An enormous quantity of information related to restorative dentistry is published every year. Some of this information is science based, some appears to be science based but is not, and some is clearly based on anecdote, opinion, or represents marketing. All of this information may be of value; many clinicians have difficulty gaining access to much of the published information. Part of the problem with access is the sheer volume and number of publications, both peer-reviewed journals and trade publications. In addition, many studies related to restorative dentistry are currently being published in nondental journals involving disciplines that have interests in common with dentistry.

The real problem, however, for most clinicians is time. Most dentists subscribe to a few peer-reviewed journals and receive complimentary trade publications. In addition, they attend at least the minimum number of continuing education courses to maintain licensure and have access to information over the internet. However, many other variables compete for their time. Dentists, like it or not, are managing a small business, and this requires time and effort. They are also managing a team of auxiliary professionals, which can, at times, be difficult and frustrating. They are also spouses and parents, which clearly requires time and effort. They may serve as leaders in their communities. Most dental professionals also have personal interests and hobbies, in which they participate. In addition to acquiring the knowledge and skills required to provide appropriate contemporary restorative dentistry for their patients, they also are required to be aware of advances in the specialties so that their patients may receive those benefits if indicated.

With all of these activities, most clinicians are not able to access much of the available information, nor do they have the time to critically evaluate the information they have. This review is conducted partially to help clinicians find pertinent studies that are relevant to their practices and also to help critically analyze new information and the validity behind the science that produced that information. The reader is advised to read this review one section at a time, digest the changes that have occurred over the past year in that discipline, and then access any specific studies they may want to investigate in greater depth.

This analysis of the scientific literature for the year 2011 is divided into 7 sections: (1) dental caries and cariology; (2) pulp pathology; (3) periodontics; (4) dental materials; (5) occlusion and temporomandibular disorders; (6) prosthodontics; and (7) implant dentistry. Obviously, some studies may fall into 2 or more of these groups.

**DENTAL CARIES AND CARIOLOGY**

The understanding of dental caries, its processes, and its interaction in the human host continues to advance albeit slowly and methodically. The breadth and granularity of this...
year’s research continues to increase, while a holistic assembly of these data in systems biology is beginning to tie sometimes seemingly disparate research together to provide a better understanding of the disease. The diversity of publications about dental caries and related topics from allied disciplines and sometimes surprising sources is also ever expanding. These data may eventually lead to better diagnostics and preventive treatment therapies. This year’s publications were also rich in materials directly applicable to the practice of dentistry with a number of outstanding reviews.

Demographics

Dental caries has consistently been associated with economic disadvantage and the education level of the mother and the individual incurring the disease. This correlation is seemingly consistent across international boundaries as shown this year in well performed Finnish and Brazilian studies.1,2

There are an increasing number of publications related to statistical design and caries evaluation indices that are important to researchers in that they provide new approaches to data analyses that have the potential to yield a better understanding of the factors influencing dental caries.3,7

The health status of individuals and its influence on dental caries generated a series of clinically useful papers. Examples include asthma, essentially doubling the risk of caries in both the primary and permanent dentition;5 body mass index (BMI) with a direct association with the incidence of dental caries probably due to common lifestyle factors9; HIV infection in children, which increased the prevalence of dental caries;10, and systemic sclerosis (scleroderma), which may result in limited oral opening and the potential for treatment related adversity, especially for those on bisphosphonate therapy.11

North American Indigenous and Alaskan Native populations were once again noted as having serious health concerns by both the Centers for Disease Control and the American Academy of Pediatrics.12,13 Both groups note a high prevalence of disease in these populations and suggest water fluoridation, fluoride varnishes, and earlier interventions in children. These recommendations are not new, and the disease continues unabated in these populations.

Risk Factors and Assessment

Research in risk assessment and risk factors is designed to give the clinician or policy making entities information with which they can make informed clinical decisions or public policy. The usual suspects such as sugar consumption,14,15 including sports drinks,16 and lack of fluoride were validated as risk factors in this year’s literature. Enamel defects as identified by the World Health Organization (WHO) criteria17 were significantly associated with the development of caries in a cohort study of children from birth to 54 months of age.18 Defective margins and contacts (both too heavy and too light) on metal ceramic crowns are significantly associated with increased caries on adjacent teeth.19 So too is the absence of space in the maxillary labial segment of preschool children.20 The chronic use of methamphetamine and its connection to dental caries has previously been well documented. For the clinician, the other clinically relevant manifestations of chronic methamphetamine use are well reviewed.21

Prevention

Research into the prevention of dental caries followed predictable lines in 2011 with steady progress but no breakthroughs in behavioral, chemical, mechanical (sealants), or probiotic therapies. Of interest to the practicing clinician is a report on a hand-held water fluoride analysis unit that correlates highly with laboratory testing devices, allowing the optimum analysis of the patient’s water supply and titration of fluoride supplements.22 Chemically, fluoride in the form of silver diamine fluoride and fluoride varnish was investigated.23-25 Silver diamine fluoride research provided confirmatory evidence of its efficacy, while fluoride varnish (22 600 ppm applied 3 times per year) failed to reduce caries against an untreated cohort in a well conducted 3-year school-based trial.24 A systemic review of the chlorhexidine varnish treatment of root caries showed no conclusive evidence of benefit in patients with regular professional oral prophylaxis.27

Microbiology /Biofilms

The technologies being applied to understanding the putative pathogens and their in vivo ecology in dental caries is quite remarkable and is yielding an ever clearer, albeit currently incomplete, picture of the microbiology of dental caries. In the not too distant past, Streptococcus mutans (SM) was considered the primary pathogen in dental caries because of its ability to metabolize many sugars and produce a hardy biofilm, and because of its acidogenic and acidoduric nature. The plentiful elution of an acid waste product is still a formidable weapon for SM in its battle for resources in its environment since many of its competitors cannot tolerate low pH environments. Today the roles that SM and other organisms play in dental caries are being shown to be more diverse, and the knowledge of this study of dental biofilms is still evolving.

Genotypic methods, such as 16S rRNA gene sequence analysis, have become the standard bacterial identification technology, supplanting the use of phenotypic characteristics. This technology, developed in the 1980s, allows better analysis of the oral biome and gives rise to the identification of a larger number of potential pathogens such as Scardovia wiggsiae, Veillonella parvula, Streptococcus crista tus, and Actinomyces gerensceriae in early childhood caries.28
S. mutans glucosyltransferases (Gtfs) are increasingly seen as important in the generation of biofilms and the virulence of those biofilms. These Gtfs adsorb to enamel and synthesize glucans, which are adherent in all dimensions providing adhesion for other bacteria. They also adsorb to the surface of other oral bacteria converting them to glucan producers. Both of these actions enhance biofilm formation and are being studied as potential targets for emerging therapeutics.

Both the innate and adaptive immune systems were investigated as therapeutic strategies in the modulation of the oral biofilm. An interesting study of dendritic cells (messengers between the innate and adaptive immune systems) shows the complications of these attempts. In vitro, dendritic cells presented antigens and initiated the proliferation of T-cells in a normal manner. In vivo, with live bacteria, this did not work. Antimicrobial peptides (AMP) of the innate immune system for use against oral biofilm residents is reviewed by Bato et al and a representative example exploration of an individual AMP is found in the work of Liu et al.

For those who want to refresh their knowledge of the layered human immune system, many current resources exist on the web. An examples is: http://uhaweb.hartford.edu/BUGL/immune.htm#summary A current understanding is becoming imperative for understanding both periodontal diseases and dental caries.

Treatments

Treatments of dental caries can be viewed as the treatment of the lesions produced by the disease dental caries and treatment of the disease processes themselves. Clearly overlapping areas such as glass-ionomer restorations that elute fluoride, affect the disease process. Glass ionomer was investigated in a nonsurgical use to assess its effect on interproximal lesions. The test group of initial, noncavitated interproximal lesions was more likely to remain stable or regress radiographically than the control group (odds ratio [OR] 6.3 at 95% confidence with a confidence interval of 1.3 to 30.9.)

The predominant nonmechanical interventions investigated in 2011 were fluoride and chlorhexidine. The systematic investigation and suggested research protocols of natural products are reviewed in a publication by Jeon et al. A number of investigations in 2011 on natural plant extracts, including Evening Primrose (Oenothera biennis) and Prune (Prunus mume) extracts showed efficacy in treating dental caries. The mechanism of action of Evening Primrose appears to be a polyphenol in the extract that inhibits glucosyltransferase (Gtf) in S. mutans as reviewed above. An investigation of infiltration polymers showed that they are not effective in treating cavitated lesions.

A review of the benefits and risks of fluoride toothpastes in children showed that only those dentifrice formulations with greater than 1000 ppm fluoride were effective in reducing cavities. An increased benefit to increased fluoride content with only weak association to increased fluorosis was observed.

Dental erosion was reviewed and information provided on the biochemical aspects of erosion and the microscopic and macroscopic histopathology of the processes. An in vitro study of evolving anti-erosion products compared to conventional NaF products showed no increased benefit for the 4 anti-erosion formulas tested. Finally, Simonsen and Neal provided a succinct and clinically relevant review of dental sealant application.

PULP PATHOLOGY

A recommendation of many operative departments is to achieve a minimal thickness of 2 mm of combined base/liner/remaining dentin thickness between the definitive restorative material and the pulp. One of the challenges for the clinician when making decisions regarding pulpal protection is attempting to ascertain the remaining dentin thickness (RDT). An in vitro study attempted to determine if RDT under caries could be determined from a radiograph. Twenty-five individuals who were having a posterior tooth extracted and had a radiograph showing caries with remaining dentin thickness participated in the study. Before extraction, a periapical radiograph was made with F-speed film. After extraction, another film radiograph and a digital radiograph were made of the tooth. The tooth was then sectioned mesiodistally, and the caries was hand excavated until firm dentin remained, at which point the actual RDT was measured. Overall, only 25% of the radiographs demonstrated good agreement with the actual measurements. There was a general trend for the radiographs to
overestimate the RDT, although the films tended to show a greater overestimation than did the digital image. Controversy regarding what is the best pulp cap material continues. A retrospective clinical study evaluated the long-term success of direct pulp capping with calcium hydroxide. Over ten years, 1075 direct pulp caps performed by dental students and dentists at the dental school in Mainz, Germany were assessed. Pulp exposure was due to caries or trauma. Only teeth that had pulps assessed as being normal or as having reversible pulpitis with normal periapical radiographic findings were included. The exposure could be no larger than 1 mm² and with no-to-little bleeding after the exposure. Upon pulp exposure, the tooth was isolated with a rubber dam and disinfected with hydrogen peroxide until bleeding stopped and any coagulated blood was removed. The pulp was covered with soft calcium hydroxide (Calcyt; Otto & Co, Frankfurt, Germany) followed by hard setting calcium hydroxide (Life; Kerr Corp, Orange, Calif). The tooth was definitively restored with a variety of restorative materials, including amalgam, compomer, glass ionomer; and composite resin. Participants were followed at 3 months and annually thereafter. Treated teeth were evaluated by cold, percussion, palpation, occlusion testing, and radiographs. The success rates (regardless of reason for pulp exposure) by time were the following: year 1: 80.1%; year 2: 75.2%; year 3: 72.0%; year 5: 68.0%; year 6: 62.5%; year 8: 58.7%. The greatest percentage of patients requiring endodontic treatment was in the 50 to 69 year age range. There was a significant correlation with the number of surfaces of the pulp involved in the exposure and the outcome; as more pulp surfaces were involved, the survival rate decreased. Teeth restored with amalgam demonstrated a higher survival (84.2% after 9 years) rate than those restored with glass ionomer (51.5% after 9 years).

Tooth type, age, and gender had no significant effect on outcome.

**PERIODONTONTOLOGY**

For 2011 clinical research findings were reviewed to identify systemic conditions that may be related to periodontal health and nonsurgical periodontal therapy. Studies were also reviewed that dealt with periodontal regeneration and various methods for treating mucogingival problems.

**Periodontal/Systemic Conditions and Smoking**

The association between metabolic diseases and periodontal diseases is a continuing topic for discussion. The systemic inflammation in both metabolic syndrome (MetS) and periodontitis is a common denominator when associating these conditions with a higher risk of atherosclerosis. This study investigated whether periodontal therapy may reduce systemic inflammation in patients with metabolic syndrome and reduce cardiovascular risk. A parallel-arm, double blind, randomized clinical trial of 1 year in participants with MetS and periodontitis was conducted. Participants were randomized to an experimental treatment group (ETG) (n=82) that received plaque control and root planing plus amoxicillin and metronidazole or to a control treatment group (CTG) (n=83) that received plaque control instructions, subgingival scaling, and 2 placebos. Risk factors for cardiovascular disease were recorded; serum lipoprotein cholesterol, glucose, body mass index (BMI), C-reactive protein (CRP) and fibrinogen concentrations, and clinical periodontal parameters were assessed at baseline and every 3 months until 12 months after therapy. The primary and secondary outcomes were changes in CRP and fibrinogen levels, respectively. The patients’ baseline characteristics were similar in both groups. No significant changes in lifestyle factors, frequency of hypertension, BMI, serum lipoprotein cholesterol, and glucose levels were observed during the study period. The periodontal parameters significantly improved in both groups 3 months after therapy and remained lower than baseline up to 12 months. The improvement of periodontal status was significantly greater in the experimental treatment group (P<.001). A multiple linear regression analysis, controlled for gender, smoking, hypertension, and extent of periodontitis, demonstrated that CRP levels decreased over time and that this reduction was significant at 9 and 12 months in both groups. There was no difference between the groups. Fibrinogen levels significantly decreased in the ETG at 6 and 12 months, but not in the CTG. Periodontal inflammation either with root planing and systemic antibiotics or with plaque control and subgingival scaling was significantly reduced. It should be noted that the study groups were somewhat small, and definitive conclusions are difficult to make.

Recent epidemiological studies have shown that individuals with periodontitis have a significantly increased risk of developing coronary heart disease. In addition to conventional risk factors, dyslipidemia may be associated with this increased risk. The authors measured concentrations of lipids in patients with moderate to severe periodontitis before and 3, 6, and 12 months after local periodontal treatment. Fifty participants with periodontitis and 25 participants without periodontitis were included in the analyses. Lipoproteins were measured by using serological analyses. Periodontal health indicators included the plaque index, gingival bleeding index, and periodontal disease status (defined by pocket depth and attachment loss). Patients were nonsurgically treated with mechanical debridement of calculus once a week for 1 month. Results showed a significant relationship between indicators of poor periodontal status and serum level lipoproteins. Periodontal ther-
apy resulted in a significant reduction of local inflammation and tissue destruction as reflected in reduced pocket depth and reduced bleeding indices. The levels of lipoproteins after therapy seemed to be lower than those reported before treatment in patients with periodontitis than in healthy patients. Lipoproteins decreased significantly after treatment except for high-density lipoprotein cholesterol. This pilot study shows that periodontal disease significantly affects the serum levels of lipoproteins and suggests that successful periodontal treatment decreases serum lipid concentration. This study also suggests that lipoproteins are possible intermediate factors that may link periodontal disease to elevated cardiovascular risk.

Another pilot study evaluated the association of severe periodontitis with pulse wave velocity (PWV), carotid artery intima-medial thickness (IMT), and clinical, metabolic, and atherogenic inflammatory markers in 79 participants with heterozygous familial hypercholesterolemia (hFH).50 All participants were free of previous vascular disease manifestations. Body mass index (in kilograms per square meter), plasma lipids, glucose, C-reactive protein, and white blood cell counts were evaluated. After complete-mouth periodontal examinations, patients were categorized into the severe periodontitis group (SPG) or nonsevere periodontitis group (NSPG). The SPG showed significantly higher values of cholesterol-year scores, triglycerides, glucose, PWV, IMT, and diastolic blood pressure (DBP) than the NSPG. After adjustment for traditional risk factors for atherosclerosis, only the association between severe periodontitis and DBP (odds ratio: 3.1; 95% confidence interval (CI): 1.1 to 8.5; P=.03) was confirmed. In individuals with hFH, severe periodontitis was associated with a higher DBP, which suggests that severe periodontitis itself may contribute to the increased cardiovascular risk profile in this population.

A number of epidemiologic studies were published that looked at the association between coronary heart disease (CHD) and periodontal disease.51,52 However, debate exists about whether this association is a true relationship or simply an example of an uncontrolled confounder. One retrospective cohort study examines the relationship between periodontal disease and CHD.52 Digital panoramic radiographs were used to assess alveolar bone loss (ABL) using a Schei ruler. Participants consisted of Veterans Administration (VA) patients who were eligible for dental benefits and had a digital panoramic radiograph made at the VA Medical Center, Denver, Colorado. Information on CHD and other important clinical variables were obtained from electronic medical records. The examination of the relationship between ABL and CHD revealed a significant nonlinear relationship with a threshold at approximately 20% bone loss with a doubling of the probability ratios of CHD compared to those at 7.5% bone loss. This is the first study to demonstrate a nonlinear relationship between ABL and CHD. A significant positive association between ABL and CHD was found even at low levels of bone loss between 10% and 20%.

Erectile dysfunction (ED) and chronic periodontitis (CP) may share common risk factors. There is only 1 report on the association between ED and CP.53 The purpose of this study was to find the association between vasculogenic ED and CP. A total of 70 individuals clinically diagnosed with ED were included in the study. They were given the Sexual Health Inventory for Men Questionnaire and subjected to colored penile Doppler ultrasound. Periodontal parameters of probing depth and periodontal attachment level were recorded. Five participants with ED and CP were selected randomly for cardiac color Doppler to assess the integrity. Among the selected vasculogenic patients with ED, mild-to-moderate vasculogenic ED showed the highest prevalence, whereas prevalence for CP among all vasculogenic patients with ED was highest among severe ED (81.8%). The association of CP and vasculogenic ED was correlated positively but showed no statistical significance. Two of 5 participants were found to have vascular insufficiency. It can be hypothesized that an association exists between vasculogenic ED and CP in young men. However, a large-scale study with confounder analysis and a longitudinal follow-up is warranted.

Adjunctive Periodontal Therapy

The purpose of one study was to assess the clinical benefit of metronidazole, amoxicillin or doxycycline administered immediately after completion of full-mouth scaling, and root planing (FRP) for treatment of generalized aggressive periodontitis.54 Patients, 18 to 40 years of age, referred to the Karadeniz Technical University department of periodontology between January 2009 and September 2009 were randomly chosen for inclusion in the study if radiographic examination showed they had ≥ 20 teeth, clinical attachment loss and a probing pocket depth (PPD) ≥ 6 mm at 2 sites in ≥ 12 teeth, ≥ 3 of which were not first molars or incisors. Participants were divided into 3 groups and received FRP alone, FRP combined with metronidazole and amoxicillin, or FRP combined with doxycycline. PPD, clinical attachment level, gingival index, gingival bleeding index, and plaque index values were measured at baseline and 2 months after treatment. Thirty-eight participants with untreated generalized aggressive periodontitis participated in the study. In all 3 groups, the periodontal index values 2 months after treatment were significantly lower than baseline values (P<.05). Values for PPD and clinical attachment level were more improved in the antibiotic groups than in the FRP group and more improved in the metronidazole and amoxicillin group than in the doxycycline group (P<.05). However, no statistically
significant intergroup difference was observed in the other clinical parameters (P > 0.05). Systemic use of metronidazole and amoxicillin or doxycycline was clinically superior to FRP for reducing PPDs ≥ 7 mm (P < 0.05). The treatment of generalized aggressive periodontitis with FRP alone or with FRP combined with systemic antibiotics provided significant clinical benefits that reduced the need for periodontal surgery. Both antibiotic treatments had more clinical benefits than FRP alone.

Periodontitis, the most common chronic inflammatory condition known to mankind, is a disease that results in the destruction of tooth supporting tissues. Periodontitis is initiated by a bacterial biofilm on the tooth surface below the gingival margin. Until fairly recently it was assumed that the bacteria were the primary cause of tissue destruction; however, a large body of research has revealed that it is the patient’s immune response that is actually responsible for the majority of the breakdown of tooth supporting tissues. Contemporary thinking suggests that successful, long term management of chronic periodontitis may combine local mechanical and antimicrobial strategies. This approach may reduce the microbial bioburden and modulates the host’s excessive immunoinflammatory response to the bacterial exposure, an approach known as host modulatory therapy (HMT). Based on the data from extensive literature, documenting the enzymatic inhibition and related anti-inflammatory properties of the tetracyclines, a new drug was developed as a host modulatory agent and approved for use as an adjunct to conventional scaling and root planing for the treatment of chronic periodontitis by the United States Food and Drug Administration (FDA). A subantimicrobial dose of doxycycline (SDD) at 20 mg (Periostat, CollaGenex Pharmaceuticals, Newtown, Pa) has been found to be a safe and effective adjunct when taken twice daily for at least 3 months and up to 24 months in randomized placebo-controlled clinical trials. Periostat is currently the only FDA-approved inhibitor of the matrix metalloproteinases implicated in the plaque-induced pathologic degradation of connective tissue collagen of the periodontal supporting structures. This review paper begins with a brief description of the disease process known as periodontitis and is followed by an extensive review of the Phase I to IV clinical trial data that established the safety and efficacy of subantimicrobial dose doxycycline (SDD) as an adjunct to scaling and root planing for the treatment of periodontitis.

Moxifloxacin works extremely well against most putative periodontal pathogens and has been shown to kill bacteria in biofilm and host cells. Participants with chronic periodontitis were randomly assigned to receive a single subgingival application of a 0.125%, 0.4%, or 1.25% moxifloxacin gel or placebo gel immediately after full-mouth scaling and root planing (SRP). Clinical efficacy measurements were assessed in sites with baseline probing depth (PD) of ≥5.4 mm at 6 weeks and 3 months, and any adverse events were determined. In addition, putative periodontal pathogens and the resistance of subgingival bacteria against moxifloxacin were assessed. The data of 57 participants were included in the statistical analysis. In all treatment groups, the PD decreased from baseline to 3 months, with the greatest reduction seen in participants treated with moxifloxacin 0.4% (1.5 ±0.6 mm; P = .023 compared to placebo), followed by participants receiving moxifloxacin 1.25% (1.2 ±0.4), moxifloxacin 0.125% (1.1 ±1.1), and placebo (1.0 ±0.6). No linear trend for PD reduction with increasing moxifloxacin concentrations was found. Porphyromonas gingivalis showed the greatest reduction in prevalence among the assessed pathogens, without any significant intergroup differences. No correlation or systematic relationship between adverse events, including bacterial resistance against moxifloxacin, and the investigational gels was found. In periodontal pockets with a PD of ≥5.4 mm, a single subgingival administration of a 0.4% moxifloxacin gel as an adjunct to SRP may result in additional PD reduction compared to SRP alone. In addition, the investigated moxifloxacin gels seem to be safe.

Systemic metronidazole and amoxicillin significantly improved the outcomes of nonsurgical debridement in individuals with generalized aggressive periodontitis. A study was conducted to observe whether retreatment with adjunctive antimicrobials would give the placebo group benefits comparable with the test group. Thirty-eight of 41 participants from the initial 6-month trial completed the second phase retreatment of sites with remaining pockets of 5 mm. Participants on placebo in phase 1, received adjunctive antimicrobics for 7 days. Clinical parameters were collected at 2 months after treatment (8 months from baseline). Participants who received antibiotics at initial therapy showed more statistically significant improvement in pocket depth reduction and a higher percentage of sites improving above clinically relevant thresholds than participants who received antibiotics at retreatment. In deep pockets (7 mm), the mean difference was 0.9 mm (P = .003), and in moderate pockets (4 to 6 mm), it was 0.4 mm (P = .036). For pockets converting from 5 mm to 4 mm, this was 83% compared with 67% (P = .041), and for pockets converting from 4 mm to 3 mm, it was 63% compared with 49% (P = .297). At 8 months, participants who had antibiotics at initial therapy showed more statistically significant benefits than those who had antibiotics at retreatment.

A study was designed to evaluate the clinical efficacy of subgingival ultrasonic instrumentation irrigated with essential oils (EOs) of residual periodontal pockets. Sixty-four individuals with chronic periodontitis were invited to participate in this randomized, double blind, parallel, and
placebo-controlled clinical trial. All participants received nonsurgical periodontal therapy. After reevaluation (baseline), residual pockets (pocket depth ≥5 mm) received test (ultrasonic instrumentation irrigated with EOs) or control therapy (ultrasonic instrumentation irrigated with negative control). Probing pocket depth (PPD), gingival recession (R), clinical attachment level (CAL), bleeding on probing (BOP), and plaque were assessed at baseline and after 4, 12, and 24 weeks. Differences between groups and changes over the course of time were analyzed according to a generalized linear model. A significant reduction in PPD and BOP and a significant gain in CAL between the 2 groups (P<.001) were noted. Nevertheless, no differences were found between the groups at any time in the study. When only initially deep pockets (PPD ≥7 mm) were analyzed, a significantly greater CAL gain (P=.03) and PPD reduction (P=.01) were observed in the test group. The adjunctive use of EOs may promote significant CAL gain and PPD reduction in deep residual pockets.

A group of investigators compared the effects of systemic amoxicillin (AMX) plus metronidazole (MET) or placebo combined with anti-infective mechanical debridement on the subgingival microbiota of generalized aggressive periodontitis (GAP). High levels of periodontal pathogens, as well as some nonperiodontal species were observed. Most of the periodontal pathogens decreased significantly over time (P<.05), whereas “nonperiodontal” bacteria tended to increase in both groups. Sites that showed attachment loss and probing depth increase exhibited higher levels of Dialister pneumosintes, Campylobacter rectus, Fusobacterium necrophorum, Prevotella tannerea, and Peptostreptococcus anaerobius than sites that improved after both therapies (P<.05). Systemic AMX+MET or placebos adjunctive to anti-infective mechanical debridement were comparable in lowering periodontal pathogens up to 6 months after treatment. Species not commonly associated with GAP were less affected by both therapies.

Another study investigated the impact of 2 surface debridement/decontamination (DD) methods on the clinical outcomes of combined surgical treatment of periimplantitis. Thirty-two participants suffering from advanced periimplantitis (n=38 combined suprabony and intrabony defects) were treated with flap surgery, granulation tissue removal, and implantoplasty at buccally and supracrestally exposed implant parts. The intrabony aspects were randomly allocated to surface DD by using either (i) an Er:YAG laser (ERL) device, or (ii) plastic curet+cotton pellets+sterile saline (CPS). In both groups, the intrabony component was augmented with a natural bone mineral and covered with a collagen membrane. Clinical and radiographic parameters were recorded at baseline and after 6 months of nonsubmerged healing. Two participants were lost during follow-up. At 6 months, ERL-treated sites failed to reveal higher reductions in mean bleeding on probing (ERL: 47.8±35.5% versus CPS: 55.0±31.1%) and CAL values (ERL: 1.5±1.4 mm versus CPS: 2.2±1.4 mm) when compared with the CPS group. Both groups exhibited a comparable radiographic bone fill at the intrabony defect component. The study failed to demonstrate a significant impact of the method of surface DD on the clinical outcome after the combined surgical therapy of advanced periimplantitis lesions.

**Periodontal Regeneration - Ridge Preservation**

The purpose of a randomized, controlled clinical trial was to determine whether residual ridge preservation using an osteoinductive allograft (test) would prevent ridge resorption and promote bone maturation compared to extraction alone (control). Seventeen participants, for a total of 20 sites in need of a nonmolar extraction and delayed implant placement were randomly selected to receive either ridge preservation or extraction alone. A cone beam computed tomograph (CBCT) was completed with a radiographic stent in place before extraction and 10 to 12 weeks postoperatively for dimensional and buccal plate analyses. Bone cores were taken for micro-CT and histologic analyses. Resorption of the alveolar ridge occurred at all sites with no statistically significant differences found between test and control sites. A significant correlation was found between the initial buccal plate thickness and the loss of vertical ridge height. Micro-CT and histologic analyses found a mean new bone volume (BV) of 44.9% with micro-CT and 37.4% with histology in test sites, and 39% with micro-CT and 35.5% with histology in control sites. The residual graft volume (RGV) was 2.4% with micro-CT and 4.5% with histology. Test and control sites lost similar amounts of alveolar ridge, with the loss of buccolingual width occurring predominately at the expense of the buccal bone. A thicker buccal plate was associated with less ridge loss in the vertical dimension. The percentage of new bone was not statistically significant between either the test or control sites, measured with either micro-CT or histologic analyses.

Treatments for mandibular second
molar (M2) periodontal defects after third molar (M3) removal in high-risk patients are a clinical dilemma for clinicians.62 One study compared the healing of periodontal intrabony defects at distal surfaces of mandibular M2s by using bioabsorbable and non-resorbable membranes. Eleven participants with bilateral probing depths (PDs) ≥6 mm distal to mandibular M2s and intrabony defects ≥3 mm related to the total impaction of M3s were treated with M3 extraction and covering of the surgical bone defect with a bioabsorbable collagen barrier on one side and a nonresorbable expanded polytetrafluoroethylene (ePTFE) barrier contralaterally. The PD, clinical attachment level (CAL), M2 mobility, and fucration class probing were evaluated preoperatively and 3, 6, and 9 months postoperatively. Intraoral periapical radiographs were made immediately preoperatively and 3 and 9 months postoperatively. Both treatment modalities were successful. At 9 months, the mean PD reduction was 5.2 ±3.9 mm for bioabsorbable sites and 5.5 ±3.0 mm for nonresorbable sites; the CAL gain was 5.9 ±3.3 mm and 5.5 ±3.4 mm, respectively. The outcome difference between the 2 sites for PD and CAL did not differ statistically (P=.05) at any assessment time. Bioabsorbable collagen membranes in the guided tissue regeneration treatment of intrabony defects distal to the mandibular M2 obtained the same marked PD reductions and CAL gains as nonresorbable ePTFE membranes after M3 extraction.

The purpose of a single-masked, randomized, controlled clinical trial was to compare hard and soft tissue changes after ridge preservation performed with (control, RPc) and without (test, RPe) primary soft tissue closure in a split-mouth design.63 Eleven participants completed this 6-month trial. Extraction and ridge preservation were performed by using a composite bone graft of inorganic bovine-derived hydroxyapatite matrix and cell binding peptide P-15 (ABM/P-15), demineralized freeze-dried bone allograft, and a copolymer bioabsorbable membrane. Primary wound closure was achieved on the control sites (RPC), whereas test sites (RPe) left the membrane exposed. Pocket probing depth on adjacent teeth, repositioning of the mucogingival junction, bone width, bone fill, and postoperative discomfort were assessed. Bone cores were obtained for histologic examination. Intragroup analyses for both groups demonstrated statistically significant mean reductions in probing depth and bone width. However, intergroup analysis did not find these parameters to be statistically different at 6 months. The test group showed statistically significant mean change in bone fill (7.21 mm; P<.001). Compared to the control group, the test group showed statistically significant lower mean postoperative discomfort (RPc 4 versus RPe 2; P=.002). Histomorphometric analysis showed a presence of 0% to 40% of ABM/P-15 and 5% to 20% of new bone formation in both groups. A comparison of the clinical variables between the 2 groups at 6 months revealed that the mucogingival junction was statistically significantly more coronally displaced in the control group than in the test group, with a mean of 3.83 mm versus 1.21 mm (P=.002). Ridge preservation without flap advancement preserves more keratinized tissue and causes less postoperative discomfort and swelling. Although ridge preservation performed with both methods results in bone width loss of approximately 27% to 30%, ridge preservation can minimize the loss of alveolar bone subsequent to tooth extraction in preparation for implant therapy.

The purpose of another study was to histologically and clinically compare human demineralized bone matrix (DBM) putty with 1 size of bone particles (SPS) to human DBM putty with 2 different sizes of bone particles (MPS) in ridge preservation after molar extractions.64 Molar tooth extraction and ridge preservation were performed in 20 participants for each treatment group. Approximately 20 weeks after grafting, core biopsies were obtained during implant placement and analyzed with light microscopy. Specimens were analyzed for the percentage area of vital bone, residual graft particles, and nonmineralized structures (CT). Changes in alveolar ridge dimensions were also determined. The results were that 16 participants in the SPS group and 14 in the MPS group completed the study. The SPS group had a mean of 49% vital bone, 8% residual graft, and 43% CT. The MPS group had 53%, 5%, and 42%, respectively. Participants in both groups lost a mean of less than 1 mm alveolar height on the buccal and lingual aspects and less than 1.5 mm of total ridge width. There were no statistically significant differences between the 2 groups for any clinical or histological parameters. The results of this study suggest that adding larger bone particles to a DBM putty does not offer additional benefit in the preservation of alveolar bone after the extraction of molar teeth.

Periodontal Regeneration

A systematic review was conducted to review the literature and to determine the clinical performance of conservative surgery (CS) for the treatment of intrabony defects (ID).65 Randomized clinical trials (RCTs) on intrabony defect (ID) treatment with 12 months of follow-up were identified through electronic databases and hand-searched journals. Primary outcomes were tooth survival, clinical attachment (CAL) gain, probing depth (PD) reduction, and gingival recession (REC) increase. Weighted means and forest plots were calculated for each outcome variable 12 months after surgery. Long-term stability was explored with RCTs of at least 24 months of follow-up. Subgroup analysis was performed according to the type of flap. Twenty-seven trials reporting 647 participants and 734 defects were identified. Twelve months after CS, tooth survival was 98% (In-
terquartile range (IQ): 96.77 to 100), CAL gain 1.65 mm (95% CI: 1.37 to 1.94; *P* < .001), PD reduction 2.80 mm (CI: 2.43 to 3.18; *P* < .001), and REC increase 1.26 mm (CI: 0.94 to 1.49; *P* < .001). Longer follow-up showed similar findings. The CIs of CAL gain were 1.44 to 3.52 for recently introduced papilla preservation flaps and 1.25 mm to 1.89 mm for access flaps. The treatment of intrabony defects with CS is associated with high tooth retention and improvement of periodontal clinical parameters. Clinical performance may vary according to the type of surgical flap used.

The purpose of a randomized, long-term clinical trial was to compare clinically based and patient-based outcomes after periodontal regeneration or extraction and replacement of hopeless teeth with chronic peri-endo lesions and/or attachment loss to or beyond the apex. Fifty patients presenting with generalized severe periodontitis and at least 1 hopeless tooth to be extracted for periodontal reasons were entered in this study. The test treatment consisted of the application of a regenerative strategy to 25 hopeless teeth. The control treatment consisted of the extraction of the 25 hopeless teeth and their replacement with conventional or implant-supported partial fixed dental prostheses. In the control group, 14 teeth were replaced with implant-supported restorations, 8 with tooth-supported fixed prostheses, 2 with resin-bonded prostheses, and 1 was not replaced. All fixed prostheses survived the 5-year follow-up period, and 83% were free from biological complications. In the test group, 23 of the 25 regenerated teeth showed important clinical improvements: the 2 teeth with unsatisfactory outcomes were extracted at 1 year. The 23 successfully regenerated teeth (92%) were in good health and function at the 5-year examination visit, and 84% did not develop biological complications during the recall period. All participants consistently reported comfort in function. In the test group, the average clinical attachment level gains were 7.7 ±2.8 mm, the radiographic bone gain 8.5 ±3.1 mm, and the probing pocket depth (PPD) reduction 8.8 ±3 mm. Residual PPDs were 4 ±1.7 mm. Most of the regenerated teeth showed a decrease in tooth mobility. Regenerative therapy can be applied to hopeless teeth and has the potential to change their prognosis; it is a suitable alternative to the extraction of severely compromised teeth with intrabony defects at or beyond the root apex.

A 3-arm study compared the clinical and radiographic efficacy of the modified minimally invasive surgical technique (M-MIST) alone and combined with enamel matrix derivative (EMD) or EMD plus bone mineral derived xenographs (BMDX) in the treatment of isolated, interdental intrabony defects. Forty-five deep, isolated, intrabony defects in 45 participants were included, accessed with the M-MIST, and randomly assigned to 3 balanced experimental groups. The M-MIST consisted of a small buccal flap without elevation of the defect-associated papilla. After removing the granulation tissue by sharp dissection and root instrumentation, the regenerative material was applied before obtaining primary closure with a single internal modified mattress suture when indicated. Surgery was performed with the aid of an operating microscope and microsurgical instruments. Outcomes were evaluated as pocket depth reduction, attachment level gain, radiographic bone fill, and patient-related. Primary wound closure was maintained in all treated sites with the exception of one M-MIST EMD+BMDX site. No patient reported intraoperative or postoperative pain. Within group differences between baseline and 1 year were statistically significant in the 3 groups in terms of probing pocket depth reduction, clinical attachment level (CAL) gain and bone fill (*P* < .001). Comparisons among the 3 groups showed no statistically significant difference in any of the measured clinical outcomes. In particular, CAL gains of 4.1 ±1.4 mm were observed in the M-MIST control group, 4.1 ±1.2 mm in the EMD group, and 3.7 ±1.3 mm in the EMD+BMDX group. The percentage radiographic bone fill of the intrabony component was 77% ±19% in the M-MIST control group, 71% ±18% in the EMD group, and 78% ±27% in the EMD+BMDX group. M-MIST with or without regenerative materials resulted in significant clinical and radiographic improvements. Interestingly, while this initial study did not have sufficient power to detect intergroup CAL differences of less than 0.96 mm, the observed outcomes were remarkably similar and warrant further investigations.

Enamel matrix derivative (EMD) is commonly used in periodontal therapy. The purpose of one systematic review was to provide an updated answer to the question of whether the additional use of EMD in periodontal therapy is more effective than control or other regenerative procedures. A literature search in MEDLINE (PubMed) for the use of EMD in periodontal treatment was performed up to May 2010. The use of EMD in treatment of intrabony defects, furcations, and recession was evaluated. Only randomized controlled trials with at least 1 year of follow-up were included. The primary outcome variable for intrabony defects was the change in clinical attachment level, for furcations the change in horizontal furcation depth, and for recession complete root coverage. After screening, 27 studies (20 for intrabony defects, 1 for furcation, and 6 for recession) were eligible for the review. A meta-analysis was performed for intrabony defects and recession. The treatment of intrabony defects with EMD showed a significant additional gain in clinical attachment of 1.30 mm in comparison to open flap debridement, EDTA, or placebo, but no significant difference in comparison to resorbable membranes was shown. The use of EMD in combination with a coronally advanced flap compared
to a coronally advanced flap alone showed significantly more complete root coverage (OR=3.5), but in comparison to a connective tissue graft the result was not significantly different. The use of EMD in furcations (2.6±1.8 mm) gave significantly more improvement in horizontal defect depth than resorbable membranes (1.9±1.4 mm). In the treatment of intrabony defects, the use of EMD is superior to control treatments but only as effective as resorbable membranes. The additional use of EMD with a coronally advanced flap for recession coverage will give superior results to control but as effective as a connective tissue graft. The use of EMD in furcations will give more reduction in horizontal furcation defect depth than resorbable membranes.

One study compared the clinical and radiographic outcomes of a combination of enamel matrix derivatives (EMD) and a synthetic bone graft (EMD/SBG) with EMD alone in wide ≥2 mm) and deep (≥4 mm) 1-wall and 2-wall intrabony defects 12 months after treatment. Seventy-three participants with chronic periodontitis and 1 wide ≥2 mm) and deep ≥4 mm) intrabony defect were recruited in 5 centers in Germany. During surgery, defects were randomly assigned to EMD/SBG (test) or EMD (control). Assessments at baseline after 6 and 12 months included bone sounding, attachment levels, probing pocket depths, bleeding on probing, and recession. Changes in defect fill were recorded radiographically. Both treatment modalities led to significant clinical improvements. In the EMD/SBG group a mean defect fill of 2.7 ±1.9 mm was calculated, and in the EMD group the defect fill was 2.8 ±1.6 mm. A mean gain in clinical attachment of 1.7 ±2.1 mm in the test group and 1.9 ±1.7 mm in the control group after 1 year was observed. Radiographic analysis confirmed that deeper defects were associated with greater defect fill for both groups. The results show comparable clinical and radiographic outcomes for both treatment modalities 12 months after treatment.

**Mucogingival Treatment**

The standard of care for increasing keratinized gingiva adjacent to teeth that do not require root coverage is the free gingival graft (FGG). A pilot study indicated that the use of a living cellular construct (LCC foreskin) could be effective in this clinical scenario. A pivotal, multicenter, randomized, within-patient, controlled, open-label trial was conducted (n=96 participants). After the removal of the mucosa and keratinized gingiva from the test site, either an LCC or FGG was applied. The primary efficacy endpoint was the ability of the LCC to regenerate ≥2 mm keratinized gingiva at 6 months. Secondary measures were the same color and texture as the adjacent tissue, a 1 mm width of keratinized gingiva at 6 months, patient treatment preference, surgical site sensitivity at 1 week, and patient-reported pain after 3 days. Safety was assessed by reports of adverse events. At 6 months, the LCC regenerated ≥2 mm of keratinized gingiva in 95.3% of participants (81 of 85 participants; P <.001 versus a 50% predefined standard). As expected, the FGG generated more keratinized gingiva (4.57 ±1.0 mm) than the LCC (3.2 ±1.1 mm). The gingiva regenerated with the LCC matched the color and texture of the adjacent gingiva. All participants achieved ≥1 mm keratinized gingiva with the LCC treatment by 6 months, and more participants preferred treatment with the LCC than with the FGG. No difference in sensitivity or pain was noted between the treatments. The treatments were well tolerated, and reported adverse events were typical for this type of periodontal surgery. The purpose of one study was to evaluate the local tolerance and efficiency of 2 experimental collagen matrices to increase the width of keratinized tissue. In 12 pigs, 2 apically positioned flaps were prepared on both sides of the mandible. The denuded defect areas were randomly covered with 1 of 2 experimental porcine-derived collagen matrices (M1; M2). The other defect area was left untreated (control). At 1 and 6 months, clinical measurements for the width and thickness of the keratinized tissue were recorded. At 6 months, all animals were sacrificed. Descriptive and semiquantitative histologic analyses were performed. For statistical analysis, the Kruskal-Wallis test and the McNemar test were applied. Results revealed collagen matrices integrated well into the surrounding tissue without any signs of inflammation. The thickness and width of the keratinized tissue increased significantly over 6 months in all the groups, resulting in slightly more favorable results for M1 (compared with M2) with respect to the thickness and for M2 (compared with M1) with respect to the width of keratinized tissue. No statistically significant differences were observed for any of the evaluated clinical and histologic parameters among the 3 treatment modalities. Within the limits of this animal study, the prototype collagen matrices can be safely used to increase the width of keratinized tissue.

An interesting randomized clinical trial compared the long-term results of subepithelial connective tissue grafts (SCTG) versus acellular dermal matrix allografts (ADMA) in the treatment of gingival recession. In 16 participants with bilateral Miller Class I/II gingival recession, one side was treated with SCTG and the other side with ADMA. Clinical parameters were measured at baseline, 6 months, and 5 years postsurgery. Fifteen participants completed the study. At 6 months, all parameters showed significant improvement in ADMA and SCTG groups [complete root coverage (CRC): 73.3% versus 26.7%, P=.027; reduction of recession depth (RD): 2.6 ±1.1 mm versus 2.2 ±1.1 mm P=.376; reduction of recession width (RW): 3.0 ±1.4 mm versus 2.4 ±1.4 mm, P=.207, respectively]. At
5 years, significant relapses were detected in CRC and reduction of RD and RW in both groups with no statistically significant difference (CRC: 20.0% versus 13.3%, P = 1.00; RD: 1.6 ± 1.2 mm versus 1.5 ± 1.4 mm, P = .838; RW: 1.8 ± 1.4 mm versus 1.3 ± 1.5 mm, P = .367). Participants practicing horizontal toothbrushing showed more relapse (OR = 11.2; P = .01). Compared with baseline, the gingival width (GW) did not increase in ADMA-treated sites (P = .903). Five-year results of SCTG and ADMA were similar in terms of CRC and reduction of RD and RW. Both techniques showed a significant relapse associated with participants returning to horizontal tooth brushing habits. The increase of GW was stable in SCTG-treated sites but reached presurgical values in ADMA-treated participants.

The objectives of another study were (1) to test the reliability of a new classification system of gingival recession by using the level of interproximal clinical attachment as an identification criterion and (2) to explore the predictive value of the resulting classification system on the final root coverage outcomes. Participants showing at least 1 buccal gingival recession were recruited by 1 operator. Three recession types (RT) were identified. While class RT1 included gingival recession with no loss of interproximal attachment, class RT2 recession was associated with interproximal attachment loss less than or equal to the buccal site and class RT3 showed higher interproximal attachment loss than the buccal site. The classification was tested by 2 examiners blinded to the data collected by the other examiner. Intrarater and interrater agreement were assessed. Furthermore, the 6-month root coverage outcomes of consecutively treated gingival recession were retrospectively evaluated to explore the predictive value of the proposed classification on the final recession reduction (Rec Red). The new classification system of gingival recession was tested in a total of 116 patients with gingival recession (mean 3.2 ± 1.2 mm) in 25 participants. The intraclass correlation coefficient (ICC) for interrater agreement was 0.86, showing an almost perfect agreement among the examiners. The RT classification was predictive of the final Rec Red (P < .001) at the 6-month follow-up in 109 patients with treated gingival recession. The evaluation of the interproximal clinical attachment level may be used to classify gingival recession defects and to predict final root coverage outcomes.

DENTAL MATERIALS

Dental Adhesives

Much of the focus of research on adhesive systems continues to be on improving bond durability to enhance restoration longevity. An excellent review paper examined factors that compromise resin-dentin bond durability, including hydrolytic degradation by water sorption into the adhesive interface and incomplete infiltration by resin monomers into the demineralized dentin surface. A factor of increasing importance to bond degradation is the release of matrix metalloproteinases (MMPs) as a result of the bonding process, which can degrade collagen fibrils in adhesive zones that are incompletely infiltrated with resin. Approaches that are being actively investigated include the use of MMP inhibitors such as chlorhexidine, benzalkonium chloride, and quaternary ammonium salts, either applied separately to the dentin surface or incorporated into the adhesive resin. Approaches that are being actively investigated include the use of MMP inhibitors such as chlorhexidine, benzalkonium chloride, and quaternary ammonium salts, either applied separately to the dentin surface or incorporated into the adhesive resin. An additional experimental approach is biomimetic remineralization in which portions of the adhesive zone that have been depleted ofapatite during the etching process are remineralized by using polyanionic analogs of acidic matrix proteins to induce the growth of apatite.

A combination in vivo and in vitro study evaluated the effect of chlorhexidine use and biomimetic remineralization on the integrity of resin-dentin interfaces. Participants requiring premolar extractions for orthodontics (age 12 to 17 years) had a total of 18 premolar pairs that received a standardized occlusal composite resin restoration. The preparations were etched with phosphoric acid and 1 randomly assigned tooth of each pair had 2% chlorhexidine applied for 30 seconds; the control tooth had deionized water applied for 30 seconds. The surface was blot dried and a 2-step adhesive (Prime & Bond NT; Dentsply Intl, York, Pa) was applied, air dried, and polymerized. A microfill composite (Epic TMPT; Parkell Inc, Edgewood, NY) was used to incrementally fill the preparations. Ten tooth pairs were immediately extracted and used for the in vitro aspect of the study; the other 8 tooth pairs were allowed to function for 1 year and then extracted. Following extraction, the tooth/restoration was sectioned to create a 1 mm thick slab that included the bonded interface. Eight tooth slabs prepared from the immediately extracted chlorhexidine-treated teeth were aged in simulated body fluid for 12 months. Eight tooth slabs from the control group were placed in a remineralization medium and stored for 12 months. The final 2 tooth pairs of the immediate extraction group were used for baseline analysis. After aging, all slabs were prepared and subjected to transmission electron microscopy (TEM). In vivo specimens bonded without chlorhexidine revealed extensive hybrid layer degradation, whereas both the in vivo and in vitro chlorhexidine-treated specimens showed an intact hybrid layer after 12 months of function. The specimens subjected to biomimetic remineralization protocol showed collagen remineralization in the hybrid zone. The authors concluded that both the use of chlorhexidine and biomimetic remineralization provided similar results in terms of preventing degradation of the hybrid layer, although the biomimetic remineralization protocol is experimental at this time.

The effect of 2% chlorhexidine on bond strength and silver nitrate uptake over 2 years when applied as an
aqueous solution or when associated with acid etchant was examined in an in vitro study. Forty-two extracted human third molars had their occlusal surface reduced to produce a flat dentin surface. Two, 2-step etch-and-rinse adhesives (Adper Single Bond 2; 3M ESPE, St Paul, Minn) ethanol-water solvents; and (Prime & Bond NT; Dentsply Intl), an acetone solvent, were used. The teeth were divided into 6 groups: 2 control groups, in which the 2 adhesives were applied after normal etching, rinsing, drying, and rewetting with water; 2 groups in which the same bonding procedure as the controls was used except the etchant contained 2% chlorhexidine; and 2 groups bonded as for the control group except that rewetting was accomplished with a 2% chlorhexidine solution. Composite resin was polymerized onto the bonded surfaces, stored for 24 hours, sectioned into 0.8 mm² sticks, and randomly assigned for immediate testing or 2 year storage in distilled water before testing. Two sticks from each tooth were immersed in silver nitrate and subjected to scanning electron microscope (SEM) analysis to measure silver uptake, and the remainder were used for microtensile strength testing. The control specimens had a significant decrease in bond strength over 2 years, while the specimens that used chlorhexidine in either the acid etchant or the rewetting solution showed no such bond strength reduction. There was increased silver uptake into the hybrid zone of all groups, but the amount was significantly higher in the control groups than in the experimental groups. Both the silver uptake and bond strength results demonstrated the improved stability of the resin-dentin zone when chlorhexidine was used in conjunction with bonding procedures.

The effectiveness of chlorhexidine on resin-dentin bond stability in normal and caries-affected dentin was the subject of an in vitro study. Extracted human molars (n=120) with occlusal caries were ground down until dentin hardness, visual examination, and staining with dye determined that affected dentin remained surrounded by normal dentin. The tooth roots were sectioned and attached to a device that simulated intrapulpal pressure. The teeth were divided into 3 groups: control, in which water was applied to the dentin surface before the application of a 2-step self-etch adhesive (Clearfil SE; Kuraray America Inc, Houston, Tex); a second group, in which 2% chlorhexidine solution was applied before the adhesive; and a third group, in which 5% chlorhexidine solution was applied before the adhesive. All bonding procedures were accomplished by using simulated intrapulpal pressure. Half of the specimens in each group were tested after 24 hours, and the other half were tested after 2 years storage in artificial saliva and under intrapulpal pressure. Double-faced adhesive tape with holes punched to isolate an area of affected dentin and an area of normal dentin was applied before bonding. Polyethylene tubes with a 0.9 mm internal diameter were used to apply resin composite to the bonded areas. The specimens were tested for microshear bond strength. There was no statistical difference among the 2-year strength specimens in normal dentin, although the chlorhexidine groups had numerically higher bond strength values. In affected dentin, the 5% chlorhexidine group had statistically higher bond strength at 2 years compared to the 2% chlorhexidine and control groups. There was a significant degradation of bond strength from 24 hours to 2 years for all groups except the 5% chlorhexidine-affected dentin group. Again, this study showed the beneficial effect of chlorhexidine on bond stability, although the effect was limited, perhaps due to the application of chlorhexidine before dentin conditioning, necessitated by the use of a self-etch adhesive.

An alternative technique for enhancing bond stability was the subject of a 24 month clinical trial. The effect of using a vigorous rubbing action to apply 2 different adhesives to noncarious cervical lesions (NCCLs) under both wet and dry bonding conditions was evaluated in this study. Forty participants received 160 restorations of NCCLs with moderate sclerosis. Individuals were excluded for poor oral hygiene, severe or chronic periodontitis, or heavy bruxism. No additional tooth preparation or bevelling was done. Two, 2-step etch-and-rinse adhesives (One-Step, Bisco Inc, Schaumberg, Ill; Adper Single Bond, 3M ESPE) were applied according to manufacturer instructions. Following acid etching, one half of the cavities were left dry after rinsing, and the other half were rewet with water. The adhesive systems were applied with vigorous rubbing. The restorations were filled and polymerized in 3 increments. Two evaluators blinded to experimental assignment and who were not involved in restoration placement evaluated the restorations at baseline, 6, 12, and 24 months. At the end of 24 months, no restorations exhibited secondary caries, nor were there any significant differences among the groups for hypersensitivity, retention (91.9% to 97.5%), or marginal adaptation. There was no difference between rewet and dry conditions for either adhesive. However, there was significantly greater marginal discoloration in the One Step restorations at 24 months versus at baseline than in the Adper Single Bond restorations, regardless of dentin moisture. The authors attributed this latter result to One Step's higher solvent content and higher hydrophilicity.

The effect of the application technique on immediate and long-term bonding performance of 1-step adhesives was investigated in an in vitro study. The occlusal surfaces of 42 extracted human molars were reduced to create flat dentin surfaces. Three 1-step adhesives (Adper Prompt L-Pop, 3M ESPE; Xeno III, Dentsply Intl; Clearfil S3 Bond, Kuraray) were applied either following manufacturer instructions (control)
or applied as per manufacturer instructions but with the microbrush being scrubbed on the dentin surface under manual pressure (active). After adhesive application, composite resin was placed and polymerized, the teeth were sectioned into bonded resin was placed and polymerized, under manual pressure (active). After adhesive application, composite resin was placed and polymerized, the teeth were sectioned into bonded resin. One half of the specimens was tested immediately, and the other half was tested after 3 years storage in water. The microtensile bond strengths of the 3 year specimens were significantly lower than those of the immediately tested specimens. However, the active application groups showed significantly higher bond strengths at both time periods. A significant increase in silver nitrate uptake was observed after 3 years of storage; however, the active application groups showed less silver nitrate uptake, particularly in the aged specimens. The authors attributed the higher bond strength and lower silver nitrate uptake in the active application groups to higher dissolution of the smear layer and a resultant improved penetration of resin monomers into the dentin surface and to enhanced solvent evaporation.

It is well established that bonding immediately after bleaching will reduce bond strength due to the retention of released oxygen from peroxide bleaching agents. An in vitro study evaluated the amount of time 35% hydrogen peroxide is retained in dentin after bleaching and the effect of sodium ascorbate on the removal of residual peroxide. Seventy recently extracted human third molars, which were then divided into 10 groups (5 enamel groups and 5 dentin groups). The 8 experimental groups were etched with 35% PA and either 5% or 9.5% HF; however, the order in which the etchants were applied was varied. After rinsing and drying, a 2-step etch-and-rinse adhesive (Excite; Ivoclar Vivadent, Amherst, NY) was applied and polymerized. The enamel and dentin control groups were treated according to manufacturer instructions without HF acid etching. After bonding, composite resin was applied with a 3.5 mm diameter polyethylene mold, polymerized, thinned, and bond strength tested in shear. The 2 control groups had significantly higher bond strength than the experimental groups. For enamel, significantly lower bond strength was obtained when HF was applied before PA. The results were mixed for the dentin groups, with the specimens that were treated with PA followed by 9.5% HF demonstrating significantly higher bond strength than specimens treated with 5% HF followed by PA. HF clearly reduced the bond strength to both enamel and dentin, demonstrating that the clinician should avoid applying HF to adjacent tooth.
Composite Resin

Composite resin is an area of emphasis in restorative dental materials research, and researchers, both in academics and employed by manufacturers, expend considerable effort on improving these materials. A comprehensive review that begins by summarizing the major components of composite resin and then explains the current state of the art from a materials perspective gives the reader a good foundation for understanding the ongoing research into each of these components.83 Areas of active research include finding new initiators that are more efficient, reducing colored by-products, and lessening reliance on toxic amine co-initiators. Another area of intensive investigation is finding new monomers that can improve mechanical properties, reduce polymerization shrinkage and shrinkage stress, and lessen the amount of unreacted monomer that can leach out of a completed restoration. Recent investigations have examined incorporating an acidic functional group into the composite resin monomer with the intent of eliminating the separate placement of an adhesive. Much of the recent improvements in dental composite resins can be attributed to altering filler shape, size, nature, type, and surface modification. Research continues to consider the filler component, including novel compositions, and morphology.

A key shortcoming in dental composite resin is polymerization shrinkage, and research continues to focus on methods to mitigate its effect on restorations. One study compared the effect of bulk and incremental fill techniques by using composite resin with different elastic moduli on cuspal deflection.84 A standardized mesio-occlusodistal (MOD) preparation was performed on 120 extracted human premolars, the enamel was etched with phosphoric acid, and a 2-step self-etch adhesive (AdheSE; Ivoclar Vivadent) was applied. The preparations were filled with one of 4 different composite resins with similar volumetric polymerization shrinkage but varying elastic moduli in one of 3 techniques: bulk fill, or 2 or 3 horizontal layers with an LED polymerization light. Cuspal deflection was measured with a custom screw and pin measuring device. The results showed that cuspal deflection was significantly greater in the bulk placement group than in the incremental placement groups and that the use of 2 horizontal layers induced greater cuspal deflection than did the use of 3 horizontal incremental layers. In addition, there was a significant correlation between the elastic moduli of the composite resins and cuspal deflection, with the stiffer composite resins demonstrating greater cuspal deflection. This study emphasized the benefit of a multilayer incremental approach to reducing the adverse effects of polymerization shrinkage and shrinkage stress.

Another technique that has been reported as effective in lessening the impact of polymerization shrinkage is the use of flowable composite resin as a liner. Investigators evaluated the effect of using flowable composite resin in MOD composite resin restorations on cuspal deflection.85 Forty extracted human mandibular molars of similar dimension received standardized MOD preparations and a 2-step etch-and-rinse adhesive (Excite; Ivoclar Vivadent). The teeth were divided based on the use of 1 of 2 different composite resin systems (Tetric EvoCeram/Flow; Ivoclar Vivadent; Grandio, VOCO America Inc, Briarcliff Manor, NY). Each half was further subdivided into 2 groups: one group had a flowable composite resin applied to the internal cavity line angles before placement of the respective nanohybrid restorative composite resin, while the other group was filled entirely with the restorative composite resin. Cuspal deflection was measured with strain gauges. Specimens with flowable composite resin liners demonstrated significantly greater cuspal deflection than those filled with the restorative composite resin alone, probably due to the greater resin in content and polymerization shrinkage of the flowable composite resins.

Another study evaluated the impact of adhesive type (etch-and-rinse versus self-etch) and restoration with or without a flowable composite resin liner on marginal and internal integrity.86 Eighty extracted human molars were prepared for standardized MOD cavities with the gingival margin below the cementoenamel junction (CEJ). Cavities were randomly treated with 1 of 2 etch-and-rinse adhesives (Syntac; Ivoclar Vivadent and XP Bond; Dentsply Intl) or 1 of 3 self-etch adhesives (Xeno V; Dentsply Intl, Prompt-L-Pop; 3M ESPE, and iBond SE; Heraeus Kulzer, South Bend, Ind). One half of all specimens was restored by filling the apical 4 mm of the preparations with a flowable composite resin (SDR; Dentsply Intl) and the coronal 2 mm of the preparations with the manufacturer’s composite resin (Ceram.X Mono, Dentsply Intl; Tetric EvoCeram, Ivoclar Vivadent; Filtek Supreme XT, 3M ESPE; and Venus Diamond, Heraeus Kulzer). The other half of the preparations was filled with the composite resin only by using a horizontal incremental fill technique. Specimens were stored for 21 days at 37°C in distilled water, subjected to 100 000 cycles in a masticatory simulator and 2500 thermal cycles (5°C/55°C), examined by SEM for external marginal integrity (% gap-free margin), sectioned mesiodistally, and reexamined for internal marginal integrity. For both external enamel margins and internal dentin margins, etch-and-rinse adhesives demonstrated significantly better marginal integrity than self-etch adhesives. The flowable composite resin had no effect on marginal integrity.

The effect of a flowable composite resin liner compared to a resin-modified glass ionomer (RMGI) liner on microleakage in class 2 composite resin restorations was the subject of
in an in vitro study. Forty-eight extracted premolars received 2 standardized class 2 slot preparations with the gingival margin below the CEJ. The teeth were randomly divided into 6 groups. Half received a 2-step etch-and-rinse adhesive (Single Bond; 3M ESPE), and the other half received a 2-step self-etch adhesive (Clearfil SE; Kuraray America Inc). One group for each adhesive received a 0.6 mm to 0.8 mm thick layer of flowable composite resin (Filtek Flow; 3M ESPE), and 1 group for each adhesive received a RMGI lining (Fuji II LC; GC America, Alsip III) before the application of the adhesive. All cavities were filled with Filtek P60 composite resin (3M ESPE) by using horizontal increments. After finishing, all specimens were thermocycled (5°C/55°C) for 1000 cycles and immersed in methylene blue for 48 hours, sectioned, and the gingival margin graded for microleakage. The groups that received the RMGI liner had significantly lower microleakage than either the flowable composite resin or no liner groups.

The benefits of an RMGI liner for maintaining the composite resin-dentin interface were also demonstrated in an in vitro study of class 1 composite resin restorations. Standardized occlusal cavities were prepared in 60 extracted third molars and randomly assigned to 1 of 6 groups. Two groups received no liner; 2 groups received a 0.5 mm glass ionomer cement liner (Ketac Molar Easymix; 3M ESPE); and 2 groups received a 0.5 mm RMGI liner (Vitrebond; 3M ESPE). All groups were restored with a 2-step etch-and-rinse adhesive (Adper Single Bond 2; 3M ESPE) and composite resin (Filtek Z250; 3M ESPE) by using a horizontal incremental technique. One half of the specimens were thermocycled (5°C/55°C) for 5000 cycles and cut into 0.8 mm thick slices for microtensile bond strength testing and confocal microscopic analysis. The results showed that glass ionomer did not improve the bond strength to dentin; however, the use of an RMGI liner significantly reduced the presence of interfacial gaps after thermocycling, suggesting that the long-term quality of the adhesive interface is improved when RMGI liner is used.

A challenge in the restoration of posterior composite resin restorations is achieving appropriate proximal contacts. An in vitro study evaluated the impact of 3 different matrix techniques on the proximal contact tightness of a restoration. To maximize standardization, an MOD cavity was manufactured in 45 ivorine mandibular right first molars that were individually restored in a dental manikin with 1 of 3 fill techniques: a sectional matrix system (Palodent; Dentsply Intl) and wooden wedge were applied and used to fill the mesial box, removed and a fresh matrix placed to restore the distal box, followed by an occlusal increment of composite resin; mesial and distal matrices were applied simultaneously and the tooth filled as in the first group; a circumferential matrix (Walser Matrices; Walser Dental GmbH) was placed and the tooth filled as for the other 2 groups. The contact tightness was evaluated with a tooth pressure meter that has been used in multiple previous studies of this type. The application of 2 matrix bands simultaneously produced the tightest proximal contacts. The circumferential system produced a mesial contact that was similar to the first group but lower than the simultaneous matrix application group, whereas the distal contact was the lowest of any contact tightness in the study.

An in vivo study evaluated the proximal contact tightness of class 2 cavities restored with a sectional or circumferential matrix system. Eighty-five individuals in need of a MOD cavity assigned to the sectional matrix group, both the mesial and distal surfaces received the matrix, ring, and wooden wedge at the same time. Restorations were bonded with Optibond FL (Kerr Corp) and Herculite composite resin (Kerr Corp) was applied in a multilayer incremental technique. All restorations were done by using rubber dam isolation. Proximal contact tightness was measured with the tooth pressure meter before treatment and immediately after restoration placement at 5 proximal contacts: both contacts of the restored tooth and an additional contact in a mesial direction in the same quadrant and corresponding contacts in the contralateral quadrant. For the 2-surface restorations, the use of the sectional matrix resulted in a significantly tighter proximal contact than did the circumferential matrix. The sectional system resulted in an increase of contact tightness, whereas the circumferential system resulted in a decrease of contact tightness. Regarding the 3-surface restorations, the sectional matrix resulted in a slight increase in proximal contact tightness, while the circumferential system resulted in a slight decrease. The difference was not significant. The authors suggest that the result with the MOD restorations was likely due to the simultaneous application of the matrices and rings, resulting in a separation effect in opposite directions and thereby diminishing their effect at the contact area.

A study evaluating the light intensity of quartz-tungsten halogen (QTH) and light-emitting diode (LED) polymerization lights emphasized the importance of monitoring polymerization lights in dental offices. At 8 government dental health institutions in Saudi Arabia, 210 dental polymerization lights were evaluated for light intensity output with a digital spectrometer. Each light was tested 3 separate times, and the tip diameter was accounted for in determining the light intensity. Any light with a reading below 300 mW/cm² was considered unsatisfactory. The test included 120 QTH lights and 90 LED lights.
The intensity values of the QTH lights ranged from 6 to 795 mW/cm², and only 32.5% of the tested QTH lights achieved the minimum 300 mW/cm² cutoff value. The intensity of the LED lights ranged from 2 to 986 mW/cm², and only 15.6% of the LED lights were considered unacceptable. This study reflects findings in earlier polymerization light assessments and clearly shows that just because a unit emits light does not mean that it is adequately polymerizing composite resin.

Finishing and polishing composite resin restorations is a concern for clinicians, not only to make the restoration more esthetic but also to minimize plaque adherence. An in vitro study evaluated 5 mutans biofilm adherence to different composite resin types subjected to different polishing regimens. Sixty 6.0 mm diameter × 3.0 mm high specimens were made with each of 3 composite resin materials: nanofilmed (Filtek 350; 3M ESPE), nanohybrid (Esthet X; Dentsply Intl), and microhybrid (Vit-l-essence; Ultradent Products Inc, South Jordan, Utah). Composite resin was placed into the mold in a single increment, covered with a Mylar strip, and polymerized. After 24 hours dark storage in distilled water for 24 hours, 20 specimens of each composite resin were submitted to 1 of 3 finishing techniques: none (control); sequential finishing with Sof-Lex disks (3M ESPE); and 30 blade tungsten carbide bur (Beaver), followed by silicon carbide brushes (Astrobrush; Ivoclar Vivadent). One half of the specimens from each group were incubated in sterile human saliva for 1 hour. All specimens were incubated with a standard suspension of S mutans and tested for biofilm adherence. The nanofilmed composite resin presented the lowest level of bacterial adherence, regardless of the finishing technique or presence/absence of human saliva. In the presence of saliva, no difference in bacterial adherence to the nanohybrid or microhybrid composite resins was found, regardless of the finishing technique used. The nanofilmed composite resin showed the lowest bacterial adhesion to the unfinished surface.

Caries Diagnosis and Prevention

Accurate caries detection continues to be a problem for clinicians. A number of caries detection devices are commercially available, although the one that has attracted the most attention to date is DIAGNOdent (KaVo Dental, Charlotte, NC). A clinical study compared the diagnostic ability of laser fluorescence using DIAGNOdent to visual inspection in newly erupted, noncavitated molars in children with active caries. This study was conducted in 505 mandibular first molars with no visible cavitation in 307 children, aged 6 to 7 years. Bitewing radiographs were made, and teeth with either dentin or enamel radiolucencies were excluded from the study. The teeth were professionally cleaned with a polishing rubber cup and pumice before diagnostic assessment. Previously calibrated and blinded evaluators assessed each tooth. Visual examination was done with the teeth wet and after air drying, and the teeth were scored by using a previously validated system. Teeth in which caries was not detected either visually or radiographically were measured by using DIAGNOdent; the scores of the 2 examiners were averaged. Interexaminer reliability was excellent. Of 322 teeth scored as sound by visual examination, DIAGNOdent only scored 217 (67.4%) as sound, with the remainder scoring caries anywhere from enamel caries to deep dentin caries. Of 183 visually scored as having enamel caries, DIAGNOdent scored 20 (10.9%) as sound, 24.6% with enamel caries and 59% with dentin caries. Statistical analysis found poor agreement between DIAGNOdent and the visual caries assessment. The lower specificity (higher rate of false positive diagnosis) with DIAGNOdent compared to visual assessment could lead to overtreating sound teeth. A weakness of this study was a lack of histologic diagnosis for the true level of caries in the teeth, although the visual scoring system used has been evaluated and found to be reliable in other studies.

An in vitro study evaluated the ability of DIAGNOdent in determining the end point for carious dentin removal. Extracted molars with occlusal caries presumed to extend into dentin were selected. Teeth were cleaned with an air scaler and radiographed, and teeth without dentin caries were excluded. Fifty-six teeth were assigned to 7 different caries excavation methods (tungsten carbide burs, ceramic burs, sono-abrasion, and chemomechanical using 4 different solutions), by using caries removal endpoints specific to the technique. After caries removal, DIAGNOdent measurements were made of the deepest point of the caries excavation site. Color stereomicroscopic images were used to correlate the staining of dentin to residual caries. The excavated teeth were subjected to microcomputerized tomography (micro CT) to determine the residual mineral density; this is considered a “gold standard” for dentin caries determination. The results showed that the higher DIAGNOdent readings were recorded with greater dentin staining; however, micro CT determined that stained dentin was more mineralized. The authors noted that the results indicate that DIAGNOdent would not be reliable in determining the end-point for caries excavation.

A procedure that is receiving more attention as a treatment for initial proximal and white spot caries lesions is the infiltration technique. One study evaluated the impact of caries infiltration and fluoride application on white-spot appearance. Sixty enamel-dentin specimens were cut from bovine incisors and their color was measured with a spectrophotometer. They were then subjected to demineralization to artificially produce white spots, and the color was remeasured. The teeth were divided into 4 groups: control (artificial saliva storage for 8 weeks); daily immersion
for 1 minute in 0.05% NaF solution, followed by storage in artificial saliva for 8 weeks; application of 2% NaF gel for 1 minute, followed by storage in artificial saliva for 8 weeks; and infiltration with low viscosity resin (Icon; DMG), followed by storage in artificial saliva for 8 weeks. Specimens were retested for color change after 4 and 8 weeks. The group treated with resin infiltration showed a more significant reduction in whiteness than the other 3 groups.

A systematic review of the effectiveness of resin-based versus glass ionomer sealants was conducted. The purpose was to update a systematic review on the same topic in 2009. A search of English language articles was conducted by using criteria determined a priori, and articles were assessed for quality and risk of bias. A total of 16 trials met the criteria for inclusion in the review. Data were pooled and a meta-analysis conducted. The cumulative Relative Risk showed no statistical difference in the performance of the 2 materials in preventing caries after 5 years. However, the authors noted that the risk of selection, detection, and performance bias is high and recommended that more high quality, randomized controlled clinical trials should be done to more conclusively determine whether both resin-based and glass ionomer sealants are equally effective in preventing pit and fissure caries.

Silver Amalgam

Amalgam continues to be an area of less emphasis in materials research. However, some valuable research continues. One clinical study evaluated the effect of various treatment alternatives, other than replacement, for amalgam restorations diagnosed as having 1 or more features that deviated from the ideal. Fifty participants with 113 defective restorations were included in the study. Restorations with localized defects were assigned to one of the following treatment groups: repair (defective site repaired with amalgam), sealing of defective margins (marginal ditching filled with resin sealant), and refinishing (excess amalgam in defective areas was reduced/polished with carbide burs and rubber polishing points). The remaining restorations were either replaced or received no treatment. Restorations were evaluated and scored clinically by using modified USPHS criteria preoperatively, immediately after treatment, and after 1, 2, and 7 years. After 7 years, the repair group had significantly less downgrades or failures than the no treatment group. None of the other groups were significantly different from the no treatment group. The authors noted the study showed that repair was an effective alternative to replacement for amalgam restorations exhibiting the defects addressed by the study. After 7 years, the restorations in the replacement group performed similarly to the other treatment groups. A shortcoming of this study is low recall after 7 years (48%) and subsequent low sample size (54 restorations).

The impact of fetal exposure to metallic mercury from maternal amalgams was the subject of a retrospective cohort analysis. A cohort of children and mothers that was part of the Seychelles Child Development Study had been studied previously because they consumed a diet high in fish (methylmercury exposure) and had already undergone extensive neurodevelopmental testing. Researchers were able to construct the dental status of 587 mothers to determine the number of amalgam surfaces that were present during gestation. Prenatal methylmercury exposure had been previously determined by analyzing the maternal hair growing during gestation. At age 66 months, the children underwent a comprehensive battery of tests to assess their neurological development. The analysis, adjusted for covariates, showed that amalgam surfaces were not statistically associated with any outcome, either with or without adjustment for prenatal and postnatal methylmercury exposure.

Diagnostics

The use of a properly adjusted dental articulator is believed to assist in accurate diagnostic procedures and in the precise fabrication of indirect dental restorations in the laboratory. While intentional overcompensations during adjustment of the articulator’s posterior controls have been suggested as a means of assuring negative prosthesis errors (more than adequate posterior eccentric occlusal clearance), careful and accurate management of the articulator controls may facilitate optimal mechanical

PROSTHODONTICS

Once again, the 2011 literature yielded much clinically important information in the area of prosthodontics for clinicians to consider. A small portion of this voluminous documentation will be considered here. Additionally, several interesting review articles were published that may be of interest to the reader and assist in the intellectual management of an ever expanding body of knowledge in prosthodontics. Although not targeted in the present effort because of limited time and space, readers may choose to investigate synopses addressing guidelines for the care and maintenance of complete dentures, guidelines for maxillary implant therapy, treatment options for missing mandibular incisors, caries risk assessment for prosthodontic patients, the epidemiology and etiology of denture stomatitis, the dimensional stability of irreversible hydrocolloid, impression materials in fixed prosthodontics, the evidence base for restorations of posterior bounded edentulous spaces, zirconia-based partial fixed dental prostheses, posterior ceramic inlays, an update on soldering technology, the inviolability of the biologic width, allergic reactions in the dental office, research trends in prosthodontics, and implant dentistry in modern dental school curricula.
and functional occlusal morphologic results. In an attempt to identify average values for articulator settings, investigators\textsuperscript{115} used electronic pantography (Cadiax Compact; Whip Mix Corp, Louisville Ky) to measure 3 characteristics of condylar movement [sagittal condylar inclination (SCI), immediate mandibular lateral translation (IMLT), and progressive mandibular lateral translation (PMLT)] in 73 healthy individuals that varied with respect to horizontal and vertical skeletal relationships.

Data gathered from participants included profile photographs with the Frankfort plane horizontal and the teeth in maximum intercuspation and an electronic pantographic record. Three senior investigators scored each profile photograph according to horizontal (skeletal Class I, II, or III) and vertical (reduced, average, or increased) classifications.

Results indicated good or total agreement for sagittal (97%) and vertical (70%) skeletal patterns. Participants judged to be skeletal Class II had significantly higher SCIs than Class I (4 degrees) and Class III (7 degrees) participants, while skeletal Class I and III participants were statistically similar. Participants with average vertical skeletal patterns displayed significantly lower SCIs than those with reduced and increased vertical skeletal patterns. No statistically remarkable trends in the data could be identified with respect to progressive horizontal condylar guidance (PMLT), although clustering around the minimum of 5 degrees and maximum of 15 degrees was seen. An IMLT of limited clinical impact (>0.5 mm) was recorded across all participants.

The authors concluded that during prostodontic therapy for patients with noticeable skeletal discrepancies, consideration should be given to the acquisition of appropriate clinical records to facilitate the adjustment of articulator controls, thereby optimizing treatment outcomes.

During this time of great emphasis by patients on dentofacial esthetics, successful clinicians must consider societal perceptions of beauty, harmony, balance, and proportion when treatment planning. It has been suggested that the general public considers the smile second only to the eyes when evaluating the facial features most important to esthetics. But what in the smile is considered esthetically attractive and who should be the final judge of dental esthetics when clinician and patient opinions diverge?

To begin to answer these important questions, investigators\textsuperscript{116} searched the Internet using the key phrases “best smile” and “female celebrities.” The search resulted in 50 celebrities voted by lay people to have beautiful smiles. Large, frontal view images of these individuals displaying entire faces and open smiles at public events were acquired. Images were evaluated by a single examiner with the aid of image analysis software to qualify 8 specific esthetic smile criteria.

Results indicated that 80% of the smile specimens exhibited an average upper lip position (revealed 75% to 100% of maxillary anterior teeth), 62% displayed upward upper lip curvature (corners of mouth higher than midpoint of upper lip), and 78% had a parallel smile line (maxillary incisal edges parallel to lower lip curvature). Forty-two percent of the images revealed maxillary incisal edges not touching the lower lip (34% were touching, 24% were covered). With regard to total tooth visibility, 60% displayed up to the second premolar, and 32% displayed up to the first molar. In 64% of the sample the dental midline was coincident with the facial midline, while 36% demonstrated a midline discrepancy. None of the frontal view images exhibited maxillary anterior tooth widths that abided by the golden proportion. No midline diastemas were detected.

During diagnostic and therapeutic interventions, clinicians should have a clear understanding of the esthetic expectations of patients. Often these expectations are derived from high profile individuals considered beautiful by the general public. If this is true, then a beautiful smile might contain the following: exposure of the entire cervicoincisal length of the maxillary anterior teeth, maxillary incisal edges parallel to the lower lip, maxillary first molars in the esthetic zone, coincidence of the dental and facial midlines, absence of diastemas, and emphasis on the harmony of the smile composition as opposed to strict adherence to the golden proportions. The authors suggested that the opinions and perceptions of lay people regarding beauty must be clearly understood in order to satisfy the esthetic desires of an increasingly demanding dental patient population.

When the prostodontic replacement of some or all of the anterior maxillary teeth is required, or when substantial portions of anterior tooth structure must be restored, the correct diagnosis of the appropriate outline form of the teeth is considered critical to the esthetic success of the restorative effort. Classic dental literature has been relied upon to aid in selecting the tooth form. J. Leon Williams\textsuperscript{117} suggested that the maxillary central incisor outline form was oval, triangular, or quadrangular and that the outline form should harmonize with the inverted shape of the patient’s face (Typal Form Theory or Law of Harmony). Later, John Frush and Roland Fisher\textsuperscript{118} discussed the concept of “Dentogenics,” which recommended an esthetic relationship between gender and the outline form of the maxillary anterior teeth. Accordingly, a feminine personality is best associated with a rounded maxillary incisor outline form, while a masculine personality is best represented by a square or angular tooth form.

To identify more scientifically credible parameters for the diagnostic selection of maxillary anterior tooth form, researchers\textsuperscript{119} have assessed differences between males and females in terms of oval, triangular, and quadrangular tooth form. The experimental population consisted of 433 participants (mean age of 15.92 years).
Maxillary right central incisors were photographed by using a standardized protocol, and the images were digitized and subjected to a detailed software-aided, graphical image evaluation.

Results indicated that an oval outline form was most prevalent in both genders (male = 54.93%, female = 57.73%). However, significant differences were identified with respect to the triangular and quadrangular forms. The triangular form was significantly more common in men (36.15%) than in women (23.54%), while the quadrangular form was significantly more prevalent in women (18.64%) than men (8.92%).

The authors suggest that predictive theories of prosthetic tooth outline form can serve, at best, as diagnostic guidelines or selection starting points. Ultimately the prosthetic provision of anterior tooth forms that differ from the patient’s original incisor outline form may not compromise the esthetic outcome of the reconstruction. Perhaps the esthetic preferences of the observers are more important than anticipated form-gender correlations. If so, careful consideration must be given to modern esthetic perceptions and the many personal, professional, social, and cultural factors that temper estimations of facial-dental beauty.

Removable Prosthodontics

Denture tooth debonding during extended, high-force oral function remains a concern, particularly when involving complicated and expensive, fixed or removable implant-supported dental restorations. Long-term successful repair of denture tooth bonding failures are both challenging and inconvenient. Attempts to improve denture tooth-to-base adherence have focused on surface treatments (tooth preparation, creation of diatorics, and chemical priming), and resin chemistry manipulations.

A recent in vitro investigation addressed fatigue failure between highly cross-linked central incisor denture teeth and 2 popular denture base resins, including compression-molded, heat-activated, polymethyl methacrylate (PMMA) resin and light-activated, urethane dimethacrylate (UDMA) resin. Experimental manipulations of the denture teeth included: (1) grinding on the tooth ridge lap, (2) grinding plus placement of a diatoric, (3) grinding plus use of a bonding agent, and (4) grinding plus diatoric plus bonding agent. The bonding agent used was a proprietary material (Eclipse Bonding Agent; Dentsply Intl). Following fabrication, all specimens were stored in water for 7 days, thermocycled (1000 cycles, 5°C to 55°C, 30 second dwell time), stored in water for an additional 28 days, and subjected to cyclic loading (22 N, 14 to 400 cycles, 1.5 Hz, 5 mm/minute crosshead speed, water submerged) until failure. Incisal edge loading occurred at a 135-degree angle to the tooth’s long axis. Fractured surfaces were assessed microscopically to characterize mode of failure.

Results indicated no significant differences in mean shear bond strength for all surface treatments investigated in the PMMA group. In the UDMA group, specimens fabricated without a bonding agent were too weak to test, while specimens incorporating a bonding agent demonstrated statistically similar shear bond strengths. A comparison between the PMMA and UDMA groups revealed significantly higher shear bond strengths in the UMDA group.

The authors concluded that the use of the denture tooth surface treatments investigated before the fabrication of PMMA denture bases yields similar bond strengths, indicating no need for proprietary bonding agents. The highest shear bond strengths were seen with the UDMA denture bases when proprietary bonding agents were used. Evaluation of the mode of failure indicated mixed adhesive-cohesive failure or pure cohesive failure in both the PMMA and UDMA systems.

Varying opinion exists regarding the optimal posterior occlusal conditions for conventional complete dentures. Consideration should likely be given to the physiologic health of the stomatognathic system, including residual ridge dimensions, neuromuscular coordination, and a number of other edentulous diagnostic criteria. Pressure transmission originating from occlusal loading and force distributed along the denture foundation are thought to have a role in the health and durability of the denture supporting tissues. Occlusal form and denture tooth material may influence this pressure transmission and distribution.

To investigate this concept, an in vitro study considered 3 denture tooth materials (acrylic resin, micro-filled composite resin, and ceramic) and 4 posterior cusp angulations (0, 20, 33, and 35 degrees). Eight pairs of maxillary and mandibular left and right first molar denture teeth were incorporated into simple single tooth denture segments (flat acrylic resin bases, 15x15 mm, 3 mm thick). Maxillary and mandibular tooth pairs were arranged into Class I occlusal relationships and introduced into a vertical test frame, and occlusal contacts were refined. A simulated 50 N occlusal impact load was used. Color-keyed, pressure sensitive sheets registered pressure transmission and distribution under the denture bases. Pressure-sensitive sheets were then digitally analyzed.

Results indicated significant interactions between denture tooth materials and cusp angulations with respect to average and maximum pressure transmission. In general, 0 degree teeth showed lower pressure transmission than 33 degree and 35 degree teeth for all materials evaluated. Authors were careful to note the dramatic deviation of their experimental design from clinical reality. However, they believe that under carefully controlled conditions, smaller posterior denture tooth cusp angulations may result in less force transfer through the denture base and, therefore, may be preferred for
compromised edentulous patients. Unfortunately, the authors did not comment on the likely influence of occlusal morphology on the masticatory efficiency and force needed for bolus penetration. Additional studies incorporating conditions that more closely simulate clinical reality are needed to further delineate these important questions.

At a time when the dental profession has a great variety of nonremovable prosthodontic options to offer patients, the cost effectiveness and therapeutic conservatism of conventional complete dentures and partial removable dental prostheses (PRDP) render them the therapy of choice for many. The past year’s professional literature yielded a number of interesting articles addressing conventional PRDPs. Two of these publications addressed the appropriateness of mouth preparation and prescription writing in the provision of PRDP therapy.

It remains the clinician’s responsibility to appropriately prepare the patient to receive a PRDP and to assure that the design of the PRDP is optimal for existing conditions. Researchers have studied the degree to which dentists have fulfilled these responsibilities by examining work authorizations and definitive casts sent to a dental laboratory for PRDP fabrication. This investigation specifically addressed the prevalence of requests for occlusal and cingulum rests in work authorizations and the indications of quality rest seat preparations on accompanying definitive casts.

Definitive casts and work authorizations provided by 45 general dentists to a single dental laboratory for PRDP framework fabrication over a 5 month time period were investigated. The best available literature was used to define criteria for ideal rest seat preparations. Upon examination of available definitive casts, rest seats that fell outside these criteria were classified as either underprepared or overprepared.

Over the time period of this study, 68 definitive casts were provided to the dental laboratory for PRDP framework fabrication. Of these casts, 48% did not have work authorization, prescribed framework designs, or any indication of rest seat preparation on the definitive casts and so were excluded from further investigation. Of the remaining 35 casts, a cumulative total of 81 rests were prescribed. Only 24 of the prescribed 81 rests had obvious rest seat preparations on corresponding definitive casts. When compared with the defined criteria, 18 of the 24 rest seat preparations (75%) did not satisfy the criteria. Eye opening examples of inadequate definitive casts, resultant PRDP frameworks, and work authorizations are illustrated in the article.

Overwhelmingly conservative concluding remarks provided by authors suggested that mouth preparations for PRDPs and accompanying laboratory work authorizations are not always of adequate quality. The authors go on to suggest that dental professionals should aim to provide high quality dental prostheses and that emphasis should be placed on the importance of denture design in continuing dental education courses for dentists and dental laboratory technicians.

Investigators undertook a second investigation, surveying materials provided to 5 commercial dental laboratories in the Midwest related to requests for new PRDP fabrication. All submitted materials were photographed upon receipt by the laboratory and before their return to the dentist. The photographic images documented work authorizations, casts, impressions, interocclusal records, articulators when provided, completed frameworks, and completed PRDPs. A total of 573 matched images (before and after photographs) and an additional 330 unmatched images were available for data analysis.

Findings indicated that Kennedy Class I PRDPs remain the most common (39% of total), followed by Class III (31%), Class II (25%), and Class IV (5%). Approximately 70% of the PRDPs produced incorporated a metal framework, 25% were fabricated in acrylic resin without metal frameworks, and 5% were fabricated with flexible acrylic resin. Approximately 42% of the available work authorizations did not contain dentist-directed PRDP design information. Based on liberal criteria for rests (extension onto either prepared rest seat, or over occlusal/incisor tooth surface, or over dental implant), 79% of PRDPs were considered to have rests; this included no flexible PRDPs and only one-third of the acrylic resin PRDPs. With respect to major connectors, the U-shaped major connector was most frequent in the maxilla (73%), while the lingual plate major connector was most frequent in the mandible (60%). For PRDPs that did not incorporate a metal framework, a U-shaped design was most frequently used in the maxilla (95%), and a lingual plating design was most frequently used for mandibular restorations (91%).

The authors concluded that PRDPs of all Kennedy classifications continue to be prescribed, even though dentist input into design and fabrication is minimal. The incidence of PRDPs that do not incorporate metal frameworks in this sample was 33%, higher than in previous reports. Additionally, an unfavorably high incidence of PRDPs fabricated without appropriate tooth support (20%) was identified. This report represents the disappointing level of professionalism brought to bear on the treatment of partial edentulism with PRDP prosthodontics.

For extension base PRDPs, the inclusion of dental implants in edentulous areas may alter the rotational mechanics on functional loading of the prosthesis. The potential for improved prosthesis support, stability and retention, and short-term and long-term biologic/physiologic benefit necessitates the consideration of this underused treatment option. Two researchers provided a retrospective investigation quantifying the posterior mandibular ridge resorption associated with Kennedy Class I implant-supported and implant-retained partial removable overdentures (PRODs).
Thirty-four healthy males with edentulous maxillae and 8 remaining mandibular anterior teeth were studied. Single, root-form dental implants were placed bilaterally in the first molar positions by using a 2 stage surgical protocol. Implant lengths ranged from 8.0 mm to 13.0 mm and implant diameters ranged from 3.6 mm to 5.0 mm. After healing, mandibular PRODs and maxillary complete dentures were provided by using a balanced, semi-anatomic occlusal scheme. Half of the participants received implant-supported PRODs in which extension bases directly contacted the healing abutments fastened to the dental implants. The remaining participants received implant-retained RPRODs by using a ball and gold matrix attachment system. Attachment components were incorporated into the RPRODs by using a direct intraoral functional pick-up procedure. Appropriate maintenance was provided over a 5-year recall period.

Two panoramic radiographs, one immediately before and one 5 years after prosthesis placement, were obtained for comparison. The posterior residual ridges were evaluated on panoramic radiographs by using a previously described method of proportional area measurement in terms of area index. This method is said to control for inherent magnification problems in the posterior mandible on panoramic radiographs. Results indicated that the overall loss of edentulous ridge height associated with implant-supported PRODs was 0.15 mm (0.03 mm/yr) during the 5-year recording period. For implant-retained PRODs over the same time period, the loss of edentulous ridge height was significantly greater at 1.03 mm (0.21 mm/yr).

The authors carefully suggested that direct vertical resistance to functional loading provided by implant-supported PRODs may be linked to the reduced loss of edentulous ridge height in this study. However, the authors caution that additional clinical trials on larger, mixed-gender patient populations are needed before any definitive conclusions can be reached.

Fixed Prosthodontics

Evidence-based dentistry involves reducing available science to the best, most credible information and clinically applying that information during patient management. A comprehensive appraisal of the cumulative professional literature is challenging for private practitioners due, in part, to convoluted search strategies, complicated statistical techniques, and the lack of universal access to published material. With this in mind, Layton126 detailed the efforts of one clinician to use an evidence-based approach to answer a clearly defined, clinically important question that contains the 4 elements: P-Patient, I-Intervention, C-Comparison, O-Outcome or PICO: For a patient with biologically and structurally sound natural tooth abutments, are the survival and complication rates of ceramic partial fixed dental prostheses (PFDPs) comparable or superior to those of metal ceramic PFDPs?

A 6S search strategy27 was used to identify relevant clinical evidence in a timely manner. This search method involves referencing 6 layers of cumulative evidence: systems (decision support services), summaries (evidence-based textbooks), synopses of syntheses (descriptions of systematic reviews), syntheses (systematic reviews), synopses of studies (evidence-based journal abstracts) and original studies.

The author’s search yielded the following: no systems or summaries; no synopses in the journal Evidence-Based Dentistry, 3 synopses in the Trip database; 3 systematic reviews in the Cochrane database; 6 systematic reviews in MEDLINE OVID; and no systematic reviews in Embase database. Of the potential resources identified, 1 systematic review28 and 1 original prospective cohort study129 were considered valid and relevant to the PICO question posed.

Although the internal validity of the single selected systematic review was deemed compromised, it was believed that careful consideration of results could be applied to clinical practice. Estimated event rates and 5-year outcomes (95% confidence) suggested the survival rate of metal ceramic PFDPs to be significantly higher than that of ceramic PFDPs. Ceramic PFDPs were shown to experience a higher incidence of technical failure. Having good internal validity, the selected prospective cohort study demonstrated high survival rates for metal ceramic PFDPs.

The author concluded that for patients with sound natural abutments, the provision of a metal ceramic PFDP is likely to have a significantly greater 5-year survival rate than a ceramic PFDP. While differences in clinically important complications remain unclear in the current literature, studies indicate that the incidence of complications for metal ceramic PFDPs is lower than that for ceramic PFDPs.

The interest of the general population in improved dental esthetics and the demand for ceramic laminate veneers remains great. While good long-term survival rates have been demonstrated for ceramic veneers given ideal clinical conditions, questions remain regarding the clinical application of veneers in patients presenting with worn dentitions and limited natural tooth structure. When limited tooth structure exists, consideration must be given to the optimal tooth preparation design and fracture resistance of the definitive restoration.

To address this clinically important question, investigators130 reported on an in vitro investigation involving 32 intact, nonworn, nonrestored, extracted, human maxillary central incisors. Available teeth were distributed to 4 experimental groups; 2 groups of teeth without incisal wear and 2 groups with incisal wear. The incisal edges of the teeth allocated to the wear groups were reduced by 2 mm to simulate clinical incisal attrition. The teeth in 1 of the nonwear groups received veneer preparations incorporating palatal shoulder finish lines, while teeth in the other nonwear group received palatal chamfer finish
lines. Likewise, 1 of the wear groups received palatal shoulder finish lines, and the other wear group received palatal chamfers. All preparation finish lines were maintained in enamel.

Pressed ceramic veneers (IPS Empress; Ivoclar Vivadent) of consistent overall dimensions were fabricated. Veneers were luted by using standard bonding procedures. Each specimen was positioned in a universal testing machine, loaded 1 mm apical to the incisal edge at 90 degrees to the palatal surface (0.05 mm/min crosshead speed) until catastrophic failure. Results indicated that the highest load-to-failure was seen in the nonwear/palatal chamfer group. Load-to-failure for the nonwear/palatal shoulder and the wear/palatal chamfer groups were statistically similar. The lowest load-to-failure was seen in the wear/palatal shoulder group.

The authors concluded that preparation design and the presence of incisal edge wear significantly affected the load to failure of bonded press ceramic veneers. The use of a palatal chamfer preparation significantly increased load to failure compared to palatal shoulder preparation for both worn and nonworn central incisors.

Severe occlusal wear is generally characterized as a complex multifactorial, biomechanical phenomenon. The successful restoration of severely worn occlusal tooth structure requires the broad consideration of etiologic, biomechanical, chemical, clinical, and patient-related factors. Restoring advanced occlusal wear with minimal tooth preparation and additive adhesive techniques is certainly an attractive alternative in carefully selected situations. However it is unknown which materials or processes offer the greatest opportunity for long-term restorative success.

Ultrathin bonded posterior occlusal veneers may represent a viable and conservative alternative to traditional occlusal coverage restorations in the management of severe occlusal wear. By using an in vitro protocol, researchers assessed the influence of ceramic and composite resin computer-aided design and computer-aided manufacturing (CAD/CAM) restorative materials on the fatigue resistance of ultrathin (0.6 mm) posterior occlusal veneers.

The selective removal of occlusal enamel from 40 sound, freshly extracted human maxillary molars maintaining cuspal inclinations was accomplished to simulate occlusal wear. Occlusal veneer restorations were fabricated by using a CAD/CAM system (Cerec 3; Sirona Dental Systems GmbH, Bensheim, Germany). All tooth specimens were fitted with a standardized occlusal overlay from the CAM database. The average thickness of the restorations was 0.6 mm at the central groove, a maximum of 1.3 mm at the cusp tips, and 1.0 mm at the internal cusp slopes. Ten restorations were milled from each of the following materials: leucite ceramic (Empress CAD; Ivoclar Vivadent), lithium disilicate ceramic (e.max CAD; Ivoclar Vivadent), composite resin (Paradigm MX100; 3M ESPE), and an experimental polyethylene fiber reinforced composite resin (XR material; Kerr Corp). All restorations were luted to tooth specimens by using standardized bonding protocols.

Fatigue testing incorporated closed-loop, servohydraulic loading through a 7 mm diameter composite resin spherical loading probe. All occlusal loads were delivered to tripod, simultaneous intercuspal contacts while submerged in water. Isometric masticatory loading was simulated at 5 Hz, starting with 200 N for 5000 cycles, followed by stages of 400, 600, 800, 1000, 1200, and 1400 N at a maximum of 30 000 cycles each. The number of cycles to initial failure (crack detection) and the number of cycles to catastrophic failure (restoration fragmentation) were recorded.

Results indicated that both the composite resins tested demonstrated significantly increased fatigue resistance when compared to the ceramic materials tested. None of the leucite or lithium disilicate occlusal veneers withstood all 185 000 load cycles, while 60% of the composite resin and 100% of the experimental resin veneers survived the full loading regimen.

The authors concluded that, within the limitation of this in vitro accelerated fatigue study, the CAD/CAM composite resins investigated may be considered for ultrathin posterior occlusal veneers, even in patients with expected high functional loading. Among the ceramic materials tested, only the lithium disilicate should be used for the fabrication of this restoration type and should only be considered when light to normal functional loading is expected. Additional in vivo testing under carefully controlled conditions must be carried out.

Implant Prosthodontics

The accuracy or passivity of fit of multiple-implant, screw-retained, metal frameworks has been an area of interest to the profession for many years. While definitive information on adverse outcomes related to inaccurate fit is lacking, concern for optimizing prosthesis fit has been expressed, and methods for achieving such outcomes have been developed and applied. To assess evidence-based, best manufacturing methods, investigators systematically reviewed all in vitro research on the fit of screw-retained implant frameworks fabricated by using available techniques and materials.

An electronic search of the professional literature produced 248 articles related to implant framework fit. After applying predetermined inclusion criteria and manually searching additional publications, 26 articles were selected for review. The heterogeneity of experimental design, the use of different implant/abutment systems, and the varying fit assessment methodologies and conditions complicated the systematic review process. Fit accuracy recordings were made by using microscopic measurement, photogrammetric assessment, laser videography, coordinate measurement, and modeling techniques.
The fabrication methods reviewed included the conventional casting of noble and base metal alloys; connection of sectioned frameworks with soldering, cast-to, and laser welding processes; electric discharge machining corrective processing; CAD/CAM; and fabrication by means of the resin bonding of premachined cylinders to the framework body.

The results of the systematic review of in vitro studies indicate that no one implant framework fabrication method or material provides absolute accuracy or passivity of fit. The casting of noble alloys is a predictable method for producing accurately fitting frameworks without the need for additional corrective processing. However, the casting of base metal alloys generally does not yield acceptable framework fit, necessitating additional corrective measures (laser welding or electric discharge machining). The benefits of soldering were found to be unclear and likely of historical interest given modern laser welding alternatives. Electric discharge machining, CAD/CAM, and bonded framework constructions have great potential to produce multiple-implant frameworks of excellent fit. To date, the CAD/CAM process provides the most consistent fit accuracy outcomes.

The authors were careful to conclude that despite the processes available for producing accurate implant frameworks by using in vitro protocols, overriding clinical concerns must be considered. When the inherent inaccuracies of impression procedures and definitive cast fabrication are considered, the provision of passively fitting, multiple-implant, screw-retained prostheses becomes a far more complicated issue.

Implant-assisted dental restorations are often called upon to resist substantial functional and parafunctional loads. To avoid technical complications (loosened, bent, or fractured screws or damage to the implant-abutment interface), the load-bearing capacity of the implant and its components becomes a critical feature of the restorative system. By using an in vitro protocol, researchers evaluated the static load-bearing capacity of 6 different implant systems, representing various implant-abutment connection designs.

Experimental specimens from 6 implant companies were developed. Implant-abutment connection designs included internal conical interface with hexagon index (Astra Tech Inc, Waltham, Mass); internal butt interface and short conical matrix with hexagon index (Bego USA, Lincoln, RI); internal butt interface with trilobe index (Camlog Industries, Basel, Switzerland); internal conical interface without index (Dentsply-Friadent, York, Pa); internal butt interface with hexagon index (Nobel Biocare, Zurich, Switzerland); and internal conical interface with octagon index (Straumann USA, Andover, Md). Implants were mounted in a universal testing machine at 30 degrees to the loading trajectory. The abutments were placed by using prescribed screws and torque specifications. A custom-made, hemispherical loading device was seated on all unmodified abutments. Loading was accelerated at a constant crosshead speed of 1 mm/min. The load-displacement curves were developed, and the onset of notable plastic deformation was determined. After load testing, the specimens were embedded, sectioned, and visually inspected at ×10 magnification to assess failure mode.

The results indicated that the implant-abutment load-bearing capacities of Straumann, Friadent and Astra Tech were significantly lower than those for Camlog and Bego, while there was no statistical difference between Nobel Biocare and all other systems. Applied loads at the onset of plastic deformation for Straumann, Friadent and Astra Tech were significantly lower than for Camlog, while Bego and Nobel Biocare did not differ significantly from other systems tested. The system-specific failure modes resulting from this static overload experimental approach varied widely. In general, long opposing lateral surfaces at the implant-abutment interface appear to be advantageous with respect to load-bearing capacity when compared to relatively short connection designs.

The authors made 2 important concluding statements. First, the load-bearing capacities of all systems tested were considerably higher than the expected average functional forces. Second, static overload testing of implant-abutment connections does not permit reliable conclusions with respect to long-term clinical mechanical durability or success. The performance of these constructions during in vivo functional and parafunctional loading conditions may be influenced by other factors not considered in the present protocol, including cyclic loading, variable load trajectories, screw loosening and fatigue, and progressive interfacial microgap formation to name only a few.

Solid documentation of the benefits of implant-retained and implant-supported mandibular overdentures compared with conventional mandibular complete dentures has appeared in the professional literature over the past 15 years. Enhanced prosthesis retention and stability are likely 2 of the more important factors contributing to the success of mandibular implant overdentures. However, information related to the number of implants needed and the attachment systems used to provide optimal treatment outcomes remains ill-defined. Investigators evaluated 3 different mandibular implant overdenture treatment modalities with respect to 4 treatment outcomes (prosthesis retention and stability, tissue response, patient satisfaction and preference, and complications) by using a prospective, randomized, crossover, clinical trial design to determine statistical equivalence among treatment approaches.

Thirty edentulous participants (63% male; mean age 58.9 years) with at least 1 year of conventional complete denture experience received 4
root-form, threaded, 3.75 mm diameter dental implants (Bränemark, Nobel Biocare) in the anterior mandible by using a conventional 2-stage surgical approach. After 4 to 6 months of healing, 3 different overdenture attachment systems were developed for each participant in the trial: a 4-implant bar-clip attachment system, a 2-implant bar-clip attachment system, and a 2-implant ball-ring attachment system. The crossover experimental design incorporated 4 observation periods (12 months per period) and 6 different patient exposure sequences to the 3 different overdenture attachment systems. Direct transfer clinical procedures were used to switch among attachment systems during the course of the trial. All participants were provided with new prostheses incorporating 0-degree occlusal schemes. Patients received denture adjustments and attachment maintenance as needed throughout the experimental period.

Results indicated that the 3 treatments were not equivalent, with respect to physical retention measurements, with the 4-implant bar-clip system demonstrating the greatest physical retention and the 2-implant bar-clip the least. Observational, criterion-based retention was judged equivalent among treatments. Both physical and criterion-based stability measurements revealed equivalence among the 3 treatments. In general, all other criterion-based evaluations (condition of prosthesis supporting tissues and periimplant tissue health) revealed equivalence, although the 2-implant ball-ring treatment tended to be more favorable than the 4-implant bar-clip attachment approach. No differences among treatments relative to complication rates were noted. With respect to participant reported treatment preferences, 53% selected the 2-implant ball-ring attachment system, 32% preferred the 4-implant bar-clip system, while only 16% selected 2-implant bar-clip prostheses.

The authors concluded that restoring 2 interforaminally placed implants with independent ball-ring attachments and a mandibular overdenture provided equivalent or more favorable outcomes for most of the measured parameters in the present clinical trial when compared with the more costly and more complicated 2-implant and 4-implant bar-clip alternatives. Perhaps the most telling experimental finding was that patients expressed greater satisfaction with the 2-implant ball-ring approach. This finding seems to suggest that the level of physical retention may not be as important to patient satisfaction and implant overdenture success as previously thought.

OCCLUSION AND TEMPOROMANDIBULAR JOINT DISORDERS

The quest to understand temporomandibular disorders (TMDs) more clearly continued in 2011 with a number of interesting articles. The increase in temporomandibular (TM) joint imaging resulted in several studies with clinical relevance. The first study investigated the association between the disk position and degenerative bone changes of the TM joints. The study was conducted with 218 participants who were clinically diagnosed with internal derangements defined as “an abnormal positional relationship of the articular disk to the mandibular condyle and the articular eminence.” The abnormal positional relationship in internal derangements is more commonly referred to as an anteriorly displaced disk. The significance of anteriorly displaced disks has been recognized in recent years because of TM joint imaging with magnetic resonance imaging (MRI) and computed tomography (CT) scanning. Condylar changes such as cortical bone erosions, marrow space alterations, and decrease in size are some of the changes that can occur with an anteriorly displaced disks.

The purpose of this study was to determine the frequency and possible relationship between disk position and TM joint degenerative bone changes. The inclusion criteria considered individuals who had been clinically diagnosed with an internal derangement in at least 1 TM joint and who had not received any previous treatment. Individuals younger than 16 years and older than 65 years and individuals with systemic diseases, removable dental prostheses, or a history of TM joint surgery were excluded. There were 179 females (82.1%) and 39 males (17.9%), and the average age was 33.4 years. The participants were imaged with both MRI and CT.

The MRI imaging was performed by using a number of different sequences. The 2 most commonly seen sequences in TM joint imaging are the sagittal image with either T1 or proton density (PD) weighting. The condyle, disk, and eminence can be clearly seen in T1 images. The PD helps identify the disk in the scan. Different sequences such as the T2 and the spectral presaturation with inversion recovery (SPIR) help evaluate the condition of the condylar marrow. The coronal sequences allow a different view and help create a 3-dimensional understanding of the anatomy of the TM joint. The echo gradient series was taken at closed mouth, 10 mm, 20 mm, and 40 mm of interincisal opening. This series assesses the position of the TM disk in various stages of opening to determine if the disk realigns when opening. The CT scans were taken in both closed and open mouth positions. The mouth opening was maintained by a disposable occlusion block.

The MRI was used to evaluate both the condition and the position of the TM disk. The disks were determined to be normal (DWD), disk displacement with reduction (DDR), or disk displacement without reduction. (DDWR) Additionally, the MRI assessed and classified range of motion as normal, reduced, or increased. Finally, the MRI was used to evaluate joint effusion in the T2 images. The CT scan determined the presence of
degenerative bone changes in participants with condylar erosion, concavity, flattening, osteophyte formation, osteosclerosis, or subchondral cysts. The MRI and CT scans were evaluated twice by a clinician who was blinded to previous clinical information.

The hypothesis of the study was that there is a relationship between degenerative bone changes and disk displacement without reduction in symptomatic patients with internal derangement of the temporomandibular joint. Of the initial 218 participants, 38 were excluded by the exclusion criteria. The remaining participants were close to the original gender mix, with 82.8% females with an average age of 35.2 years and 17.2% males with an average age of 34.4 years. The most frequent disk position observed was disk displacement with reduction observed in 58% of the participants and disk displacement without reduction observed in 36% of the participants. Of the participants in the study, 6% presented with normal TM joints after imaging. Degenerative bone changes were found in 112 participants (62.2%), with multiple changes found in many TM joints. The bony changes that occurred were, in order of frequency, flattening of the anterior surface of the condyle, surface irregularities and erosions of the articular surfaces, flattening of the articular surface of the temporal eminence, subchondral cysts, and osteophytes.

A statistically significant association between disk displacement without reduction (DDWR) and degenerative bone changes was found in the TM joints of participants with internal derangement ($P<0.001$), and a high probability of degenerative changes with DDWR was present in both the right and left TM joints. Sixty-eight (37.7%) of the participants did not demonstrate degenerative bone changes on imaging, while 112 (62.3%) exhibited some signs of degenerative bone change. Fifteen participants exhibited changes in the right TM joint (8.3%), 17 exhibited changes in the left TM joint (9.4%), and 80 (44.4%) exhibited bilateral changes. An interesting analysis of the participants with DDR demonstrated that DDR did not relate to degenerative bone changes in symptomatic participants.

The significance of degenerative bone changes in DDWR as opposed to the lack of bone changes in DDR resulted from the lack of any disk tissue between the condylar bone and the temporal eminence in both resting and functional positions. Without the benefit of disk tissue to cover the bony structures, changes in cartilage and synovial tissue can occur. Adaptation can occur if the body can respond and repair the areas of damage. As the degenerative process exceeds the adaptation process, the changes can become clinically apparent.

When reviewing the participants who were excluded from the study, 28 of the 38 excluded participants were younger than 16 years old. This is an important issue since the incidence of structural changes in the TM joints occurs in patients younger than previously assumed. When structural changes occur early in life, patients may bear the consequences for decades.

In reviewing the study protocol, the open mouth CT scan could have been eliminated, since information such as joint spacing gained from the open mouth CT could have been seen in the open mouth MRI. The considerable strength of this study was the use of both MRI and CT scanning to evaluate the structural changes that occur in TM joints with internal derangements. Using MRI to evaluate disk conditions and disk position in combination with CT to evaluate condyle conditions and condyle position allows for an accurate assessment of the TM joints and the foundation of the occlusion.

The clinical significance of structural changes in the TM joint was reviewed in a study that evaluated the concept that bilateral TM joint disk displacements without reduction (DDWO) are determinants of horizontal and vertical ramus deficiencies. The study consisted of 68 consecutive participants who were referred for TM joint pain. There were 62 women and 6 men in the group with a mean age of 35.2 years. Inclusion criteria were having a TMD diagnosis, being aged from 18 to 50 years, being of European origin, having all first molars, and being ambulatory and available for the study schedule. Exclusion criteria included acute infection or other significant diseases of the teeth, ears, eyes, nose, or throat, a debilitating physical or mental illness, the presence of a collagen capsular disease, a history of traumatic orthodontic treatment, a history of rheumatoid arthritis, and congenital anomalies.

The participants underwent clinical and cephalometric evaluations, followed by MR imaging of the TM joints in order to determine whether bilateral DDWO is related to the cephalometric parameters of horizontal and vertical mandibular ramus deficiencies. The MR imaging was used to diagnose disk displacement and osteoarthrosis (OA) in the TM joints. The MR imaging diagnosis of OA was defined by the presence of flattening, subchondral sclerosis and surface irregularities and erosion of the condyle. The lateral cephalograms were made with the teeth in maximum intercuspation and with the Frankfort horizontal parallel to the floor. All cephalograms were obtained by using the same radiographic machine set for a standardized exposure, and a single investigator traced all the cephalograms. The 3 reference points traced were articular, gonion, and pogonion.

The analysis of the cephalometric parameters selected for horizontal mandibular and vertical ramus deficiencies showed a significant relationship between the MR imaging group with bilateral OA and the cephalometric variable of ramus height. Additionally, there was a significant association between the MR imaging finding of bilateral OA and the cephalometric parameters of mandibular body length. The results of this study raise the question whether the use of
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Cephalometric radiographs should be supplemented by MR imaging when evaluating suspected structural changes in the TM joint and changes in mandibular morphology.

The study protocol could have been improved by imaging with the participants indexed in a fully seated joint position. Imaging in maximum intercuspation allows for a possible horizontal and vertical positional change in the mandibular position, which would impact the results of this study. Additionally, normal disk position was defined at the 12:00 position relative to the condyle and a 1:00 disk position may be a better normal reference. The clinical significance of this study relates to the discussion that internal derangements and/or OA may have a role in skeletal relapse after orthognathic surgery. Since orthognathic surgery is necessary in many patients who have significant horizontal mandibular and vertical ramus deficiencies, the use of MR imaging preoperatively during the diagnostic process will help determine if the deficiencies are related to structural changes in the TM joint.

A similar study137 examined participants who presented with disk displacements without reduction (DDWO) and osteoarthrosis (OA). The participants had clinical and cephalometric evaluations followed by MR imaging of the TM joints in order to determine whether bilateral DDWO and/or OA are related to the cephalometric parameters of mandibular backward positioning and clockwise rotation. Fifty individuals, 44 women and 6 men with a mean age of 35.5 years and with similar exclusion and inclusion criteria as the above study, participated in this study. The angular measurements used for mandibular backward positioning were the facial plane angle (FH to Na-Pog), the angle of convexity (Na-A-Pog), and the SNB angle. The angular measurements for mandibular clockwise rotation were the Frankfort occlusal plane angle (FH to OP) and the Frankfort mandibular plane angle (MP to FH).

The analysis of the cephalometric parameters selected for mandibular backward positioning and clockwise rotation showed a significant relationship between the MRI group of bilateral DDWO and the cephalometric variables of the angle of convexity and Frankfort mandibular plane angle. There was a significant association between the MRI finding of bilateral OA and the cephalometric parameters of the SNB angle, Frankfort occlusal plane angle, and Frankfort mandibular plane angle. Lastly, there was a significant association between the MRI finding of bilateral DDWO and OA and the cephalometric variables of the facial plane angle and Frankfort plane angle. The authors hypothesized that increasing changes in dental morphology may be related to the progressive osteoarthritic changes occurring in individuals with DDWO. This concept warrants the close attention of both general dentists and specialists when attempting to achieve an occlusal scheme with anterior tooth contact to achieve posterior discusion in excursive mandibular movements.

While the previous study looked at the effect of disk displacement on the mandibular morphology, another interesting study138 examined the effect of disk displacement on the shape of the condyle in juvenile females. Ninety-six females between the ages of 9 and 20 years with clinical signs and/or symptoms of TMD, including joint sounds, limitation of opening, and mouth pain, participated in the study. The exclusion criteria included cortical bone abnormalities.

The MR imaging was performed with a 1.5 Telsa system with 7.5 cm TM joint bilateral surface coils. Images were obtained in closed and open mouth positions. The disk position of the right and left TM joints on sagittal T1 weighted images was classified into a normal group with no disk displacement in the closed or open mouth view, the DDW group with anterior disk displacement without reduction, and the DDWO group with anterior disk displacement without reduction. One radiologist who was blinded to the clinical symptoms of all participants evaluated these classifications.

The condyles were examined by using MR from the horizontal and frontal plane. The horizontal plane evaluation used 8 points matching the outline of the condyle, and the entire horizontal condylar area was estimated as an octagon. The frontal plane evaluation used 9 points matching the outline of the condyle, beginning at the medial pole. The 192 condyle-disk assemblies were evaluated in the 96 participants. Sixty-two (32%) of the condyles were judged as having a normal disk position. Eighty-four (44%) were diagnosed as DDWO, and 46 (24%) were diagnosed as DDW. The condylar area in a horizontal dimension measured 111.1 mm² in normal joints, 106.7 mm² in DDW joints, and 85.8 mm² in DDWO joints. In the frontal perspective, with structural changes to the TM disk, the condyles decreased in size throughout the midpoint of the condyle, with the greatest decrease occurring in the DDWO joints. The hypothesis of the study, that condylar shape varies based upon disk position, was supported.

Alterations in disk position can affect normal physiology, lubrication, nutrition, and joint function. The change may negatively influence the adaptive capacity of the condylar cartilage, which may alter the normal growth of the condyle in adolescence and subsequent facial development. The results of this study support the concept that disk displacements cause a smaller condyle but may be understated since patients with any cortical bone abnormalities were excluded. The clinical significance of this study underscores the importance of realizing that disk displacements, especially in younger patients, may be associated with facial asymmetries.

As demonstrated in these studies, disk displacements create an environment where changes in the articular cartilage and synovial membrane can
cause both pain and structural changes in the TM joint. A logical approach to treatment would include attempts to reduce the degenerative process. One study using hyaluronic acid (HA) injections in the TM joint attempted to identify predictors of positive outcomes of arthrocenteses plus HA injections in damaged TM joints. While techniques for TM joint lavage and injections have been investigated over the last 20 years, few studies address the mechanism of action. In this study, the search for strongly significant predictors failed, and little clinical information was gained.

An intriguing animal study investigated the effects of the intra-articular injection of an insulin-like growth factor (IGF-1 suspended in HA on the cartilage and subchondral cancellous bone repair in osteoarthritis (OA) of the TM joints. Fifty skeletal mature (6 months old) New Zealand white rabbits were used in the study, 48 of which were anesthetized and the TM joints exposed over the zygomaticosquamosal suture. One-third of the TM disk in the anterior and lateral regions of the TM joint was resected with a scalpel. After the disk resection, the articular capsule and the skin were closed independently. Two rabbits were used as normal controls, and their TM joints remained intact.

Four weeks after the induction of OA as described above, the rabbits were randomly divided into 4 groups. The first group was the OA group with OA induction only. The second group was the HA group with OA induction and a single intra-articular injection of HA. The third group was the IGF-1 group with OA induction and a single injection of IGF-1. The fourth group was the HA/IGF-1 group with OA induction and a single intra-articular injection of IGF-1 suspended in HA. Six animals from each group were sacrificed at 12 and 24 weeks after the injections.

The mandibular condyles of the sacrificed animals were dissected, fixed in 10% buffered formalin, decalcified with 5% ethylenediamine tetraacetic acid (EDTA), and embedded in paraffin. For each specimen, 3 randomly selected sections in each joint were evaluated for the severity of OA by 2 independent blinded observers. At 12 weeks post injection, the OA group had highly irregular surfaces, and most condyles exhibited small osteophytes. After 24 weeks, the joint had a marked reduction in joint space, which may indicate a fibrous ankylosis between the articular surface and the condyle. The gross appearance of the condyles in the HA group and the IGF-1 group was similar to the OA group at both 12 and 24 weeks. The condyles in the HA/IGF-1 group showed round, smooth, consistent surfaces that resembled normal cartilage.

The key factor in this experiment was the suspension of IGF-1 in HA during the injection. While HA injections can restore the properties of synovial fluid, it is not known at this time whether HA injections can modify structural damage in TM joints with OA. The injection of IGF-1 alone did not improve the articular cartilage or protect the microarchitectural properties of the subchondral cancellous bone. This finding is not surprising since IGF-1 has a short biological life span. The combined therapy of HA and IGF-1 resulted in decreased cartilage surface lesions and nearly normal microarchitectural properties. Research in this area will continue to develop new options for treating structurally altered TM joints.

The diversity of opinion in the profession is demonstrated in a position paper addressing TM disorders. The role of dental occlusion in TMD is discussed in detail with different studies quoted mentioning how experimental occlusal contacts were added to the dentition and how, as a result, muscle hyperactivity occurred as measured by surface electromyography. The authors claim the results of these studies clearly substantiate the role of occlusion in the onset and perpetuation of TMD and a return to normal masticatory function when occlusal harmony is restored. The occlusal scheme advocated in this article is neuromuscular occlusion with isotonic contraction of relaxed masticatory muscles achieved through stimulation of those muscles on a trajectory beginning at a muscularly rested mandibular position. While occlusal treatment has historically focused on decreasing masticatory muscle activity, the current challenge is for the general dentist and specialist to understand not only how the teeth contact but also the condition and position of the TM disk and condyle. Understanding not only how the teeth fit but also how the joints fit will increase the ability to help patients make a more informed decision.

**Sleep-Disordered Breathing**

One study was done to evaluate the influence of an oral appliance on morning headache and orofacial pain in individuals without sleep-disordered breathing. Twelve individuals suffering from frequent morning headache were recruited for this study. A custom mandibular advancement appliance (MAA) was fabricated for each participant. Participants spent 2 nights in the sleep laboratory for habituation and gathering of baseline data, then slept 5 nights without the MAA, followed by 8 nights with the MAA in the neutral position, followed by 5 nights without the MAA, followed by 8 nights with the MAA in the 50% advanced position, and finally 5 nights without the MAA. Morning headache and orofacial pain intensity were assessed each morning on a 100 mm visual analog scale.

Compared to the baseline period, the use of an MAA in both the neutral and advanced position was associated with a 70% reduction in morning headache and a 42% reduction in orofacial pain intensity. During the washout periods, morning headache and orofacial pain intensity returned to close to baseline levels. The use of the MAA in both positions also significantly reduced rhythmic masticatory muscle activity. The authors concluded that the use of an MAA is associ-
ated with a significant reduction in morning headache and orofacial pain intensity. They believed that part of this reduction may be linked to the concomitant reduction in rhythmic masticatory muscle activity. Readers should be cautioned that although the results seem positive, the sample size (n=12) was low.

A randomized controlled study cephalometrically assessed the possible changes in craniofacial morphology associated with the long-term use of an adjustable oral appliance with continuous positive airway pressure (CPAP) in patients treated for obstructive sleep apnea (OSA).\(^{143}\) Fifty-one individuals were randomized to oral appliance therapy and 52 to CPAP therapy. At baseline and after follow-up (2.3 ±0.2 years), a lateral cephalogram of all patients was made in maximum intercuspsation to determine relevant cephalometric variables. Both baseline and follow-up cephalograms were traced digitally, whereupon cephalometric variables were compared. Changes in craniofacial morphology between the oral-appliance group and the CPAP group were evaluated with a linear regression analysis.

Compared with CPAP, the long-term use of an oral appliance resulted in small but significant (dental) changes. Mean (SD) horizontal overlap decreased 1.0 (±1.5) mm and vertical overlap decreased 1.7 (±1.6) mm. Furthermore, a retroclination (-2.0 (±2.8) degrees) of the maxillary incisors was found as well as a proclination (3.7 (±5.4) degrees) of the mandibular incisors. Moreover, the lower total anterior facial height increased significantly to 0.8 (±1.5) mm and the total height to 0.9 (±1.4) mm. No changes in skeletal variables were found. Linear regression analysis revealed that the decrease in horizontal overlap was associated with the mean mandibular protrusion during follow-up (B) (deepest midline concavity on the mandibular symphysis)=-0.029, SE=0.014, P<.05).

The authors concluded that oral appliance therapy should not be considered as a lifelong treatment and that there is a risk of craniofacial changes. Therefore, patients treated with an oral appliance need a thorough follow-up by a dentist or dental specialist experienced in the field of dental sleep medicine.

Another study, using data collected from the same participants as in the previous study, evaluated the nature and incidence of TMDs in patients receiving either appliance therapy or CPAP for the treatment of OSA.\(^{144}\) There were 52 participants in the CPAP group and 51 in the mandibular advancement appliance group. Evaluations were made at 2 months, 1 year, and 2 years. At 2 months, 6% of the participants in the CPAP group had signs and symptoms of TMDs, while 24% in the appliance groups experienced TMDs. However, the TMDs were described as being mild and transient, and both the incidence and severity decreased over time. No participant discontinued therapy as a result of the TMDs.

Another interesting study evaluated ethnicity, obesity, and craniofacial structure as risk factors for obstructive sleep apnea.\(^{145}\) The investigators found the contribution of the risk factors of obesity and craniofacial structure differed in Asians, African-Americans, and whites. Certain craniofacial phenotypes may be more vulnerable to the development and severity of OSA than others as obesity increases. This may have implications in determining optimum prevention and treatment protocols for patients of specific ethnicities.

A Canadian study evaluated the apnea-hypopnea index (AHI) in complete denture wearers who slept with and without their dentures.\(^{146}\) Twenty-three participants completed the study, which was conducted in a sleep laboratory. The AHI was significantly increased when participants diagnosed with mild OSA slept with their dentures than when they slept without them. With individuals with moderate to severe OSA who slept with their dentures, no significant rise in OHA was noted. Accordingly, it may be of benefit to advise complete dentures wearers with OSA to consider removing their dentures at night.

A provocative review article on the use of oral appliances in the management of bruxism was published in late 2010 and is included in this review.\(^{147}\) Data accumulated in many sleep laboratories have led to changes in thinking about the function of oral appliances in the management of sleep bruxism. In the past, oral appliances were thought to be provisional measures that would assist dentists in the analysis of so-called improper dental relationships. This often led to dental treatment, including occlusal equilibrations, orthodontics, occlusal opening, and major reconstruction, to improve these improper relationships. Based on data from sleep laboratories, the proper role for oral appliances is now thought to be to protect the teeth and perhaps reduce muscle activity during sleep.

**IMPLANT DENTISTRY**

A search of PubMed on February 20, 2012 using only the words “implant dentistry” for the year 2011 yielded 932 citations. When the search was repeated with the words “dental implants,” the number of citations increased to 1616. In spite of this extensive research in the discipline, systematic reviews done to determine the answers to specific questions almost always state that more research with better study designs is required. Sadly, many studies have small sample sizes and are underpowered, are not properly randomized, have a high possibility of bias, and have no control. While the knowledge base regarding clinical performance of root-form implants is growing, little of the evidence produced by clinical trials ranks in the top categories for evidence-based dentistry.

A number of systematic reviews and meta-analyses evaluating the effect of risk factors such as smoking on implant survival and the effect of
prosthodontic considerations such as splinting were conducted. The efficacy of using platelet-rich plasma was examined as was the effect of different implant designs. The interest in the incidence and etiology of periimplantitis was high, and a number of studies related to that topic will be reviewed.

One systematic review evaluated studies identifying patient-related risk factors for implant therapy. Table I in the review is an excellent summary of the discussions in the article. While the authors commented that the evidence base related to many of the risk factors was less than perfect, they determined there was no increased risk for failure in patients with cardiovascular disorders, diabetes, autoimmune disorders, or osteoporosis. Failure rates in irradiated bone are 2 to 3 times greater than in nonirradiated bone. Patients with a history of tooth loss due to periodontitis are at higher risk for the development of periimplantitis. Failure rates of implants in smokers are more than twice those in nonsmokers and are even higher when implant placement and bone augmentations are combined. The evidence does not support the notion that failure rates are higher in patients who have taken bisphosphonates, but should osteonecrosis of the jaw develop, the morbidity is high. Success rates are dependent on bone quality, with implants in the maxilla failing at a higher rate than in the mandible and the poorest success rates occurring in the posterior maxilla. The authors suggest that genetic factors may have a role in success/failure rates but admit there is little specific evidence to support that notion.

One retrospective 5-year multicenter study specifically evaluated the influence of smoking on the survival of dental implants in 1727 participants. Nonsmokers received 4460 implants, and smokers received 2260 implants. The implant failure rate in nonsmokers was 2.9%, and the failure rate in smokers was 5.5%. Ninety per cent of the failures occurred before loading. The study is impressive because of the number of participants and implants in each group, and the data correlate well with previous studies comparing smokers and nonsmokers.

Another review evaluated prosthodontic considerations designed to optimize outcomes with single-tooth implants. The authors used existing literature to draw the following conclusions: The use of custom provisional restorations to sculpt perimplant soft tissues has been described by several authors, but there are no published studies to verify efficacy. Laboratory studies support the use of transfer impression copings and internal connections to improve stress distribution, but there are no supportive clinical data. Both cement- and screw-retained prostheses demonstrate high success rates, but the authors prefer screw-retained prostheses for long-term retrievability. Gold, titanium, and zirconia abutments exhibit excellent biologic responses, but there is insufficient evidence regarding the durability of zirconia abutments. The optimum occlusal scheme for implant supported prostheses has yet to be defined. The final conclusion was that implant-supported single crowns provide comparable service to toothborne PFDPs but are associated with an increased incidence of biological and technical complications.

Another systematic review evaluated the relative merits of splinting or not splinting implants supporting overdentures. Data were extracted from 12 studies of at least 3 years duration selected from an initial yield of 1022 titles. Survival rates for implants supporting overdentures were 95% to 100% in the mandible and 90% to 95% in the maxilla and were the same for both splinted and nonsplinted implants. Unsplinted implants with a ball and ring system required more maintenance than splinted implants with a bar and clip. The data showed no differences in perimplant hard and soft tissues between splinted and nonsplinted implants. Individuals with bar-retained implants have greater difficulty with oral hygiene. Evaluating subjective patient variables related to satisfaction, again no significant differences between the use of splinted and nonsplinted implants were found. The results from this systematic review would seem to indicate both approaches to implant-supported overdentures are clinically successful.

A systematic review evaluating the prosthetic outcome of cement-retained fixed restorations was published in 2011. Data from 32 studies were used in the review. Fifteen of these studies were considered short-term studies and yielded data from implant-supported restorations in service for less than 5 years. Seventeen studies had data from implants in service from 5 to 10 years. The prosthetic success rates in the short-term studies were between 69.8% and 100% and in the long-term studies between 56.2% and 96.7%. The most common technical complication in both groups was loss of retention. The results of this systematic review were disappointing in that no useful information was available from the included studies to provide guidelines for cement selection and/or cementation protocols. Many different cements were used with no rationale for use provided.

One meta-analysis reported on the effects of the use of platelet-rich plasma (PRP) in conjunction with implant placement and sinus bone grafting. The analysis used data from 8 controlled clinical trials with 352 sinus bone grafts in 191 participants. The use of PRP had no effect on implant survival, on either a patient or implant basis. Bone-to-implant contact was not significantly different whether PRP was used or not used. The use of PRP reduced healing time and increased early stage bone formation but had no effect on the long-term survival of the implants. The question of whether the seemingly minor benefits of using PRP in sinus lifting, justifies the additional cost was not addressed in this analysis.

Many partially edentulous patients present with compromised
bone heights in the residual ridge and cannot receive implants of standard length without bony augmentation. The use of short implants has been suggested as a solution to this problem. Two systematic reviews and 1 meta-analysis evaluated success/failure rates with short implants.154-156 The first systematic review evaluated long-term failures with short implants (10 mm or less) and factors that might influence those failures.154 In total, 35 studies involving 14,722 implants, of which 659 (4.5%) failed, were included in the review. Most of the implant failures (57.9%) were early failures and occurred before prosthetic connection. There was no statistically significant difference between the failure rates of short implants and standard implants. Machined implants had a higher rate of failure in the maxilla than in the mandible and a higher rate of failure overall than implants with rough surfaces. The authors concluded that short implants have a similar prognosis to standard implants but that stronger evidence is needed to confirm this finding.

The second systematic review evaluated the estimated survival rate of short (<10 mm) implants placed in partially edentulous individuals.155 Twenty-nine acceptable studies were identified and results from 2611 short implants were analyzed and reported as survival rates after 2 years. The authors concluded that the data suggest there is fair evidence that short implants can be successfully placed in partially edentulous individuals, although longer implants (8.5 mm) had slightly higher survival rates than shorter (6.0 mm) ones. Mandibular implants had a higher survival rate than maxillary implants, and implants placed in nonsmokers survived at a higher rate than those placed in smokers. There were no differences in the survival rates of implants with rough versus smooth implant surfaces, although these parameters were not clearly defined in most of the included studies.

The meta-analysis on the impact of implant length on early failure rates used data from 54 prospective studies and 19,083 implants.156 Implants were evaluated after the first year of prosthetic loading. Failure rates for short implants (<10 mm) were the same as for standard implants in the mandible. Short implants in the anterior maxilla had a higher failure rate than standard implants, whether the implant surfaces were machined or roughened. Again in the anterior maxilla, short implants with machined surfaces had higher failure rates than standard implants or short implants with rough surfaces. No influence of implant diameter could be seen with short implants. The authors concluded that in areas with reduced alveolar bone height, the use of short implants may reduce the need for invasive bone augmentation procedures. Readers are cautioned that this analysis only evaluated implants during the first year of prosthetic loading and thus gives little information on the long-term efficacy of short implants.

One disappointing systematic review attempted to determine whether different implant neck configurations had an effect on preserving the marginal bone level.157 The authors included 20 studies in the review and evaluated the use of microthreads, different implant diameters, modifications of implant surfaces, insertion depth, use of 1-piece implants, and platform switching on marginal bone loss. Because of poor study design and the heterogeneity of the studies, no evidence was found regarding the effectiveness of any specific modification in the implant neck area in preserving marginal bone or preventing marginal bone loss.

Interest in the topic of periimplantitis continues to be high, and a number of studies on that topic were published in 2011. The first study reviewed the scientific literature to evaluate the difference between gingivitis lesions around natural teeth and peri-implant mucositis.158 Peri-implant mucositis is defined as the presence of inflammation in the mucosa around an implant with no signs of supporting bone loss. Periimplantitis is characterized by loss of supporting bone in addition to inflammation in the mucosa. Based on data from both animal and human studies, the authors concluded that gingivitis and periimplant mucositis are not fundamentally different from the perspective of pathogenesis. Both diseases represent a host response (inflammation) to the bacterial challenge caused by biofilm formation. They also concluded that because periimplant mucositis represents the obvious precursor to periimplantitis, as does gingivitis for periodontitis, treatment of mucositis has to be the prerequisite for the prevention of periimplantitis.

A logical extension of the question posed in the previous study was posed in another review to determine whether periimplantitis lesions are different from periodontitis lesions.159 The authors reviewed human histopathological studies of both periodontitis and periimplantitis lesions and histopathological animal studies of ligature-induced experimental periimplantitis to determine similarities and differences between the 2 entities. Despite the similarity of the clinical features and etiology of periodontitis and periimplantitis, the authors found that critical histopathological differences exist between the 2 lesions. The differences are both real and complex, and interested readers should review the study carefully. The differences are important when developing potential treatment protocols for periimplantitis.

A short-term RCT was conducted to compare the efficacy of 2 anti-infective protocols for the treatment of periimplant mucositis.160 Since periimplant mucositis may progress to periimplantitis, determining an effective protocol for controlling or preventing its development is of considerable interest. Twenty-nine individuals with periimplant mucositis in 4 different centers were recruited for the study. All participants received nonsurgical mechanical debridement at the implant sites and were instructed to brush around the implant twice.
daily with a provided gel. The test group (n=15) received chlorhexidine gel (0.5%), while the control group (n=14) received a placebo gel. Participants were asked to discontinue the use of the gel after 4 weeks. Periodontal parameter and microbiologic testing were done at baseline, 1 month, and 3 months.

Both groups demonstrated reductions in bleeding on probing, and probing depth at 1 month was the same as at 3 months. Only 38% of the implants had complete reduction in bleeding on probing. There was no difference in these parameters or microbiologic results between the control and test groups. One result of note was that improvement in the periodontal parameters was greater with implants with supramucosal restoration margins than in those with submucosal restorative margins.

Currently, there is no gold standard protocol for the treatment of implants with periimplantitis. Several protocols have been proposed and used with varying degrees of success and failure. One prospective case-control study evaluated the stability of bone regenerative procedures by using a bone substitute with and without a membrane after 3 years. 161 Thirty-eight participants with progressive bone loss around an implant of 1.8 mm or more and with bleeding on probing after the first year of healing were recruited for the study. Nonsurgical treatment of all implants was first accomplished and judged to have failed. All participants had surgical regenerative treatment with a bone graft substitute (Algipore; Dentalply Friadent, Malmo, Sweden). With the first 19 participants, the graft was covered with a resorbable membrane (Osseoquest; WL Gore & Associates Inc, Flagstaff, Ariz), and the next 19 participants were treated with the bone graft substitute alone. All participants received antibiotic therapy for 10 days following surgery and used chlorhexidine mouth rinse for 5 weeks. Participants were recalled for maintenance every 3 months and finally evaluated after 3 years. Seventeen participants treated with both the graft and membrane returned for the 3-year follow-up, and 15 participants in the graft alone group were evaluated at 3 years. The plaque index was determined at baseline and at various intervals throughout the study. Bone loss/gain was determined radiographically.

At 3 years, the mean defect fill with the bone substitute alone was 1.3 mm and 1.6 mm with the graft and membrane. The differences were not statistically significant. It is important to note that the plaque index dropped dramatically after baseline and remained low throughout the study, presumably because of the aggressive recall and maintenance protocol. While the results are encouraging, readers must understand that the radiographic evaluation of bone levels around implants is imperfect at best, and with the methodology used in the study, it is impossible to determine whether the calcified tissue around the implants was actually regenerated bone or simply defect fill. The discussion section in the study should be read carefully as it clearly delineates the limitations of the study.

A systematic review evaluating the outcome of the regenerative treatment of periimplantitis by using bone substitutes and membranes was published in 2011.162 Data from 17 studies involving 173 treated implants were analyzed. It is interesting to note that there were no randomized controlled clinical trials (RCTs) available for inclusion in the review. Of the 17 articles used, 3 were controlled clinical trials, 2 were cohort studies, 8 were case series, and 4 were single-case presentations. Many different types of implants were treated with different types of membranes and different bone substitutes. Reevaluation periods ranged from 5 to 36 months. All studies investigated radiographic bone morphology, while few reported on bleeding on probing or probing pocket depth. Although most of the studies provided only qualitative or semiquantitative data for bone fill, 10% of the implants showed complete bone fill, and 86% showed partial bone fill. As discussed in the previous study, this review provides no insight as to what structure actually filled the treated bony defect. The authors’ primary conclusion was that RCTs comparing guided bone regeneration treatment and noninvasive debridement in the treatment of implants with periimplantitis are needed.

Another review was conducted in an attempt to determine the specific microbiota associated with periimplantitis.163 While the review is difficult reading for those without specific training in microbiology, data from the 18 studies selected clearly showed that the microbiota associated with healthy implants is different and less complex than the microbiota found around implants diagnosed with periimplantitis. The primary flora in these implants with bone loss consists of anaerobic gram-negative periodontopathogens. Evidence was also found indicating that certain cases of periimplantitis are characterized by periods of rapid and marked destruction compared to periodontitis and that prompt treatment is required once a diagnosis is made. The authors were unable to reach consensus regarding the optimum treatment protocol for periimplantitis but commented that the treatments proposed for periimplantitis are based on evidence gained from the treatment of periodontitis. They note that the surface of some implants facilitates the adherence of bacterial biofilm and complicates its elimination.

A prospective RCT was conducted to compare the efficacy of the nonsurgical treatment of periimplantitis with an airborne-particle abrasion device with oral hygiene instruction (APAD) to mechanical debridement and the local application of chlorhexidine.164 The authors claim that the nonsurgical treatment of periimplantitis has generally been unpredictable and that benefits have been limited and short-term, primarily because of the difficulty of completely eliminating plaque.
biofilms from the roughened titanium implant surfaces. This prevents the establishment of new bone-to-implant contact. This study was initiated on the hypothesis that the use of an airborne-particle abrasion device (APAD) might provide more thorough biofilm removal and hence improved efficacy over mechanical debridement in the treatment of periimplantitis.

Thirty individuals with at least 1 implant with periimplantitis, 15 in each group, were recruited for the study. All participants received a prophylaxis and oral hygiene instruction for 4 weeks before treatment. In the debridement group, mechanical debridement was performed by using carbon curets, followed by irrigation with 0.1% chlorhexidine gluconate and the submucosal application of 1% chlorhexidine gel. In the APAD group, air abrasion was accomplished with a specially designed instrument (Air Flow Master with Perio-Flow nozzle; Electric Medical Systems (EMS), Nyon, Switzerland) and amino-acid glycine powder (Air Flow Perio Powder, EMS). Clinical parameters were measured at baseline and at 3 and 6 months.

At 6 months, both groups exhibited comparable probing depth reductions and limited improvements in clinical attachment levels. The APAD group had higher changes in bleeding on probing scores, and it was concluded that the use of the APAD might be more effective for the treatment of initial periimplantitis than mechanical debridement. Readers should accept this conclusion with caution. Sample sizes in the study were small (n=15), the time frame short (6 months), and the differences between the 2 groups small. It is important to note that no microbiologic testing was done in this study, so there is no information on actual biofilm reduction. It is also worthy of note that the study was partially funded by EMS.

Another RCT was conducted to determine the impact of 2 different methods of implant surface debridement and decontamination (DD) on the clinical outcome of combined surgical therapy for periimplantitis. Thirty participants with advanced periimplantitis were recruited and treated with 1 of 2 different protocols for DD in combination with surgical regenerative therapy. Both groups received similar presurgical debridement procedures. All participants received flap surgery, granulation tissue removal, and implantoplasty of exposed implant parts. One group had DD with an Er:YAG laser (ERL) device (Lexxion Delos; Lexxion AG, Radolfzell, Germany). In the other group, DD was accomplished with plastic curets, followed by scrubbing with cotton pellets soaked in sterile saline, followed by irrigation with sterile saline (CPS). All defects were filled with natural bone mineral (BioOss; Geistlich, Wolhusen, Switzerland) covered with a collagen membrane (BioGide; Geistlich). Periodontal parameters were recorded and radiographs obtained at baseline and at 6 months.

At 6 months, both groups exhibited comparable radiographic bone fill, reductions in bleeding on probing, and improvements in clinical attachment levels. The method of surface DD did not have an impact on the clinical outcome. These are short term results (6 months), and there is no way of determining whether the observed radiographic bone fill is actually bone or simply the graft material.

Given that the effective removal of biofilm from contaminated implant surfaces is important to the successful treatment of periimplantitis, a systematic review on the effect of chemotherapeutic agents on contaminated titanium surfaces would be of interest. Such a systematic review was published in 2011. Unfortunately, it provided little useful information for the practicing dentist. Only 4 studies were found that addressed the issue, 3 of which were in vitro studies and the other an ex vivo investigation. The use of chlorhexidine, citric acid, and saline or water was investigated with different concentrations and techniques. Citric acid appeared to be more useful than chlorhexidine but did not result in complete biofilm removal and was only as effective as saline or water. Clearly this is a subject that should receive thorough investigation in the immediate future.

Another review evaluated the role of different implant systems on the initiation and progression of periimplant disease. While implants with a roughened surface have demonstrated improved bone-to-implant contact compared to implants with machined surfaces, it is possible that implants with rough surfaces may be more susceptible to periimplantitis. Limited data from human studies suggest that smooth implants may be less affected by periimplantitis than implants with rough surfaces. Data from animal studies using a spontaneous progression model of periimplantitis suggest that the progression of periimplantitis is more pronounced in implants with a porous anodized surface. Based on the limited data available, the authors concluded that there is no evidence that implant surface characteristics have a significant effect on the initiation of periimplantitis.

In summary, it is clear there was a significant amount of investigative activity in the discipline of implant dentistry in 2011. In spite of this high volume of activity, little evidence at the top of the evidence-base hierarchy has been produced. It is clear that failure rates of implants in smokers are 2 times those of non-smokers. It seems that short implants (<10 mm) may be used predictably in the mandible and may reduce the need for bony augmentation. Clear definitions for perimucositis and periimplantitis have emerged, and it does appear that the incidence of periimplantitis is higher than originally thought in implants in place 10 years or more. No optimum protocol for the treatment of periimplantitis has been determined, and no technique for optimum decontamination of the implant biofilm has been developed. The role of different implant surfaces on the progression of periimplantitis requires further investigation. Indeed,
almost all aspects of the relatively young discipline of implant dentistry require further investigation.

REFERENCES


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