats ($P<.001$). The conclusion from the study was that the condylar cartilage is sensitive to both estrogen and dietary load.

Investigators evaluated the effect of functional shift to the mandible on lubrication of the TMJ.[158] Lubrication of synovial joints reduces the coefficient of friction of the articular cartilage surface. To investigate the effect of malocclusion on the lubrication of the TMJ, the lubricin expression in the rat TMJ was evaluated immunohistochemically, under conditions of a functional lateral shift of the mandible during a period of growth. Thirty 5-week-old male rats were divided into experimental, recovery, and control groups. Each rat in the experimental and recovery groups was fitted with an acrylic resin plate-guiding appliance. The rats in the experimental and control groups were killed at 14 and 28 days after the appliance was attached. Each rat in the recovery group was detached from the appliance at 14 days, and it was killed 14 days after the appliance was removed. In the experimental group, the expression of lubricin staining in TMJ cartilage was significantly decreased during the experimental period. In the recovery group, the expression of lubricin staining in TMJ cartilage was significantly greater than in the experimental group, and there was no significant difference at 28 days between the control and recovery groups. Analysis of these data suggests that a functional lateral shift of the mandible during the growth period influences lubrication of the TMJ.

Another group hypothesized that sustained inflammation in the TMJ induces structural abnormalities, and accordingly characterized the disk and synovium in a novel model with dual injections of complete Freund adjuvant (CFA), using behavioral, morphologic, cellular, and molecular assessments.[159] Thirty-five days after double CFA injections in 7-year-old female Sprague-Dawley rats, the disk in the CFA-induced inflammation group had multiple degenerative changes, including marked thickening, opacity, and deformation. The disks in the CFA group also had significantly greater net weights, and elevated collagen, aggrecan, and total glycosaminoglycan contents. The synovium in the CFA-induced-inflammation group had marked infiltration of mononucleated cells and accumulated subsynovial adipose tissue. Both the disk and synovium had significantly higher inducible nitric oxide synthase and interleukin-1β mRNA expression than controls with saline injections. These findings are consistent with the hypothesis that sustained TMJ inflammation, even within the presently observed 35 days, may be a predisposing factor for structural abnormalities. Insight into TMJ inflammation and degeneration is expected to improve our understanding of the pathogenesis of TMJ arthritis and help design clinically relevant strategies for tissue engineering.

An interesting article discussed new advancements in craniofacial bone tissue reengineering.[160] There are numerous conditions, such as trauma, cancer, congenital malformations, and progressive deforming skeletal diseases, that can compromise the function and architecture of bones, causing craniofacial pain. New approaches for treatment of these disorders are needed, because conventional therapeutic strategies face many obstacles and limitations. The use of tissue engineering in the regeneration of craniofacial bone structures is a promising possibility and a great challenge for researchers and clinicians. Developments in stem cell biology and engineering have led to the discovery of different stem cell populations and biodegradable materials with suitable properties. This review summarizes the current achievements in tissue engineering of craniofacial bone, TMJ, and periodontal ligament tissues. Therapy for TMDs presents a challenge in modern medicine. The methods used have not always been effective to completely restore the functioning of the TMJ. Tissue engineering might offer possible solutions at a different stage, in which it is necessary to regenerate mandibular condyle. Ideal engineered constructs with mandibular condyle regeneration must have innervated bone and cartilage layers in the single osteochondral construct to meet the demands for anatomic structure and functional regeneration. Stem cells from the human umbilical cord can also be a potential source for tissue engineering of the mandibular condyle.

Two articles related to education warranted review. One proposed a curriculum for orthodontics and TMDs for postgraduate students.[161] The proposal included a list of topics to be covered in a 1-semester TMD course. The glaring weakness is the lack of any training on TMJ imaging with MRI and

CBCT. Given the increase in the frequency, severity, and early onset of structural changes to the TMJ, both general dentists and specialists will have to develop skills and knowledge on when to image TMJs, how to image TMJs, and what can be learned from TMJ imaging.

The second article examined the quality and content of Internet-based information on TMJ disorders.[162] The purpose was to assess the content and quality of websites about TMJ disorders and thereby provide guidance regarding the accuracy and comprehensiveness of the information on the sites. Sixty-seven websites resulting from an Internet search with the word *TMD* were evaluated by using criteria from the *Journal of the American Medical Association*, DISCERN, and Health on the Net, along with an evaluation method to assess the scientific quality of the website contents. Fewer than 50% of the sites displayed the author or references of the information, according to the benchmarks criteria from the *Journal of the American Medical Association*. For every evaluation criterion, good agreement was found among reviewers. Commercial websites were the most common; sites of nonprofit organizations had the highest content scores. The overall quality was poor to moderate for all website types. Sites concerning TMDs were poorly organized and maintained. Also, most sites contained insufficient or statistically incorrect information that could have a negative effect on the treatment outcome and prognosis of TMDs. Clinicians should guide patients to reputable sources of information that will help enhance the patients' comprehension and lead to better treatment outcomes.

Sleep disordered breathing

In the last 20 years the literature has grown dramatically in the area of oral appliances for the treatment of obstructive sleep apnea (OSA). Whereas in 1989 just 9 articles appeared in the literature (all case reports), during 2011 and 2012 more than 43 articles were published in the English language.

One interesting article describes how ideally positioned dentists are to identify many patients who eventually may be diagnosed with sleep-disordered breathing.[163] Perspectives on sleep-related issues from the viewpoint of various medical specialties are addressed with 2 goals: first, to broaden the dentist's appreciation of sleep and its relation to overall health; and second, to improve communication between all health care personnel.

An article in the medical literature further addressed the dental clinician's ideal position to screen patients for medical conditions.[164] This article assessed the proportion and characteristics of patients who do not regularly visit general health care providers but do visit dentists and whose unaddressed systemic health conditions their dentist could identify. Of the 26.0% of children and 24.1% of adults who did not access general outpatient health care in 2008, 34.7% and 23.1%, respectively, visited a dentist. This general survey found that, in 2008, 19.5 million people did not visit a general health care provider but did visit a dental provider. These data place dentists on the front line, in a position to improve health care for millions of people.

The scientific literature in the areas of occlusion and TMDs has historically contained a high level of bias by researchers. Sleep bruxism (SB) has now become a part of the TMD literature, and that bias remains firmly in place. An investigation of SB and myofascial TMDs was published in 2012. The investigation used laboratory-based polysomnographic (PSG) studies to diagnose SB. The investigators concluded that most case participants did not exhibit SB and that the common belief that SB is a sufficient explanation for myofascial TMDs should be abandoned.[165] This conclusion is deceiving. Although SB is not always the precipitating factor for TMDs, one must realize that TMDs are multifactorial and that SB can be transient, meaning that even in patients in which it seldom occurs, it may still be present on occasion.

Broad statements that tend to rule out sleep disordered breathing may be premature and may fail to appreciate the limited understanding of the complexity of both sleep and TMDs. For example, SB is not a consistent occurrence and may require more than one PSG for accuracy.[166] Tooth wear is not consistent in its association with the amount of SB.[167]

EMG is an inexact science because of variability in electrode placement, underlying anatomy, and the presence of pain.[168] This research did not address other muscle actions, such as protrusion of the lateral pterygoid or temporalis activity during sleep, which could also create myofascial pain issues. The dentist may incorrectly diagnose SB but be correct with his or her diagnosis that airway maintenance is the root cause. Much more investigation is needed in this area before any broad-stroke conclusions can be drawn.

There continues to be considerable controversy as to whether an increased vertical opening (VO) is beneficial in oral appliance therapy (OAT) for the treatment of OSA. One study addressed this important component, pointing out that each oral appliance has a given thickness causing VO.[169] Therefore, evaluation of the effects of the amount of VO on pharyngeal dimensions is mandatory. In this study, effects of VO on the cross-sectional area of the upper airway at the level of the tongue base during sleep endoscopy were scored and categorized for 40 participants with induced alteration of VO 20 mm versus VO 6.8 mm and a mean maximal comfortable protrusion of 7.2 mm. Thirty-two participants (80%) had an adverse effect of VO, 1 participant (2.5%) had a positive effect, and 7 participants (17.5%) had an indifferent effect. The results of this work indicate that the effect of VO on the degree of pharyngeal collapse as assessed during sleep endoscopy tends to be adverse, causing an increase in collapsibility in the majority of patients.

VO was addressed by another study that related OSA and temporomandibular

pain, suggesting that wearing a maxillary occlusal splint (that is, a hard acrylic resin dental appliance that covers the occlusal surfaces of the maxillary dentition and is used for the treatment of temporomandibular pain) may be associated with a risk of aggravating OSA.[170] The outcomes of this study suggest that an increased jaw gape without mandibular protrusion might be associated with a risk of aggravation of OSA for some, but not for all patients with OSA. Dental clinicians should be aware of this possible association when treating patients with oral devices that increase the occlusal dimension.

For years there have been comparisons of OAT and positive airway pressure (PAP) treatment. Reduction in apnea-hypopnea index, improvement in physiologic parameters, and quality of life have been measured. PSGs, self-report questionnaires, and bed-partner reports have been used as well. In 2006, a review by the American Association for Sleep Medicine stated that OAT and nasal continuous positive airway pressure (nCPAP) are essentially equivalent in the treatment of mild or moderate OSA. A recent study confirmed this equality in detail.[171] Previous RCTs have addressed the efficacy of OAT in the treatment of OSA. Their common control condition, nCPAP, was frequently found to be superior to OAT therapy. However, in most of these studies, only nCPAP was titrated objectively. To enable an unbiased comparison between both treatment modalities, the OAT should be titrated objectively as well. Sixty-four participants with mild or moderate OSA (mean age, 52.0±9.6 years) were randomly assigned to 3 parallel groups: OAT, nCPAP, and placebo device. From all participants, 2 PSG recordings were obtained at the hospital: one before treatment and one after approximately 6 months of treatment. The conclusion indicated that no clinically relevant difference exists between OAT and nCPAP in the treatment of mild or moderate OSA when both treatment modalities are titrated objectively.

In another article, the same research group using the same cohort group found that participants with nCPAP were more resist to accepting their treatment modality than were those with MAD.[172] The apnea-hypopnea index values achieved with OAT remained stable at 1 year; excessive daytime sleepiness was comparable to that seen with PAP; PAP had more drop-outs (6 versus 2); and compliance for both groups was 85% of the nights. In OAT, therefore, dentists have a research-proven treatment for OSA that is as effective as nCPAP for mild or moderate OSA and that seems to have higher compliance.

One of the common side effects of OAT is the movement of the dentition. An excellent study published in 2012 quantifies the forces created by progressive mandibular advancement with OAT during natural sleep.[173] A pressure transducer system was placed on the acrylic resin arms of a 2-piece oral appliance (Herbst type) used by 9 moderate to severe OSAS participants, in addition to all captors routinely used for PSG. Strains on the left and right sides were collected during stable sleep stages without arousal, for each step of 1 mm advancement. The mean force in this sample was 1.18 N/mm (120.32 gram-force/mm) and showed an almost linear evolution. Measurements had intraindividual and interindividual variability. The force values recorded in this study may explain the occlusal and skeletal side effects associated with long-term use of these oral appliances. They illustrate the influence of the amount of mandibular advancement and indicate a possible dose-dependent effect on unwanted tooth movement.

Another study of interest evaluated the effect of OAT treatment on cognitive functions in participants with OSA.[174] In this prospective study, 50 men with verified moderate-to-severe OSA received an oral appliance with mandibular advancement. The cognitive functions assessed included working memory, vigilance, executive functioning, and mental pace, measured before as well as after 6 months of treatment. PSG was used to measure physiologic treatment effects. Forty-three participants completed the 6-month follow-up study. All domains of cognitive functioning measured improved after 6 months of treatment with an oral appliance. The apnea/hypopnea and oxygen desaturation indices decreased significantly after treatment. An obvious treatment response was reached in 60% of the participants, and 54% had normalized breathing during sleep. It was concluded that OAT is an effective treatment for the physiologic symptoms of OSA and may also have a positive effect on cognitive functions after only 6 months of treatment.

One provocative study discussed the fact that when compared with controls, therapeutic adherence is frequently poor among patients with post-traumatic stress disorder (PTSD).[175] OSA is common in patients with PTSD, and inadequately treated OSA may adversely affect the patient's quality of life. The treatment for OSA is often CPAP, and achieving compliance is often challenging. The poor sleep quality, including initiation insomnia and sleep fragmentation, that is common among patients with PTSD may impair CPAP adherence. The authors concluded that with these patients, clinicians need to consider OAT as a first-line treatment, especially when CPAP is not effective.

Swedish investigators conducted an interesting study to evaluate bed-partners' and patients' self-reports of general well-being, physical strength, and mental energy after treatment for OSA with OAT.[176] After 1 year of treatment, a follow-up questionnaire was sent to patients whose sleep disorder was reduced >50% from baseline values, and it was also sent to their bed partners. The questionnaire consisted of 15 questions or statements with multi-answer alternatives concerning well-being, physical strength, mental energy, sleep, day and night symptoms, and the Epworth Sleepiness Scale (8 questions). The questionnaire was answered by 82% (110/134) of the patients and 85% of bed partners. Both patients and

bed partners reported improvement in general well-being, physical strength, and mental energy, between 70% and 80% for patients and between 55% and 68% for bed partners sharing the same bedroom. Similar results were found for concentration ability, joyfulness, and strength of effort in social intercourse, as well as decreased daytime sleepiness, improvement in the feeling of getting enough sleep, and reduced nocturia. In all dimensions, the treatment effect had a great influence, not only on patients but on bed partners as well.

In an update and comprehensive review of treatment with OAT, one research group concluded that over the past decade, OATs have been enthusiastically studied and have been found to be a simple, silent, bed-partner-friendly, less-invasive, tolerable, and efficacious choice for mild or moderate OSA.[177] The authors stated that many questions remain unanswered, such as titration management, 3-dimensional image diagnostic tools reliability, and long-term (>5 years) adherence in adult patients. Improvement of TMJ monitoring and management is recommended, although there is no scientific evidence suggesting consistent undesirable long-term effects of oral appliances on the TMJs. Now that pediatric OSA is being diagnosed more frequently, OAT is becoming a promising option for children as well. Consistent follow-up and management are needed to increase clinical success rates in OAT for OSA. Further educational preparation and support is required for dental and medical professionals to recognize OSA and to ensure the best possible patient care.

PROSTHODONTICS

A large volume of high-quality material related to the extensive topic of prosthodontics was published in 2012. 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 great interest to readers. Subjects covered included articulators,[178] occlusal vertical dimension,[179] tooth wear,[180-185] tooth replacement,[186-188] computer-aided design/computer-aided manufacturing (CAD/CAM) prostheses,[189,190] prosthetic materials,[191-193] esthetics,[194] tooth preparation,[195] interim restorations,[196] treatment decision making,[197-199] implant prostheses,[200-204] implant biomechanics,[205-208] immediate implant loading,[209] implant platform switching,[210] implant success/failure,[211-215] and research methods.[216]

For convenience and clarity, this review of the 2012 prosthodontic literature is divided into the following subtopics: conventional removable prosthodontics, conventional fixed prosthodontics, implant-supported removable prosthodontics, implant-supported fixed prosthodontics, and prosthodontic biomechanics.

Conventional removable prosthodontics

Favorable mechanical and biologic acceptance of dental restorations in the oral cavity is prerequisite to successful restorative dentistry. Adverse biologic reactions in oral tissues that contact denture base materials have been reported and may include a burning sensation, redness, swelling, pain, vesicle or ulcer formation, or labial edema. In an effort to develop consensus information, investigators systematically reviewed literature published between 1979 and 2009 on the cytotoxicity of denture base and hard reline materials.[217] Inclusion criteria focused on in vitro studies addressing cytotoxicity in either animal or human cells. Studies involving resilient denture lining materials, genotoxicity, and mutagenicity were excluded.

Of the 1443 articles initially identified, 20 reports met selection criteria. Typically, continuous cell lines were exposed to materials and mitochondrial activity was used to indicate cell viability. Test denture resins were categorized as follows: heat-activated, microwave-activated, chemically activated, light-activated, and hard chairside liner.

As is the case with many systematic reviews in dentistry, data abstraction, analysis, and interpretation were constrained by significant methodologic heterogeneity. An additional limitation was the lack of specific guidelines for systematic review of nonclinical studies.

In general terms, some evidence exists that heat-activated denture base resins are associated with less cytotoxicity than are chemically activated resins, light-activated resins, or dual-polymerized chairside reline resins. Unfortunately, owing to substantial variability in research protocols, definitive concluding statements were difficult, if not impossible, to draw.

Current opinion holds that use of denture adhesive in well-made complete dentures is indicated when (1) the denture bearing anatomy is unfavorable, (2) the patient's neuromuscular control is impaired, (3) cushioning or lubrication is desired owing to compromised soft tissues, (4) entrapment of food debris under dentures is a concern, and (5) physical and psychological support is required for those with high expectations of denture retention and stability. In light of claims made by manufacturers and perceived patient needs, investigators tested 3 denture adhesives in well-made, well-fitting complete dentures by using recognized in vivo subjective and objective measures of retention, stability, and functional movement. Two cream adhesives and 1 strip adhesive were assessed.[218]

Thirty-seven edentulous individuals (19 men, 18 women; mean age, 71 years) with well-made, well-fitting maxillary and mandibular complete dentures were enrolled in this single-center, randomized, blinded, crossover clinical trial. Four efficacy/quality tests were randomly applied: Kapur Index,[219] occlusal force, denture dislodgement, and peanut particle migration. Dentures were tested with and without adhesive. Participants provided ratings of comfort, confidence, satisfaction, and

perceived denture wobble during mastication of apples and peanuts.

Results indicated that all adhesives tested resulted in significantly improved Kapur Index, maximum occlusal force, and denture dislodgement, suggesting improved denture retention and stability, as well as decreased denture movement during function. Patient ratings of comfort, confidence, and overall satisfaction were significantly higher in the presence of adhesives. Additionally, participants perceived significantly less functional denture movement when adhesives were used. The cream adhesives yielded better results than the strip adhesives. Of particular note was the strong performance of one of the creams containing a long-acting adhesive polymer that likely improved both adhesive quality and resistance to adhesive washout.

The authors concluded that dental professionals play a key role in guiding patients to proper denture adhesive use. It is critical for patients to understand that use of increasing amounts of adhesive over time is no substitute for maintenance of adequate prosthesis fit. Informed patients are more likely to use denture adhesives properly and seek clinical evaluation and denture maintenance on a regular basis.

Patients with teeth restored with fixed and removable resin-based prostheses may exert considerable functional occlusal loads, particularly when dental implant support is available. In an effort to make prostheses comfortable and hygienically accessible, reduced resin base dimensions are desirable. However, crack initiation and propagation, particularly associated with tensile stress application, in underdimensioned resin sections, leading to prosthesis failure, are an all-too-frequent occurrence. Using an in vitro experimental approach, investigators evaluated the effect of thickness on flexural strength of denture base resin samples containing a prosthetic tooth.[220]

Beam-shaped specimens 65 mm in length, 12 mm in width, and 1, 2, 3, 4, or 6 mm in thickness were made with a popular injection-molded, high-impact, modified polymethyl methacrylate denture base material. Each of these specimens incorporated a single resin molar denture tooth processed to the beam with a 0.5-mm collar. A control group of 3-mm thick specimens were fabricated without denture teeth. After fabrication, all specimens were artificially aged by water storage and thermocycling (5°C to 55°C, 1000 cycles, 30 seconds travel, 120 seconds dwell). Three-point bend testing was accomplished in a universal testing machine (2.5 mm/min crosshead rate) placing the specimens' simulated intaglio surfaces in tension. Fractured specimens were evaluated with light microscopy. Mean load, relative strength, and fracture toughness were calculated.

The 1-mm and 2-mm thick beams underwent significant deformation at low loads. Maximum flexure loads varied from 0.6 kg (1-mm beams) to 38 kg (6-mm beams). Brittle fracture was commonly encountered in 3-mm, 4-mm, and 6-mm specimens, which had a mean relative flexural strength of 73 MPa. The presence of a denture tooth substantially reduced relative fracture strength. Crack initiation typically occurred at small intaglio surface defects away from the specimen's denture tooth.

The authors concluded that increased acrylic resin thickness for beams containing denture teeth markedly increased load-bearing capacity, with 2-mm thickness being the threshold for reasonable strength levels of the denture base resin investigated. In total, results indicated that denture base thickness of 2 mm or more may be necessary for clinically predictable mechanical performance and durability.

Although denture base durability is important to clinical success in removable prosthodontics, durability of the oral denture foundation is equally critical. The coincidence of maintained natural mandibular anterior teeth with hypermobile soft tissues along the anterior aspect of the edentulous maxilla has long been recognized. Using a clinical examination protocol, investigators studied the effect of natural mandibular anterior teeth on resorption of the maxillary anterior residual ridge.[221]

A total of 410 elderly, home-bound individuals currently using their dentures (144 men, 266 women; mean age, 70 years) were enrolled. Clinical examinations were used to indicate the presence or absence of hypermobile anterior edentulous soft tissues. Existing occlusal relationships were qualified as anterior tooth contact only, posterior tooth contact only, or occlusal contacts involving both anterior and posterior teeth. Prostheses were judged based on retention and stability. Participants provided information on nocturnal denture wear, denture age, and duration of complete maxillary edentulism. Chi-square statistics and logistics regression analysis were used to identify variable effects.

Results indicate that both the presence of anterior teeth and the duration of edentulism were risk factors for deterioration of the anterior maxillary denture foundation. Individuals with edentulous maxillae and natural mandibular anterior teeth are approximately twice as likely to display hypermobile maxillary soft tissues compared with edentulous patients. Additionally, patients having maxillary edentulous periods exceeding 30 years are at 4-fold increased risk of hypermobile maxillary anterior soft tissues. Although qualitative outcomes were not surprising, quantifying common clinical circumstances yielded therapeutically valuable information.

Partial removable dental prosthesis (PRDP) design has been implicated in optimal transference of functional loading to the supporting tissues. In the design of extension-base PRDPs, reducing the number of prosthetic teeth (reducing occlusal support length [OSL]) has been suggested to decrease overload of underlying residual ridges and preserve associated abutments during mastication. However, reducing the number of denture teeth may adversely influence masticatory efficiency. An investigative team evaluated

the immediate influence of reduced OSL on masticatory function in patients with extension-base PRDPs.[222]

Twenty-three participants (5 men, 18 women; mean age, 55 years) with maxillary edentulism, mandibular Kennedy class I partial edentulism (canines and incisors remaining), and moderate residual ridge resorption were enrolled. Optimal dental health was assured and included the provision of new maxillary complete dentures and mandibular cobalt-chromium framed PRDPs. Bilaterally balanced occlusion through second molars was used. The participants wore their new prostheses for 2 months before experimental observations.

Standard tests were used to measure masticatory performance, masticatory efficiency, chewing rate, bolus selection chance, bolus breakage function, and cyclic masticatory patterns. Initial testing (baseline data) occurred at 2 months after new prosthesis placement. Subsequent testing occurred at weekly intervals, accompanied by the bilateral elimination of the most posterior denture teeth to sequentially reduce the OSL. Second molars were first to be eliminated, followed by first molars, then second premolars, and finally first premolars. Masticatory function data were collected and analyzed.

Results indicated that masticatory performance, masticatory efficiency, bolus selection chance, and bolus breakage function all deteriorated with reduction of OSL. Additionally, more masticatory strokes per minute were required as the OSL was reduced. However, comparison of mandibular movement patterns during mastication for the various OSL conditions found no differences.

The authors concluded that a reduction of OSL adversely affected overall masticatory function. Decreased masticatory performance and efficiency associated with reduced OSL was related to a diminished capacity to select and break down food. Similar mandibular movement patterns for different OSL conditions likely reflected time-dependent learning required to reestablish masticatory patterns. The masticatory benefits afforded by optimal OSL should be considered when accomplishing prosthodontic rehabilitations involving extension-base removable partial dentures (RPDs).

Denture stomatitis (DS) is a chronic problem affecting wearers of complete dentures. Although a definitive etiology has not been determined, association between wearing complete dentures and DS is clinically evident. Prevalence of DS ranges widely in edentulous patients, but little consensus has been reached regarding the effect of DS on RPD wearers. With this in mind, one group systematically reviewed published data for the occurrence of DS and potential risks in PRDP populations.[223] The specific question addressed in this systematic review was this: Is wearing a PRDP associated with a high prevalence of DS in partially edentulous individuals?

A search of reports published between 1950 and 2010 resulted in identification of 1152 citations with general relevance. After application of specific exclusion criteria, 8 publications were selected. In general, these publications were observational studies, representing moderate to low level of evidence.

Results indicated that the prevalence of DS in PRDP wearers ranged from 1.1% to 36.7%. Available data on potential risk factors were unclear, although PRDP wearers seemed to be less affected by DS than were wearers of complete dentures. Vitamin A deficiency and diabetes mellitus may be predisposing factors, and tissue trauma, denture base material, prosthetic support, and PRDP instability may all have a role in the development of DS in PRDP wearers.

The authors were careful to indicate that definitive cause-effect relationships could not be inferred from available data owing to methodologic limitations and the cross-sectional design of published research, and they suggested that future research efforts should seek use of higher levels of evidence to investigate the etiologic basis for DS in PRDP wearers.

Conventional fixed prosthodontics

With the ever-increasing demand for highly esthetic dental restorations, the profession must continuously critically evaluate clinical success rates associated with new esthetic materials and processes. One group reported on a clinical retrospective study evaluating the quality, success rate, and estimated survival rate of silicate glass ceramic restorations in both dental arches with up to 20 years of follow-up.[224]

This study involved 1335 ceramic restorations (470 crowns, 318 veneers, 213 onlays, 334 inlays) placed in 302 participants (120 men, 182 women) between 1987 and 2009. Mean participant age at the time of restoration placement was 47 years. All restorations were prepared, processed, and placed in accordance with accepted guidelines for the time. Evaluative data consisting of esthetic match, porcelain surface quality, marginal discoloration, and marginal integrity were gathered by 2 calibrated dentists using the California Dental Association and Ryge criteria.[225,226]

Kaplan-Meier survival analysis of all 1335 restorations yielded estimated survival rates of 97.3% after 5 years, 95.6% after 8 years, 93.5% after 10 years, 85.5 % at 15 years, and 78.5% at 20 years. Twenty-four restorations remained in service after 20 years. Ninety-five ceramic restorations were rated as failures, mainly owing to ceramic fracture. Increased failure was associated with parafunction (bruxism) and nonvital abutments. Cement type was significantly associated with the probability of restoration failure. The authors concluded that within the limitations of this up-to-20-year retrospective clinical analysis, good clinical outcomes for silicate glass ceramic crown, veneer, onlay, and inlay restorations can be expected.

The year 2012 was replete with published information on zirconia-based dental restorations. Relatively recent advances facilitate the use of zirconia in the fabrication of partial fixed dental prostheses (PFDPs)

possessing relatively high strength and reasonable esthetics. Investigators conducted a systematic review to qualify zirconia-based PFDPs in terms of survival and clinical complications.[227] This review also addressed techniques for veneering zirconia frameworks with porcelain by means of pressing or conventional layering methods.

A search of peer-reviewed clinical studies published between 1999 and 2011 was conducted. Based on the prescribed inclusion/exclusion criteria and the relatively short time in common clinical use, only 12 articles involving clinical studies on zirconia-based PFDPs were identified, and only 1 RCT was available. Unfortunately, owing to the relatively low number of identified studies, no statistical comparisons were possible.

Short follow-up times, small sample sizes, the lack of guidelines for qualifying porcelain chipping, and general protocol heterogeneity made drawing definitive conclusions impossible. However, complications of note included marginal discrepancy, secondary caries, chipping of veneering porcelain, abutment failure, and framework failure. Authors concluded that available clinical data may support the use of zirconia-based PFDPs for anterior and posterior restorations. Although data were limited, there was some indication that the press-to-zirconia technique yielded better clinical outcomes when compared with conventional porcelain veneer layering of zirconia frameworks.

A second systematic review addressed clinical fracture incidence of tooth-supported ceramic crowns with respect to restored tooth type. The group searched literature published between 1990 and 2011 to identify clinical studies that reported crown fractures with mean follow-up periods of 36 months or greater.[228] Thirty-seven articles fulfilled inclusion criteria: 2 RCTs, 25 prospective cohort studies, and 10 retrospective studies. Of these, 8 reported on densely sintered alumina crowns; 10 reported on crowns fabricated with a glass-infiltrated technique; 6 involved feldspathic porcelain crowns; 5 reported on glass ceramic crowns; 4 dealt with crowns fabricated with lithium-disilicate-reinforced glass ceramic; 6 reported on leucite-reinforced glass ceramic crowns; and 2 focused on zirconia-based crowns. Consistent with the previously reviewed systematic review, these authors found "veneer fracture" and "chipping" to be poorly defined clinical conditions.

Results found acceptable overall 5-year fracture rates of 4.4% regardless of material used in fabrication. Anterior ceramic crowns were associated with significantly fewer fractures (3.0%) compared with posterior crowns (5.4%). Molar ceramic crowns had significantly greater 5-year fracture rates (8.1%) than did premolar crowns (3.0%). The 5-year fracture rate of ceramic crown cores was 2.5%, with a significantly greater core fracture rate in posterior regions. The 5-year ceramic crown veneer fracture rate was 3.0%, demonstrating no significant differences between tooth types.

The authors concluded that currently available ceramic crown materials seem to have clinically acceptable 5-year core and veneer fracture rates for restorations placed on natural teeth throughout the dental arch. As is the case with most systematic reviews in the dental literature, it was recommended that more RCTs with large sample sizes and adequate follow-up periods be undertaken to obtain more definitive conclusions.

As previously mentioned, failure of the veneering porcelain in zirconia-based prostheses is a common clinical problem, with failure modes that include surface crumbling, chipping, spalling, fracturing, and delamination. Residual stresses related to heating and cooling conditions during fabrication have been implicated, but a clear understanding of the problem and guidelines for correction remain unavailable. Investigators sought to shed light on the problem by measuring the influence of heating and cooling protocols in vitro on the strength of porcelain fused to zirconia.[229]

Fifty-four tetragonal polycrystalline zirconium dioxide beams measuring 31 mm in length, 6.5 mm in width, and 1.35 mm in thickness were prepared with airborne particle abrasion to receive porcelain. Rectangular porcelain buttons measuring 6.5 mm in length, 6.5 mm in width, and 4 mm in height were applied (4 firing cycles) to the central aspect of one side of each beam. Although clinically unrealistic, sample design was intended to facilitate interfacial failure. Three heating rates (25°C, 50°C, and 75°C/min) and 3 cooling regimens (fast, moderate, and slow) were used during porcelain application. Specimens were subjected to a modified 4-point flexural loading protocol in which porcelain buttons were located on the zirconia beams directly opposite the 2 central loading elements of the test fixture.

Specimen failure resulted in visually intact porcelain buttons and intact zirconium beams. Fractographics revealed that failure occurred with porcelain buttons separating from zirconia beams near, but not at, the porcelain-to-zirconia interface. This failure pattern indicated the development of substantial internal porcelain stresses near the interface. Slower cooling and heating regimens resulted in significantly higher failure forces, with the effect of the cooling regimen being significantly greater than that of the heating regimen. The use of slow heating and cooling rates resulted in the approximate doubling of the strength of the specimens.

Within the limitations of this in vitro study, the authors concluded that slow heating and cooling rates should be used when firing porcelain fused to zirconia prostheses. Specimen failure localized within porcelain adjacent to the porcelain-zirconia interface suggested that residual stresses of thermal origin within the porcelain led to cohesive failure close to the zirconia material. Interested readers are strongly encouraged to review this publication for its detailed discussion of current considerations in this area of inquiry.

The function of a post is to assist in structural retention of the core used to support a coronal restoration and to

favorably distribute loads of occlusal origin to the tooth and dental supporting structures. Use of a post that fails to satisfy these requirements may lead to restoration failure, fracture of the post, or catastrophic failure of the tooth. Ongoing controversy exists regarding optimal post elastic modulus, post space dimensions, use of ferruled tooth preparation, and benefit of adhesive luting, to name a few.

Interested in the effect of post rigidity, one group examined the marginal leakage pattern of complete-coverage restorations retained by either metal posts or fiber-reinforced resin posts under simulated, but clinically realistic, occlusal loading conditions.[230] Thirty-six maxillary central incisors of similar morphology were acquired. Crowns were amputated 1.5 mm coronal to the CEJ, and root canal therapy was completed. Tooth preparations included a 1.5-mm ferrule for complete-coverage crowns. Post space was prepared to a depth of 9 mm. All teeth received either a prefabricated tapered (2.0-1.3 mm diameter) quartz-fiber-reinforced resin post or a prefabricated parallel-sided (1.5 mm diameter) stainless steel post. All posts were adhesively placed. All teeth received composite resin cores. Complete-coverage crowns with palatal loading platforms were fabricated and adhesively luted. Specimens were equally and randomly divided into 3 groups: fiber posts loaded, metal posts loaded, and fiber posts not loaded (control). Experimental groups were subjected to loading at 2.0 Hz for 120 000 cycles while immersed in dye. The unloaded control group was also immersed in dye. All teeth were sectioned and photographed to assess marginal dye penetration.

All specimens remained intact throughout the experiment, with no crown dislodgements and no tooth fractures. Dye penetration occurred in all specimens and was particularly extensive along palatal margins. The loaded-fiber-post group had a significantly greater amount of leakage compared with the control group and the loaded-metal-post group.

Within the limitations of this study, the authors concluded that owing to inherent materials properties, the metal post system used was associated with improved marginal sealing of crowns under loading conditions as compared with the fiber posts. The authors emphasized that marginal leakage of crowns invariably preceded failure of post-and-core supported restorations and should be considered a precursor to treatment failure, be it restorative or endodontic. This experimental effort successfully simulated reasonable clinical conditions to obtain valuable information that is both clinically practical and conceptually necessary when considering future research in this topic area.

Implant-assisted removable prosthodontics

Compromised neuromuscular coordination and inadequate oral functional capacity have long been recognized as clinical consequences of edentulism, particularly for those with severe mandibular atrophy. Obstacles to therapeutic success relate primarily to deterioration of the mandibular denture foundation leading to unsatisfactory prosthesis stability. The use of dental implants is a popular approach to improving the prosthodontic foundation, thereby facilitating prosthesis retention, support, and stability. However, a question remains: Does the perceived improvement in prosthesis stability afforded by dental implants correspond to an improvement in the long-term neuromuscular status for patients with severe mandibular atrophy?

To address this question, investigators conducted a clinical study involving 11 participants with conventional complete dentures (6 men, 5 women; mean age, 73 years) and 11 participants wearing maxillary complete dentures and mandibular overdentures with 2-implant support (3 men, 8 women; mean age, 80 years).[231] In both groups, the participants had acclimated to existing oral conditions, having worn their prostheses for approximately 13 years. All prostheses were originally fabricated at the same treatment facility using standard methods and incorporating bilateral balanced occlusion. Although otherwise healthy, all participants were judged to have severe mandibular atrophy. To qualify neuromuscular status, kinesiographic parameters (masticatory movements and velocities) were measured by using electronic mandibular tracking, and muscle activity (bilateral masseter and temporalis muscles) was recorded by using surface EMG. All recordings were made during mastication of a synthetic test food.

Results indicated that vertical mandibular opening, horizontal mandibular movements, and maximum opening velocity during mastication were statistically similar between groups. Maximum closing velocity during mastication was significantly improved for participants with implant overdentures. Greater bilateral masseter and temporalis EMG activity was recorded in these participants, with differences being highly significant.

The authors concluded that a significant increase in maximum masticatory closing velocity for implant overdenture wearers may be related to greater mandibular prosthesis stability and improved confidence during the critical masticatory closing stroke. EMG activity was approximately 100% greater for participants with implant overdentures. When compared with elevated EMG reference values from healthy dentate individuals, the increased EMG activity in participants with implant overdentures may indicate a tendency toward normalization. Because participants enrolled in this investigation had been wearing their prostheses for approximately 13 years, the authors suggested that the neuromuscular status achieved will likely continue. Therefore, compared with conventional complete dentures, the provision of a 2-implant mandibular overdenture seems to provide edentulous patients affected by severe mandibular atrophy with improved masticatory function.

To continue this line of inquiry, a second study published in 2012 addressed masticatory performance with removable prostheses in a similar fashion.[232] Investigators compared the masticatory performance of individuals with implant overdentures, conventional complete dentures, and natural dentitions by studying the overall amount of mandibular movement during mastication.

Thirty individuals (17 men, 13 women; mean age, 53 years) were enrolled. Ten edentulous participants received new complete dentures fabricated with bilateral balanced occlusions; 10 edentulous participants received 2 interforaminal implants with ball attachments, a new maxillary complete denture, and a new mandibular overdenture fabricated with bilateral balanced occlusions; and 10 dentate participants served as controls. All new prostheses were worn for 4 weeks before testing. To quantify masticatory performance, kinesiographic parameters (maximum opening and masticatory movement area) were measured by using electronic mandibular tracking, and bolus preparation (test food comminution efficiency) was evaluated by using graduated sieve food particle processing. All recordings were made after 15 cycles of synthetic test food mastication.

When considering test food bolus comminution, results indicated that individuals with natural dentitions performed best, and participants with overdentures performed significantly better than did wearers of complete dentures. With maximum mouth opening as an indicator of masticatory performance, both dentate individuals and participants with overdentures performed significantly better than did those wearing conventional complete dentures. Finally, the maximum area traversed by mandible masticatory movements was significantly greater for dentate individuals, but statistically similar for individuals with overdentures and complete dentures.

Within the limitations of this in vivo study, the authors concluded that the observed masticatory performance of participants with implant overdenture was superior to that of wearers of complete dentures. This study contributes to the growing volume of evidence supporting the physiologic benefits of improving the edentulous mandibular denture foundation with 2 interforaminal implants before removable prosthesis fabrication.

If masticatory performance improves for patients with implant overdentures compared with those with conventional complete dentures, as indicated in 2 studies,[231,232] does this newfound improvement in masticatory performance also affect diet in some qualitative or quantitative manner? An investigative group posed this question when it assessed the dietary intake of edentulous adults dissatisfied with their existing mandibular complete dentures.[233]

An RCT, 2 years in duration, enrolled 53 healthy participants. All participants possessed conventional complete dentures of reasonable quality, but all expressed dissatisfaction with their mandibular prosthesis. Participants were randomly distributed to 2 experimental groups: a denture reline group (10 men, 16 women; mean age, 67 years) and an implant overdenture group (10 men, 17 women; mean age, 68 years). Those in the reline group received laboratory-based mandibular denture relines to optimize conventional prosthesis fit and stability. Participants allocated to the implant group received 2 interforaminal implants and a subsequent chairside reline procedure to optimize prosthesis fit and pick-up Locator (Zest Anchors, Escondido, Calif) attachments.

At 4, 8, and 11 months after treatment, 3 unannounced 24-hour dietary surveys were obtained from all participants by phone. The data collected included nutritional intake, food selection, amounts consumed, and perceived masticatory ability. Additionally, a self-administered questionnaire was completed by each participant at baseline, 3 months, 6 months, 1 year, and 2 years. Information sought included demographics, height, weight, food avoidance, and oral conditions.

Results indicated no statistically significant differences in dietary or energy intake between complete denture and implant overdenture groups: intake levels of proteins and of fats were above recommended levels; intake of vitamin D was at the recommended level; and intake of carbohydrates, vitamin C, folate, and fiber were below recommended levels. The implant overdenture group reported significantly less food avoidance, perceived an improvement in their general masticatory ability, and conveyed a greater capacity to consume more of certain foods. However, mean body mass index did not change in either group over the 2-year course of the investigation.

Within the limitations of this clinical study, the authors concluded that no measurable difference in dietary intake exists between edentulous patients wearing maxillary complete dentures opposing either relined mandibular complete dentures or mandibular implant overdentures. Unfortunately, the nutritional intake for both groups was substantially inadequate. Claims of improved masticatory ability, increased food consumption, and reduced food avoidance made by patients with implant overdentures should be interpreted carefully. Favorable claims of this type may be justification of recent significant dental therapy rather than indication of true masticatory improvement. Additional investigations into the effect of edentulous therapy on diet are necessary.

In support of the profession's general acceptance of implant overdentures as the preferred treatment for mandibular edentulism, a substantial volume of professional literature devoted to this subject area has developed. Comparatively few publications address maxillary implant overdenture treatment, particularly from prosthesis design and maintenance perspectives. Because management of overdenture complications can be time consuming and financially burdensome, reliable

maintenance data are required. With this in mind, investigators conducted a systematic review of existing literature on prosthodontic maintenance requirements for maxillary implant overdentures that incorporate various prosthesis designs.[234]

Initially, 28 relevant reports on maxillary implant overdentures, which detailed issues of maintenance, were identified. Of these, 18 studies fulfilled inclusion criteria; 10 were retrospective studies and 8 were prospective investigations. Clinical patient follow-up in these studies ranged from 3 months to 10 years.

Reports indicated a general consensus that the prosthodontic maintenance requirements of maxillary implant overdentures are a direct consequence of attachment systems, number of implants, and implant distribution. Attachment system management and denture adjustments were the most frequently encountered maintenance requirements. Defining the extent of this maintenance was impossible, particularly because early reports may be confounded by out-of-date attachment technology. Abutment screw loosening and overdenture base fracture were frequently reported. A comparison of maintenance requirements between splinted and nonsplinted attachment systems was hindered by study heterogeneity and small sample sizes. The lack of controlled trials prohibited comparison of maintenance related to plastic and metal clips. From a biologic perspective, the higher incidence of mucosal hyperplasia associated with bar attachment systems likely relates to design considerations (mucosal proximity and negative pressure beneath denture).

The authors concluded that the available literature does not provide clear consensus for prosthodontic maintenance requirements related to maxillary overdentures, citing a lack of prosthesis and attachment design standardization. Development of universally accepted criteria for overdenture maintenance reporting may assist in accurate comparative data generation and analysis in the future.

Implant-assisted fixed prosthodontics

Recent technologic advances in 3-dimensional imaging, surgical planning software, and surgical guidance systems have evolved to facilitate accurate, restoratively based implant placement in advanced cases requiring multiple implants. The accuracy of these technologies must be ensured to optimize restorative plans. Concerned about the performance of computer-based surgical implant guidance, researchers compared the accuracy of 3 surgical guide approaches: bone-supported, tooth-supported, and mucosa-supported guides.[235]

A CBCT image of an edentulous patient was used to fabricate 3 groups of stereolithography (SLA) resin mandibles: 10 models remained edentulous with osseous external contours, 10 remained edentulous with soft tissue external contours simulated by a 2-mm soft acrylic resin surface coating, and 10 models were modified to include 2 canine and 2 first molar teeth. Virtual placement of 5 implants in each model was accomplished by using 3-dimensional treatment planning software. SLA surgical implant placement templates were fabricated for all experimental models. Templates differed only with respect to available support mechanisms (bone support, tooth support, or mucosa support). Implant placement was accomplished by using a drill sleeve guidance system that accurately interfaced with surgical templates. The accurate transfer of virtual implant planning was measured by comparing presurgical virtual implant positions to postsurgical actual implant positions by using superimposed CBCT images.

The results of this in vitro study indicated no significant differences among surgical template systems when comparing angular implant deviations; the greatest was approximately 2.3° and the least, 2.2°. Mucosa-supported templates were less accurate than either bone- or tooth-supported templates with respect to linear deviations measured at the implant neck or apex, with an average deviation of only slightly more than 1 mm between planned and placed implants. The authors concluded that CBCT-designed and SLA-fabricated surgical templates provide a reliable method for accurate implant placement. Similar in vivo studies should follow to ascertain the effect of more clinically realistic conditions on the accuracy of this surgical approach.

Replacement of a single missing tooth by means of an implant-supported restoration is a viable consideration owing to proven predictability, favorable durability, and the ever-growing interest in implant dentistry expressed by informed patients. However, in private, general-practice, fee-for-service settings, there may be limited consistency in decision-making processes related to the replacement of single teeth. Therefore, researchers investigated the frequency of identifiable factors associated with decisions to accomplish single implant therapy after single tooth extraction by general dentists in the private sector.[236]

Ninety-four randomly selected general dentists (52 men, 42 women; mean age, 49 years) were enrolled in the study. Dentists agreed to report all single tooth extractions owing to caries, periodontitis, or fracture over the 8-week duration of the study. For each patient involved, dentists reported the following: restorative treatment selected, demographics, socioeconomic factors, medical parameters, oral/dental parameters, and smoking status. Dentists also reported the following personal data: demographics, work load, experience with conventional prosthodontics, and experience with dental implants.

A total of 900 single tooth extractions were reported, with 42% (n=374) electively remaining unrestored. When tooth replacement was deemed necessary (n=526, 50% men; mean age, 56 years), 54% selected a partial removable dental prosthesis, 24% chose a partial fixed dental prosthesis, 21% opted for

single implant treatment, and only 1% received resin-bonded prostheses.

Multinomial logistic regression indicated that, compared with removable restorations, the selection of implant therapy was more likely in highly educated patients with fewer missing teeth and periodontally healthy adjacent teeth. Relative to a partial fixed dental prosthesis, implant therapy was more likely in patients with healthy adjacent teeth and when extractions were performed by female dentists. Finally, the dentist's experience with implant therapy was highly predictive of the provision of an implant solution for a single missing tooth.

The authors concluded that in the private, fee-for-service setting studied, only a relatively small percentage of patients electing to restore a missing tooth after a single extraction chose implant therapy. More patients chose either conventional removable or fixed prosthodontic restorations. When implant therapy was chosen, the patient's education level and specific oral factors, as well as particular clinician-related factors, affected the decision-making process.

Although clinical reports are not typically included in this annual review, one that appeared in the 2012 literature is noteworthy. Many dentists choose to use familiar clinical procedures to cement, rather than screw-retain, single implant crowns. Unfortunately, the retrieval of residual excess cement (REC) from the structurally unique periimplant sulcus presents a practical problem with significant clinical consequences. For practical consideration, researchers reported 4 patients with varying expressions of REC, radiographic detectability, and patterns of excess cement flow.[237]

The first patient indicated the consequence of REC on the facial aspect of an implant abutment with subsequent persistent soft tissue inflammation. Radiographic superimposition of the REC rendered the material undetectable except by surgical exposure of the area for physical debridement. The second patient illustrated the advantage of highly radiopaque cement and mesiodistal REC making radiographic detection possible. Removal of the crown-abutment complex provided the necessary clinical access for complete REC removal. The third patient highlighted the radiographic presence of both REC and associated periimplant crestal bone loss related to a restoration cemented 9 months earlier. Although radiographic detection of the REC was limited to mesial and distal surfaces, this now-classic radiographic pattern is highly indicative of a circumferential problem. The site was treated successfully with closed debridement. The fourth patient detailed the consequence of radiolucent luting agents. In spite of immediate postcementation radiography to evaluate for REC, use of radiolucent cement renders radiographic detection nearly impossible. Significant amounts of REC may persist, undetectable to the clinician, for extended periods, with significant biologic consequence.

The authors concluded that the association of REC with periimplant disease necessitates meticulous implant crown cementation protocols, including immediate and thorough removal of all cement remnants. Unfortunately, tactile detection of REC alone is both problematic and unreliable. When excess cement flows to mesial and distal intracrevicular aspects of the restoration-abutment complex, radiographic detection may or may not be possible. Therefore, the value of radiopaque luting agents in the detection of REC should be considered.

A significant number of published articles in 2012 focused on the profession's current fascination with zirconia as an indirect restorative material. Several articles in this annual review involve this material. As discussed previously, the all-too-often failure of veneering ceramics in zirconia-based restorations is a concern. A better understanding of the failure modes of implant-supported ceramic restorations is required. A fatigue study compared the mode of fracture and number of load cycles to failure for ceramic and metal ceramic implant-supported restorations.[238]

This in vitro study included 4 groups of 8 implant-supported single maxillary canine restorations: (1) a test group of glass ceramic fused to zirconia restorations luted to standardized zirconia abutments, (2) a second test group of feldspathic porcelain fused to zirconia restorations luted to standardized zirconia abutments, (3) a control group of glass ceramic fused to gold alloy restorations luted to standardized titanium abutments, and (4) a second control group of feldspathic porcelain fused to gold alloy restorations luted to standardized titanium abutments. All restorations were exposed to cyclic loading (800 N, 2 Hz, 4.2 million cycles or until failure) on a universal test machine against their palatal surfaces at 15° to the implant's long axis.

Failure modes observed included fracture line formation within the veneering ceramic, veneer chipping, minor veneer fracture, and major veneer fracture. No catastrophic crown, abutment, or implant failures were observed. Veneer fracture was the most common failure mode observed, with the severity of veneer fracture being significantly greater in ceramic restorations compared with metal ceramic restorations. Of the restorations observed, glass ceramic fused to gold alloy crowns withstood significantly more load cycles until veneer failure.

The authors indicated that within the limitations of this in vitro investigation, metal ceramic complete-coverage implant-supported crowns had fewer and less-severe failures under clinically realistic cyclic loads than did ceramic crowns. Additionally, metal ceramic crowns resisted a significantly greater number of cyclic loads before failure than did ceramic crowns. The authors correctly recognized the limitations of this study and suggested that more definitive conclusions regarding the long-term performance of different implant restorations require carefully designed and controlled in vivo investigations.

Prosthodontic biomechanics

An appreciation for the effect of biomechanics on successful planning, implementation, and maintenance of

dental implant restorations is critical to sound therapeutic application. Careful evaluation of treatment outcomes and maintenance requirements is essential in forming this important biomechanical perspective. One excellent article systematically reviewed prospective clinical trials reporting on biologic and mechanical complications associated with implant-supported fixed complete dentures (ISFCD) in edentulous participants over a period of 5 years or more.[239]

A search in this subject area for publications between 1980 and 2010 that fulfilled inclusion criteria yielded 7 articles: 1 RCT and 6 prospective studies. Cumulative data included 281 one-piece ISFCDs supported by 1392 implants with an average time-in-function of 9.5 years. Although both metal resin and metal ceramic restorations were included in the review, metal resin restorations were more common.

The total number of complication events was 653, with an estimated complication rate of 24.6% per 100 restoration-years. The most common biologic complications were periimplant bone loss and hyperplasia of soft tissue around the prosthesis. The most common mechanical complications were abutment screw fracture and chipping/fracture of veneering materials. Prostheses free of complications were reported at a rate of 29.3% after 5 years and 8.6% after 10 years in service.

The authors noted that identified problems, such as screw fracture, may have been associated, to a large extent, with early and inferior technology. Improved screw designs with higher preload capabilities have substantially decreased the occurrence of screw loosening and fracture. Careful evaluation of other complications identified in this review may be similarly influenced by advanced technology. However, this systematic review clearly found that biologic and mechanical complications occur frequently with ISFCDs. Although the problems discussed may not result in catastrophic restoration failure, they frequently lead to time-consuming and costly repairs. Patients who elect to pursue ISFCD therapy should be adequately informed of potential biomechanical problems, as well as expected investments of time and money for maintenance and repair.

As was evident in the previous report, in spite of high survival rates, complications related to dental implant restorations persist. The etiology of these biomechanical complications was the focus of another systematic review.[240] The specific question posed was this: How can biomechanical dental implant complications be identified and managed?

A search of pertinent literature from before May 2011 yielded 15 publications that satisfied inclusion criteria: 3 prospective studies and 12 retrospective reports. Close examination of this material indicated that bruxism or other parafunctional activities were related to increased susceptibility to biomechanical implant complications and periimplant bone loss. Unfortunately, specific cause-effect relationships for the suspected biomechanical etiologies proposed could not be definitively ascertained. Two factors cited as prohibiting etiologic determinations were (1) ethical concerns hindering investigation of occlusal overload in human clinical trials and (2) limitations related to retrospective study designs. The authors suggested that well-designed clinical trials addressing implant occlusion must become a focus of the profession.

The balance of this report provides detailed discussion of occlusion and biomechanical occlusal overload of dental implant restorations. Potential complications secondary to biomechanical overload were addressed and may include framework fracture, framework veneer failure, screw loosening/fracture, failure of the acrylic resin denture base, implant fracture, periimplant bone loss, and loss of osseointegration. A detailed clinical regimen intended to minimize implant biomechanical complications was offered, including careful pretreatment examination and patient selection, meticulous treatment planning, strategic prosthesis design, and protection of the definitive restoration from functional overload.

Natural teeth benefit from periodontal ligament mechanoreceptors that are sensitive to load and aid in the adaptation of centrally generated mandibular movement patterns by providing afferent feedback on magnitude, direction, and rate of occlusal load. To some extent, this neurophysiologic integration of occlusion is lost when natural teeth are removed. A pilot study designed to better understand the level of neurophysiologic integration remaining for edentulous participants restored with maxillary and mandibular ISFCDs was published in 2012.[241] The objective of this pilot investigation was to compare the tactile sensitivity (using both active and passive tactile thresholds) and maximum voluntary occlusal force of dentate participants to those of edentulous participants with dentition restored with either bimaxillary ISFCDs or conventional complete dentures.

Seven edentulous participants (5 men, 2 women; mean age, 66 years) wearing bimaxillary metal ceramic ISFCDs that had been functioning satisfactorily for 5 years were selected. Seven sex- and age-matched wearers of conventional complete dentures and 7 healthy dentate individuals were recruited to serve as experimental controls.

To determine active tactile threshold, 12 copper foils of decreasing thickness (from 700 μm to 5 μm) were introduced between opposing second premolars, and participants reported their ability to perceive the presence of the foil. Three active threshold levels were determined: (1) "100% threshold" was the thinnest foil that the participant could always detect, (2) "50% threshold" was the thinnest foil that could be detected half of the time, and (3) "absolute threshold" was the thinnest detectable foil. Passive tactile threshold was measured by using a strain-gauged probe that applied a continuously increasing force on a tooth until the participant indicated perception of the force. Passive

threshold testing was accomplished on 1 tooth in all 4 dental quadrants. Maximum voluntary occlusal force was registered by using strain-gauged central bearing devices custom-made for each participant.

Results indicated that significant differences existed between groups for active tactile threshold. The absolute and 50% active thresholds of dentate participants were lowest, followed by participants with ISFCDs, and finally wearers of complete dentures. Significant differences were also found between all groups for passive tactile thresholds. Participants with ISFCDs had higher passive thresholds than either dentate individuals or those wearing complete dentures. Interestingly, maximum voluntary occlusal force did not differ significantly between groups, likely owing to insufficient sample size in this pilot study.

The authors concluded that although active dental tactile perception (between opposing occlusal contacts) remained favorable for participants with ISFCDs, passive dental tactile perception (nonocclusal tooth loading) seems relatively impaired. The concept that patients with ISFCDs are capable of greater maximum occlusal force than dentate or complete-denture-wearing counterparts was not supported by this investigation, likely owing to the experimental design used.

As found by publications previously reviewed, prosthesis design substantially affects critical biomechanical conditions over the functional lifespan of dental implant restorations. Fabrication of accurately fitting restorations is a design feature that not only may have mechanical consequences in terms of screw joint stability and implant component durability but also may influence the biologic health of the periimplant soft and hard tissues. Because most dental implant restorations require laboratory processing, the use of accurate definitive casts is a prerequisite to passively fitting prostheses. One study retrospectively questioned the likelihood of achieving a clinically passive fit when an implant-supported complete-arch prosthesis framework was fabricated with and without the aid of a verification index.[242]

A search of dental treatment records in 1 facility identified 30 patients treated with 1-piece ISFCDs between 2005 and 2009. Each patient received a single metal ceramic or metal resin ISFCD supported by 4 to 8 implants. For 16 patients, an acrylic resin verification jig was used to develop an accurate working cast, whereas the treatment provided to the other 14 patients was accomplished on casts generated from definitive impression procedures.

Working casts in the verification group and definitive casts in the no-verification group were used to fabricate metal frameworks. After framework fabrication, fit was assured in the laboratory by visual assessment of the frameworks on the casts of origin using the Sheffield test.[243] Subsequently, during clinical evaluation appointments, clinical framework fit was evaluated intraorally again with the Sheffield test, relying on direct vision as well as periapical or panoramic radiographic means of fit assessment. The presence or absence of clinically discernible fit was recorded for data analysis.

Results indicated that when a verification index was used, all frameworks exhibited clinically discernible passive fit. When a verification index was not incorporated into the fabrication process, only 2 of the 14 frameworks were judged to have a passive fit. A highly significant positive correlation was determined between use of a verification index during fabrication and clinical fit of the framework.

Within the limitations of this retrospective investigation, the authors concluded that use of an accurately constructed verification index during fabrication of multiple-implant metal frameworks helped to ensure accurate fit of the definitive prosthesis. Some may question the overall value of a verification index given that its incorporation into the treatment regimen requires an additional clinical appointment and added cost. The authors counter by stating that use of a verification index is overwhelmingly beneficial, because it both facilitates accurate prosthesis fabrication and contributes to the short-term and long-term biomechanical stability of the treatment result.

ENDODONTICS

One article reported the results of patients drawn from 64 private general practices enrolled in the Practitioners Engaged in Applied Research and Learning Network (PEARL), which is funded by the National Institute of Dental and Craniofacial Research.[244] A retrospective study design was used to assess the outcome of primary, nonsurgical endodontic therapy and to evaluate risk factors associated with the success or failure of that therapy. All patients receiving primary endodontic treatment and subsequent definitive restoration 3 to 5 years previously were included. The study excluded teeth with incompletely formed apices and patients older than 70 years. Teeth serving as abutments or teeth undergoing orthodontic treatment were also excluded.

All patients meeting the inclusion criteria were invited to participate in the study; they were distributed across 230 sites. Ultimately, 64 sites participated in the study, enrolling 1323 participants. Eleven of those participants were deemed ineligible, leaving 1312 participants to be analyzed. Endodontists treated 32% of the participants, and general-practice clinicians treated the remainder. General-practice clinicians performed all restorative treatment.

Analysis of the data found that 19.1% of the endodontically treated teeth were classified as failures after a mean follow-up of 3.9 years. Teeth were deemed as failures if they were extracted, exhibited pain on percussion, had an evident periapical radiolucency, or required retreatment or surgical intervention. Factors associated with failure were absence of a post, teeth with multiple canals, necrotic pulps, and older participant age. Factors not associated with failure were the

provider (specialist or general-practice clinician), the number of visits to complete treatment, the endodontic technique used, the type of restoration placed, or whether or not antibiotics were prescribed.

There are significant problems with the sampling methods in this study. There were 1312 teeth in the study from 64 practices. The study ran for 4 years. Simple calculations reveal that only 5 teeth per year were treated in each practice. It seems highly likely that many endodontic procedures done in these practices were not included in the study, which creates a potentially skewed sample. A sample in a retrospective study needs to be a sequential sample, with every treatment accounted for. The sampling method in this study is a classic example of sampling out of the stream. The authors also did not account for teeth in which the endodontic procedure was not successfully completed. The recall period was short (3.9 years), and the participants in the study knew that the authors were studying outcomes, which leads to potential bias in selection.

The diagnosis of vertical root fracture (VRF) can be perplexing. One article attempted to assess the value of CBCT imaging in the diagnosis of VRF.[245] The study cited 6 previous studies that claim CBCT technology is a proven diagnostic tool for accurately detecting VRFs. The article is a case series report of 7 patients treated in a private-practice setting. All of the teeth evaluated in the study had one or more of the following symptoms: pain, swelling, sensitivity to percussion, palpation soreness, deep periodontal probing, or presence of a sinus tract. All of the teeth received CBCT imaging to determine if such imaging was of diagnostic value in detecting a VRF.

The authors claim the radiographic evidence from the CBCT scan was determinative in the diagnosis of VRF in all 7 teeth. In 4 of the 7 teeth, the VRF was confirmed by a flap procedure or extraction. In 3 of the 7 teeth, extraction was performed, but it was not mentioned that the VRF was actually confirmed. The authors list 5 radiographic findings that they claim are consistent with the diagnosis of VRF, and they imply that CBCT technology has great potential to assist in the detection of VRF and can provide diagnostic information that may prevent unnecessary treatment (ie, doing endodontic therapy on a tooth with a VRF).

This article has flaws in inferential reasoning and sampling errors. The 6 studies cited that purported to claim superior diagnostic accuracy for CBCT imaging had the same errors. Determining the diagnostic accuracy of any test involves finding its sensitivity and specificity. Especially in imaging, the pretest probability greatly affects those values. To claim that CBCT imaging improves diagnostic accuracy, it would be necessary to test it in the diagnosis of difficult situations, not in situations that were already suspected of VRF. In each of the teeth considered in this study, the pretest possibility of VRF was high, and the best that can be said based on these data is that CBCT is valuable in diagnosing VRF when it is not needed.

A considered critique of this article includes the following criticisms: (1) The study had significant recruitment and selection bias, because it selected only cases with a high prior probability of VRF. There were no difficult cases presented in the study. (2) The article makes no mention of the sensitivity or specificity of CBCT in the diagnosis of VRF. (3) The article gives no method to test for false-positive or false-negative findings and to determine how they may affect diagnostic accuracy considerations. (4) There are 5 radiographic findings listed that may well indicate a tooth has a VRF, but they can also be indicative of other conditions. They do not necessarily result in greater diagnostic accuracy and may well lead to greater errors. (5) The article does not address serious issues with reader variability, and it assumes that reading a CBCT scan is not fraught with potential error and that these findings are self-evident to everyone, when in fact they are not, as evidenced by the considerable research in the medical community about this issue. (6) A true test of the diagnostic accuracy of CBCT scans would involve a multiple-case, multiple-reader test evaluating both symptomatic and asymptomatic cases with occult fractures, oblique fractures, obvious fractures, and no fractures, and it would have a variety of readers with different skill and experience levels interpreting the images. This article is an example of a study in which the conclusions of the authors are not supported by the presented data.

A systematic review evaluating the radiologic diagnosis of periapical bone radiolucencies was published in 2012.[246] Of the 181 studies evaluated, only 26 fulfilled the inclusion criteria. The review found that there is insufficient evidence to conclude that the diagnostic accuracy of digital periapical radiographs is as high as that of conventional radiographs in detecting periapical radiolucencies. The review also concluded that there is insufficient support to determine whether the diagnostic performance of CBCT technology is greater than that of intraoral films in detecting periapical radiolucencies. The review further concluded that there is no scientific support for any radiologic technique that can distinguish granulomas from cysts or scar formation.

Although the conclusions in the review seem valid, the article does have weaknesses. Each study in the review should have been evaluated for sampling bias based on case type. None of the evaluated studies used a range of evaluators in their assessments. Because radiographs are read by clinicians with varied experience and training, an assessment of the evidence should include an assessment of difference between readers. There was no assessment of case difficulty in the review, and the test of any diagnostic procedure is in cases in which the diagnosis is difficult.

IMPLANT DENTISTRY

Researchers performed an RCT with 29 edentulous participants restored

with maxillary complete dentures and either an implant-retained overdenture or a mandibular complete denture.[247] The data indicated that implant-retained overdenture provided higher overall satisfaction, chewing experience, and denture retention in spite of no significant differences in terms of chewing efficiency. This emphasizes the importance of patient-based evaluation when studying treatment outcomes.

One elegant study found that the matrix for ball attachment with implant-retained overdentures did not have significant wear at 1 year but did at 3 and 8 years.[248]

A 10-year comparative study of single implants in the anterior maxilla with early and delayed placement of the restorations was published in 2012.[249] Twenty consecutively treated participants were provided with implants placed 4 weeks or 12 weeks after tooth extraction. The overall cumulative survival rates were 100% for implants and 90% for crowns. The mean marginal bone loss was less than 1.0 mm at 10 years in both groups. No differences could be found between the groups.

A 7-year report concerning 24 participants divided into 2 groups found similar outcomes in immediate load (7 days after surgery) versus delayed load.[250] Mean marginal bone loss was 1.31 $\pm$ 2 mm at 7 years.

One study evaluated different cements for crowns supported by implants.[251] Two hundred forty-one individuals with 166 PFDPs and 232 single unit restorations were retrospectively evaluated at a mean of 2.2 years. Approximately half of these restorations were cemented with "semipermanent" cements (calcium hydroxide or zinc oxide eugenol), whereas the other half received "definitive" cementation (zinc phosphate, glass ionomer, or resin-modified glass ionomer). The mode of cementation had no influence on any complications including retention loss with single crowns, but it did influence the loss of retention with PFDPs. It was concluded that implant-supported PFDPs must be cemented with "definitive" cement.

Thirteen participants and 77 implants were prospectively included in a study aimed at evaluating the accuracy of implant placement when using a mucosally supported stereolithographic surgical guide.[252] Accuracy of the implant placement was evaluated with a postoperative scanner, which allowed fusing the images of the placed implants with the images of the planned ones. Four deviations were recorded: global, angular, depth, and lateral. Global deviation was defined as the distance between the same center points of the same planned and placed implants. All deviations were evaluated at the coronal and apical centers of each implant. The mean deviation at the entrance point was 0.91 mm; the mean angle deviation was 2.6°. Deviations were larger in the apical portions of implants and increased with implant lengths.

A retrospective study found that an overdenture with 4 implants splinted with a bar gave the best results in terms of the oral hygiene impact profile score when compared with 2 unsplinted implants (with locators or balls) and with 3 implants either unsplinted or splinted with a bar.[253] Naturally this study does not provide intrapatient comparison owing to its retrospective nature.

Another 3-year randomized study compared the use of a clip versus a soft liner in mandibular overdentures for 2 groups of 15 edentulous men each.[254] The use of a soft liner provided easier handling and better comfort for the maxillary denture, fewer maintenance appointments, and less hyperplasia.

One interesting study evaluated 270 implant-supported fixed restorations, fabricated with gold and cobalt-chromium alloys, that were followed up for an average of 10 years.[255] No significant differences in clinical performance could be found between the 2 alloys. Given the lower cost of cobalt-chromium alloys, the authors concluded that because these alloys can be milled (avoiding the issue of casting shrinkage) and are dimensionally stable with high-temperature fusing ceramics, they should now be considered as the alloy of choice for implant-supported fixed prostheses.

Another group compared gold alloy castings to milled titanium frameworks in a 10-year randomized study.[256] One hundred twenty-six edentulous patients were provided with 67 titanium frameworks (23 maxilla and 24 mandible) and 62 gold alloy castings (31 maxilla and 31 mandible). Similar clinical outcomes for implants and prostheses were observed, suggesting, as did the previous study, that alternatives to gold alloys are viable.

One elegant study evaluating the efficacy of platform switching found a more coronal bone level around the platform-switched half of custom implants than around the conventional half.[257]

A 10-year, retrospective, private-practice chart-review study was performed on charts from 36 periodontal patients (test group) and 16 controls that received 138 and 35 implants, respectively.[258] It is of interest to observe that the cumulative success rate of implants was similar, with 99.3% and 100% in the test and control groups, respectively. However, 57 of the 63 surviving implants with bone loss (periimplantitis) were concentrated in the test (periodontal patients) group.

One study compared insertion time and torque of 21 tapered implants (Osseotite NT; Biomet 3i, Palm Beach Gardens, Fla) with those of 36 straight implants (Osseotite Implants; Biomet 3i).[259] The tapered implants provided shorter insertion time and higher insertion torque (26 N·cm versus 32 N·cm), but their success rate was 86% versus 100% for the straight-walled implants. Three of the tapered implants were lost during the 90 days submerged healing period.

Another study, an RCT with 255 participants, found that the oral-health-related quality of life (OHRQoL) questionnaires correlated well with the McGill Denture Satisfaction Instrument for the measurement of denture treatment satisfaction.[260] This correlation held before treatment and at 6 and 12 months after treatment. Masticatory ability and general oral condition are

the 2 variables of denture satisfaction that are significantly associated with OHRQoL.

One group of investigators published the first cross-sectional study comparing OHRQoL in participants with implant-supported restorations and PRDPs in partially edentulous individuals.[261] The implant-supported restorations provided higher OHRQoL scores than did the PRDPs.

An interesting study evaluated the effect of a periodontal maintenance program in participants with periimplant mucositis.[262] Eighty participants were identified as having periimplant mucositis around 1 or more implants 5 years after placement. Of these, 39 had followed a preventive maintenance program and 41 had no regular maintenance. The incidence of periimplantitis in the 2 groups combined was 31%. Periimplant mucositis progressed to periimplantitis in 44% in the no-prevention group and in 18% in the prevention group. This illustrates the modern concept of the critical importance of maintenance with implant patients.

An elegant study reported on the osseointegration process in a group of participants who had lost teeth owing to advanced periodontal disease and another group who had lost teeth for other reasons.[263] Nineteen participants were in the periodontal group and 17 in the "other" group. Implants were placed in the posterior maxilla in these volunteers and were left to heal for 3 months. At that time they were surgically harvested and examined histologically both for bone-to-implant contact and for the amount of bone between the implant threads. The authors did not find any differences in terms of osseointegration when comparing periodontally susceptible participants and others. This unusually elegant study emphasizes the focus of the soft tissue inflammatory reaction in periodontally susceptible patients and indicates that bone in itself is not affected, especially for future implants.

Investigators conducted a controlled trial to evaluate the effect of new conventional complete dentures versus a maxillary complete denture and implant-supported mandibular overdentures at 6 months and 1 year after delivery.[264] The results indicate that the participants wearing implant-supported overdentures were more likely to consume fruits and vegetables than were those wearing complete dentures.

An RCT compared outcomes among mandibular overdentures supported by different numbers of implants and different means of attachment.[265] There were 3 groups in the trial. One group consisted of 36 individuals with 2 implants and ball attachments. The second group had 37 individuals with 2 implants and a bar, and the third group had 27 individuals with 4 implants and a triple bar. The participants were recalled at a mean of 8.3 years. The third group had more marginal bone loss than did the other groups. Smokers also had greater bone loss than nonsmokers in all groups.

One study evaluated the accuracy and complications that occurred with computer-designed laser sintering surgical guides for flapless implant placement and immediate definitive restoration.[266] Sixty implants and 12 prostheses were placed in 12 participants. Implants and prostheses were followed up for various times ranging up to 30 months. Survival rates for implants were 98.33% and for prostheses were 91.66%. The complication rate was 34.41%, and 41.67% of the implants had an apical deviation >2 mm. The high complication rate and variation in actual implant position versus planned position indicated that computer-aided dental implant surgery requires considerable improvement and at best can be considered to be in the developmental stage.

A special issue of the *Journal of Clinical Periodontology* reports the Proceedings of the 8th European Workshop on Periodontology. One of the working groups of the workshop stated that future research is needed to capture the following outcome variables: periimplant tissue health, patient-reported outcome measures, and performance of implant-supported restorations.[267] The authors called for consensus on outcome measures in implant dentistry. Furthermore, they emphasized the need for clinical research to reduce the risk of bias by being a collaborative work with epidemiologists and clinical trials specialists as well as to comply with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) and Consolidated Standards of Reporting Trials (CONSORT) guidelines.

Along the same line, another group reviewed current success criteria in implant dentistry.[268] The authors proposed that success in implant dentistry should also focus on the "implant-prosthetic complex" as a whole.

One interesting article found significant numbers of biologic and technical complications in a review of 1 RCT and 6 prospective cohort studies of implant-supported complete fixed dental prostheses.[269] The study found that 20% of the implants had >2 mm of bone loss at 5 years, and 40% of the implants had >2 mm of bone loss at 10 years. The rates of technical complications were 71% at 5 years and 92% at 10 years. Chipping of the veneering material was the most common prosthetic complication, with 33% at 5 years and 67% at 10 years.

One study investigated the preferred point of mastication in 26 participants with implant-supported prostheses versus 24 participants with removable prostheses.[270] This point was determined by having the participants clench on a piece of gutta-percha. The preferred point was more posterior on those with implant-supported prostheses. No differences between the 2 groups were found with a self-assessed masticatory ability questionnaire.

An elegant clinical prospective comparative study found that the deeper the microgap between the implant and the abutment was positioned, the more inflammatory markers were found in the periimplant crevicular fluid.[271] The authors thereby added to

the theory that the microgap location is related to inflammation.

One study compared the accuracy of different impression techniques for restoring multiple implants.[272] The primary finding was that when impressions for multiple implants are made, splinting the impression copings with acrylic resin provides results superior to those with nonsplinting of the copings or with splinting with photopolymerized composite resin.

Another study with edentulous participants verified the results found in the previous study.[273] The splinted technique in this study generated more accurate definitive casts than the nonsplinted technique.

CONCLUSION

Clearly many investigations related to dental implants were published in 2012, and data from those studies have improved the evidence base. As has been mentioned in previous reviews conducted by this committee, sadly, many of the studies were poorly designed and underpowered. It is hoped that investigators in the future will heed the recommendations made in this review.

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