INTRODUCTION

The effects of occlusal forces on the progression of periodontitis have been researched and debated for decades. Early theories implicated traumatogenic occlusion as the etiology of periodontitis. When the role of microorganisms as causative agents in periodontitis became evident, emphasis switched to the evaluation of traumatogenic occlusion as a cofactor in the progression of periodontitis. Glickman in the early 1960s proposed that a traumatogenic occlusion could produce a lesion of occlusal trauma which could accelerate the progression of periodontitis and direct the inflammatory process into the periodontal ligament. These early papers relied on retrospective analysis of occlusal wear patterns, mobility patterns, autopsy material, and patterns of attachment loss and pocket formation to develop the theories that linked traumatogenic occlusion and periodontitis. Later studies by Waerhaug associated the location and severity of attachment loss with the location of the "plaque front" on the tooth. These studies questioned the effect of occlusal forces on the progression of periodontitis and suggested that the various patterns of attachment loss and intraosseous defect formation could be explained by the "down growth of subgingival plaque."

Controlled prospective studies were needed to investigate this controversial issue and substantiate the effects of occlusal forces on the progression of periodontitis. Due to the ethical questions and difficulty in designing well-controlled prospective hu-
man studies, animal models were developed to study the effects of traumatogenic occlusion on periodontal attachment and bone loss. The prominent studies of the 1970s and 1980s were published by Polson and Zander using squirrel monkeys as their animal model and by Lindhe, Ericsson, and Nyman using beagle dogs as their animal model. In these animal models, the researchers could artificially induce experimental periodontitis and superimposing a traumatogenic occlusion to evaluate its effects on bone and attachment loss. Studies by both Lindhe and Ericsson and Perrier and Polson presented clinical and histologic data which indicated that heavy occlusal forces, in the absence of periodontitis, led to increased tooth mobility and bone loss. Bone loss was present principally in the form of widened periodontal ligament spaces and, in a few cases, horizontal loss of crestal bone height.

These research groups differed in their findings, however, when simulated traumatogenic occlusion was combined with periodontitis. Studies using beagle dogs indicated that heavy occlusal forces when combined with plaque induced periodontitis led to accelerated attachment loss. Studies conducted using squirrel monkeys also found bone loss and increased tooth mobility associated with "jiggling forces" used to simulate a traumatogenic occlusion. The squirrel monkey studies, however, found little or no effect of traumatic jiggling forces on the rate of plaque associated attachment loss. The authors also reported that elimination of traumatic jiggling forces in the presence of continuing periodontitis did not lead to bone regeneration or a reduction in mobility. The resolution of inflammation in the presence of continuing mobility or jiggling trauma, however, led to decreased mobility and increased bone density, but no change in attachment level or alveolar bone level. The results of these studies led clinicians to place greater emphasis on the elimination of dental plaque, the etiologic agents responsible for periodontitis, and to establish maintenance programs to maintain periodontal health. Occlusal therapy was deemphasized in the treatment of periodontitis since it appeared to have a minimal role in maintaining the attachment level once plaque was eliminated.

Human research studies reported from 1986-1987 questioned the effect of occlusal forces on the progression of periodontitis. In a report that evaluated patients with periodontal disease and occlusal parafunction, Houston et al. concluded that "...there is no or only weak correlation between periodontal disease and bruxism." Hakkarainen evaluated the effect of the resolution of inflammation versus the resolution of occlusal trauma on sulcular fluid flow. He found a significant decrease in sulcular fluid flow after inflammation was reduced by oral hygiene instructions and scaling procedures, however, no significant reduction of sulcular fluid flow was detected after the elimination of occlusal interferences. Pihlstrom et al. evaluated the association between occlusal trauma, severity of periodontitis, and radiographic bone loss. They concluded that teeth with occlusal contacts in working, balancing, and non-working positions had no greater severity of periodontitis than teeth without these contacts.

The subject of occlusal treatment was reviewed by the World Workshop in Clinical Periodontics in 1989. After examining the literature up to that date, the reviewer concluded that the role of occlusal trauma in the pathogenesis of periodontitis was controversial and the influence of occlusion on periodontal therapy remained unresolved. The 1989 Consensus Report, however, supported the use of occlusal adjustment, splinting, and orthodontic treatment for a wide variety of clinical problems faced by the dentist. These included the use of occlusal adjustment to reduce mobility and fremitus, encourage repair of the periodontal attachment apparatus, treat discomfort during function, treat parafunction, and to achieve functional relationships in conjunction with restorative dentistry. Splinting was found to be indicated for the stabilization of teeth for a variety of restorative and functional needs. Orthodontic treatment was also found to be appropriate for a variety of reasons including the facilitation of occlusal and restorative treatment, to aid in the treatment of gingival...
and osseous defects, to improve plaque control, to eliminate food impaction problems, and to correct root proximity problems.

The multitude of articles, theories, and techniques published on dental occlusion have spawned a number of descriptive terms which are at times confusing and misused. This can lead to misinterpretation of research findings and development of therapy that may not be based on sound clinical principles. To reduce possible ambiguity in the evaluation of the articles being reviewed in this paper, a glossary of pertinent terms is included at the end of this paper.

This review follows the following outline: randomized controlled trials; cohort or longitudinal studies; non-controlled case studies; indirect evidence, animal studies; indirect evidence, laboratory studies; summary; future research; and glossary.

A computer search was conducted to locate articles that could be used to evaluate the effects of occlusal forces on the progression of periodontitis. The search included key words such as occlusion, dental occlusion, bite force, periodontitis, periodontal disease, etc. The search was limited to articles published in English after 1988. From the thousands of articles published on periodontal disease since 1988, only 96 related occlusion or occlusal forces to periodontal diseases. A review of these articles was conducted to eliminate reviews, and articles on occlusal adjustment technique, discussing philosophy of occlusion, and those which did not provide direct clinical or research findings. This reduced the initial search to 9 possibly pertinent articles. It became evident that since 1988 research efforts have shifted away from dental occlusion to other areas of periodontal diagnosis and therapy. Research in the fields of dental implants, periodontal regeneration, periodontal plastic surgery, the use of antibiotics to treat periodontitis, and diagnostic techniques to identify pathogenic microorganisms and active attachment loss have drawn the interest of researchers away from dental occlusion. A journal-by-journal review of the major peer reviewed journals was then conducted to identify additional pertinent articles not found in the computer search.

The search also was expanded to include articles on risk factors to determine if occlusion had been implicated as a risk factor in these research efforts. This expanded the bibliography to those reviewed in this paper. The 12 most pertinent articles are summarized and presented in rank order in Table 1. A review of the articles related to a specific subject requires a large number of studies that address the subject to be evaluated; small differences in findings to be estimated; and an ability to rank treatments by superiority which will not be reversed for subgroups. Meta-analysis was, therefore, not used for this review due to the limited number of articles on the effect of occlusal forces on periodontitis published since 1988 and the use of research animal models which have in the past resulted in conflicting results. The reviewed articles were ranked and their findings discussed according to the following rank order, the most important at the top of the list: 1) randomized controlled trials; 2) cohort or longitudinal studies; 3) case-controlled studies; 4) non-controlled case studies; 5) descriptive studies; 6) indirect evidence, animal studies; and 7) indirect evidence, laboratory studies.

**RANDOMIZED CONTROLLED TRIALS**

Burgett et al. reported results from a randomized clinical trial designed to test the effect of occlusal adjustment as a component of the treatment of periodontitis. Fifty patients with moderate to advanced periodontitis were entered in the study. All patients received initial periodontal therapy and were randomly divided into two groups who received either occlusal adjustment or no occlusal adjustment prior to definitive periodontal therapy. The patients were then treated, in a split mouth design, with modified Widman flap surgery or scaling and root planing. Those patients who received occlusal adjustment had a statistically significant mean probing attachment gain of 0.42 mm when compared to the patients with no oc-
Table 1. Evidence of the effects of occlusal forces on periodontitis

<table>
<thead>
<tr>
<th>Author</th>
<th>Type of Study</th>
<th>Length of Study</th>
<th>Results</th>
<th>Comments</th>
<th>Ranking: Relevant, Possibly Relevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burgett et al.⁵⁶ 1992 USA</td>
<td>Randomized controlled trial</td>
<td>50 humans 2 years</td>
<td>Occlusal adjustment led to statistically significant attachment gain of 0.40 mm, no significant difference in PD, and no significant decrease in mobility.</td>
<td>Mean attachment level change may be of limited clinical importance.</td>
<td>Relevant: 8</td>
</tr>
<tr>
<td>Wang et al.⁵⁷ 1992 USA</td>
<td>Randomized controlled trial</td>
<td>24 humans 8 years</td>
<td>Teeth with furcation involvement and mobility had significantly &gt; AL than non-mobile teeth during 8-year maintenance period than teeth without these characteristics.</td>
<td>Furcation involvement and mobility were interdependent making it difficult to separate furcation associated variables from mobility. Occlusal adjustment was completed at baseline but mobility was not correlated with occlusion when evaluating results.</td>
<td>Relevant: 6</td>
</tr>
<tr>
<td>Ismail et al.⁵⁸ 1990 USA</td>
<td>Longitudinal</td>
<td>166 humans 28 years</td>
<td>Increased age, smoking, and tooth mobility were found to be the factors most highly related to AL. Teeth with furcation involvement had &gt; AL. Combined mobility and furcation involvement had &gt; risk of AL.</td>
<td>Teeth lost during the study may have had unknown effect on attachment loss measurements. Occlusion was not evaluated.</td>
<td>Relevant: 6</td>
</tr>
<tr>
<td>McGuire &amp; Nunn⁷² 1996 USA</td>
<td>Longitudinal</td>
<td>100 humans 5-8 years</td>
<td>Factors associated with a worsening prognosis included: &gt; PD, &gt; furcation involvement, endodontic involvement, smoking, diabetes, malposed teeth, poor root form, and a parafunctional habit with no biteguard. Tooth mobility was associated with a non-improving prognosis.</td>
<td>The lack of evaluation of the relationship of parafunction or mobility with any measure of advancing periodontitis makes it difficult to relate these as co-factors with periodontitis.</td>
<td>Relevant: 4</td>
</tr>
<tr>
<td>McGuire &amp; Nunn⁷³ 1996 USA</td>
<td>Longitudinal</td>
<td>100 humans 5-16 years</td>
<td>Factors associated with tooth loss included initially greater PD, furcation involvement, mobility, and bone loss, poor crown-root ratio, poor root form, parafunctional habits without a biteguard, and smoking.</td>
<td>The inclusion of teeth loss due to non-periodontal factors; i.e. caries, endodontic involvement, and prosthetic purposes, and the inability to separate out other factors such as furcation involvement and bone/AL prevents direct correlation between mobility or parafunctional habits and periodontitis.</td>
<td>Relevant: 4</td>
</tr>
<tr>
<td>Jin et al.⁵⁹ 1992 China</td>
<td>Cross-sectional (retrospective)</td>
<td>32 humans</td>
<td>Teeth with abnormal occlusal contacts, “signs of occlusal trauma” had no greater PD, AL, or bone loss. However, mobility and radiographically widened PDL were associated with increased PD, AL, and bone loss.</td>
<td>Did not determine if tooth mobility and radiographically widened PDL were etiologic factors, co-factors, or were merely a result (i.e., markers) of the disease process.</td>
<td>Relevant: 5</td>
</tr>
</tbody>
</table>
Table 1. Continued

<table>
<thead>
<tr>
<th>Author</th>
<th>Type of Study</th>
<th>Number of Subjects</th>
<th>Length of Study</th>
<th>Results</th>
<th>Comments</th>
<th>Ranking: Relevant, Possibly Relevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ericsson et al. 1993</td>
<td>Indirect</td>
<td>5 beagle dogs</td>
<td>180 days</td>
<td>Experimental and control teeth were all mobile prior to splinting of the experimental teeth. Splinting of test premolars failed to retard AL or to inhibit plaque downgrowth. Increased tooth mobility did not enhance periodontal AL.</td>
<td>The results of experimental animal model; may not directly correlate with human pathology.</td>
<td>Possibly relevant; 5</td>
</tr>
<tr>
<td>Neiderud et al. 1992</td>
<td>Indirect</td>
<td>6 beagle dogs</td>
<td>90 days</td>
<td>Despite healthy gingival tissues, teeth subjected to jiggling forces lost marginal bone and had greater PD when compared to nonjiggled control teeth. (1.2 mm vs. 0.7 mm).</td>
<td>Animal model; may not directly correlate results with human pathology. Increased PD was related to greater width and decreased density of the CT attachment following bone loss without AL.</td>
<td>Possibly relevant; 5</td>
</tr>
<tr>
<td>Giorgia et al. 1994</td>
<td>Indirect</td>
<td>5 beagle dogs</td>
<td>225 days</td>
<td>Elimination of experimental periodontitis led to decreased inflammation; reduced mobility; reduced PD, but no bone regeneration.</td>
<td>The authors' suggestion that reduced PD was partially a result of reduced mobility was unsubstantiated by data in this study.</td>
<td>Possibly relevant; 4</td>
</tr>
<tr>
<td>Kvinsland et al. 1992</td>
<td>Indirect</td>
<td>45 rats</td>
<td>1-30 days</td>
<td>Experimental occlusal traumatized led to increased blood flow in the pulp and periodontal ligament.</td>
<td>Study did not evaluate the effects of occlusal forces on periodontitis, but did demonstrate a physiologic response of the periodontal tissues to occlusal forces.</td>
<td>Possibly relevant; 2</td>
</tr>
<tr>
<td>Wylie et al. 1991</td>
<td>Indirect</td>
<td>NA</td>
<td>NA</td>
<td>Photoelastic study demonstrated optimal force transmission to the periodontium when periodontally involved tooth was splinted to 2 sound teeth.</td>
<td>Can not directly associate laboratory bench top findings with the physiologic effect of occlusion.</td>
<td>Possibly relevant; 2</td>
</tr>
<tr>
<td>Aydin et al. 1991</td>
<td>Indirect</td>
<td>NA</td>
<td>NA</td>
<td>Finite element model demonstrated increased stress levels in the alveolus when periodontal support is diminished.</td>
<td>Can not directly associate laboratory bench top findings with the physiologic effect of occlusion.</td>
<td>Possibly relevant; 2</td>
</tr>
</tbody>
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AL = attachment loss.
CT = connective tissue.
PD = probing depth.
PDL = periodontal ligament.
clusal adjustment and a mean probing attachment gain of 0.02 mm. There was no significant effect of occlusal adjustment on the reduction of probing depth. While the clinical attachment gain was considered statistically significant, this difference may be of limited clinical importance to the clinician. The authors also stated that “Surprisingly, we did not find any significant difference in reduction of tooth mobility between the adjusted and the not adjusted groups.”

In a review of data from a previous randomized controlled human study, Wang et al. evaluated the influence of furcation involvement and tooth mobility on periodontal attachment loss and tooth loss for molar teeth. They reported findings gathered from The University of Michigan longitudinal periodontal clinical trial. The data used were from 24 of 78 patients who had been treated with initial periodontal treatment followed by periodontal surgery using one of three surgical techniques. The surgical techniques used included pocket elimination surgery, modified Widman flap surgery, and gingival curettage. The 24 patients evaluated had been professional maintained for 8 years without missing appointments. The author attempted to relate attachment loss and tooth loss over the 8-year period to furcation involvement and tooth mobility. Loss of a tooth was artificially assigned an attachment loss of 3.5 mm to account for lost teeth in the attachment loss data. Teeth with furcation involvement were found to have increased tooth loss and attachment loss versus teeth without furcation involvement. Mobile teeth were reported to have significantly more attachment loss (-1.08 ± 0.41) mm during the maintenance period than non-mobile teeth (-0.48 ± 0.25 mm). A paired t test indicated that during the maintenance period, molars with furcation involvement and mobility has significantly more attachment loss than furcation involved molars with no mobility. Several problems make it difficult to relate these findings to the effect of occlusal forces or mobility on periodontitis. Occlusal adjustment was included as a standard component of initial periodontal treatment in the original study to minimize the effect of occlusion on the comparison of the surgical treatment being evaluated. The cause(s) of the ongoing tooth mobility such as continuing occlusal trauma or continued plaque induced inflammation were not reported. Due to the complexities of dental furcation anatomy, it is difficult to quantify and separate the effects of compromised plaque control due to the inaccessibility of the furcation from the other variables.

**COHORT OR LONGITUDINAL STUDIES**

Ismail et al. reported on the findings from a group of 165 adults, residing in Tecumseh, MI, who were originally examined in 1959 and reexamined in 1987. The purpose of the study was to evaluate the change in attachment level in a sample population of adults over a period of years. Results of the re-examination indicated that 10.9% (376 teeth) of the teeth present at the beginning of the study were lost during the 28-year evaluation period. One hundred (100) of the 3,487 teeth evaluated were mobile at the baseline examination. Forty-five percent (45%) of these teeth were lost by the end of the study. Three-hundred thirteen (313) (83%) of the teeth lost had an initial attachment loss of 2 mm or less. The cause of tooth loss was not identified and therefore its effect on the attachment loss measurements could not be determined. Of the remaining teeth evaluated, only 13.3% of the adults examined had a mean attachment loss of 2 mm or more from 1959 to 1987. This study identified individuals with higher levels of attachment loss as having the following risk markers: were older; smoked; had tooth mobility at the base line examination; had higher levels of gingivitis, calculus, plaque, and tooth mobility at the second examination; and had a lower education level and irregular dental attendance. Increased age, smoking, and tooth mobility were found to be the factors most closely related to attachment loss. Considering any of these factors to be risk markers does not establish a cause and effect relationship. This study did not evaluate occlusion and did not indicate if occlusion was an etiologic factor in the dis-
ease process or in the tooth mobility identified as a risk factor.

A retrospective study by Jin and Cao in 1992 attempted to relate clinical signs of a traumatogenic occlusion with severity of periodontitis in 32 patients with moderate to advanced chronic adult periodontitis. The patients received a complete periodontal examination including radiographs, recording of probing depths, gingival index, bleeding index, clinical attachment loss, plaque index, tooth mobility, tooth wear, and an occlusal analysis. Abnormal occlusal contacts; i.e., premature contacts in centric relation, non-working contacts in lateral excursions, premature contacts of anterior teeth, and posterior tooth contacts during protrusion, were identified. After analyzing the data collected, the authors concluded that there was no significant differences in probing depth, clinical attachment level, or loss of alveolar bone height when comparing teeth with and without abnormal occlusal contacts. Teeth with significant mobility, functional mobility, or radiographically widened periodontal ligaments were associated with deeper probing depths, more attachment loss, and greater bone loss. This study could not determine if tooth mobility and radiographically widened periodontal ligaments were risk factors for the progression of periodontitis or markers of the disease process.

Other studies have attempted to identify "risk factors" for periodontitis, attachment loss, bone loss, and tooth loss. Those factors reported as risk factors, listed from the most commonly identified to the least commonly identified by these studies, included: age, race, tobacco use, increased percent of sites with plaque, the presence of Prevotella intermedia, Bacteroides forsythus, bleeding on probing, prior attachment loss, probing depth, lower educational attainment, gender (male), calculus, Porphyromonas gingivalis, positive BANA test, gingivitis, socioeconomic level, diabetes mellitus, systemic disease, mobility, early loss of the first molar, and the lack of use of dental care. These articles did not clearly distinguish which of these factors were true risk factors and which were disease markers and therefore could not establish which were etiologic.

None of these studies identified occlusion as a risk factor for periodontitis; however, occlusal analysis and mobility measurements were rarely included in the factors being evaluated as risk factors.

In a series of papers on prognosis, McGuire and McGuire and Nunn reported on their ability to accurately predict future prognosis from commonly evaluated clinical factors. Mobility and parafunctional habits were identified as two of several "prognostic factors" that correlated with tooth loss or with a worsening individual tooth prognosis during a 5 to 8 year maintenance period after treatment. In "well maintained" patients, prognostic factors associated with a worsening prognosis for individual teeth included: deeper initial probing depths, more severe furcation involvement, endodontic involvement, smoking, diabetes, malposed teeth, unsatisfactory root form, and the presence of a parafunctional habit with no biteguard. Initial tooth mobility was associated with a prognosis that was unlikely to improve but was not associated with a worsening prognosis.

Prognostic factors associated with tooth loss during the maintenance period included initially greater: probing depths, furcation involvement, mobility, and bone loss as well as poor crown-to-root ratio, poor root form, parafunctional habits without a bite guard, and smoking. Tooth loss in this study was due to periodontal disease, restorative purposes, endodontic involvement, and caries. Unfortunately the authors could not associate initial prognostic factors with progressive attachment loss, the gold standard for advancing periodontitis. The inability to associate the prognostic factors of mobility and parafunction with advancing attachment loss; the inclusion of teeth lost due to non-periodontal reasons; and the inability to separate out other prognostic factors such as furcation involvement, bone loss, and attachment loss inhibit our ability to draw conclusions about mobility or parafunction in relation to progressive periodontitis. The authors also noted that these findings relate to well maintained patients and may not apply when evaluating poorly maintained individuals.
NON-CONTROLLED CASE STUDIES

Non-controlled case studies are relatively unreliable sources of information upon which to base a philosophy of treatment. Benefits of treatment demonstrated for one patient may not reliably transfer to other patients and the conclusions drawn from the results of successful therapy in a few patients under conditions where a multitude of variables were either unrecognized or poorly controlled may lead the clinician to incorrect conclusions. The following case studies are, therefore, being presented principally to illustrate points which have been previously presented in well-designed studies.

Paul et al. reported the treatment of a case diagnosed as rapidly progressive periodontitis with localized occlusal trauma involving tooth #10.74 Treatment consisted of scaling and root planing, microbiological monitoring, use of systemic antibiotics, and surgical treatment where needed. Six weeks after initial therapy, pockets involving tooth #10 had been reduced from 8 mm to 3 mm without surgical therapy or occlusal adjustment. However, 6 months later, tooth #10 remained mobile and radiographically apparent bone loss remained despite minimal probing depths. Multiple occlusal adjustments over the next year resulted in "re-eruption" of the tooth which reduced the crown-root ratio, eliminated occlusal interferences, and improved function. This case demonstrated the ability to reduce probing depth and eliminate inflammatory periodontal disease without occlusal adjustment. The authors, however, considered occlusal adjustment to be a valuable treatment to reduce mobility and improve clinical function of a tooth with severe attachment loss.

Wolff et al. documented the restorative and surgical treatment of a patient with advanced periodontitis.75 Six months following the placement of 4 fixed partial dentures (FPD), one in each quadrant, the occlusion remained stable. Over the next 2 years, the patient developed a malocclusion due to a shift of one of the FPDs in response to forces generated by the patient's tongue. The authors stated that the reduced periodontium may have contributed to the lack of stability of the splinted teeth. Occlusal adjustments led to a clinically stable occlusion. The periodontium remained healthy, with no signs of bleeding, increased sulcus depth, or mobility throughout the reported period despite the persistent forces that caused drifting of the teeth and significant changes in the occlusion.

INDIRECT EVIDENCE, ANIMAL STUDIES

In a beagle dog study, Ericsson et al. evaluated the effect of splinting on the progression of experimental periodontitis.76 Five dogs had their mandibular 2nd and 3rd premolars and mandibular 1st molars extracted. Titanium implants were then installed in the position of the 1st molar and 3rd premolar in the right side of the mandible. After 3 months of healing, non-resilient splints were placed connecting the dental implants to the 4th premolar on the right side. The 4th premolar on the left side remained unsplinted and served as a control with persistent mobility from prior attachment loss. Experimental periodontitis was initiated and maintained for 180 days by placing a ligature around the premolars. Attachment loss and down growth of plaque were evaluated with radiographs and biopsies after the 180-day test period. The researchers found that splinting the test premolars failed to retard attachment loss or to inhibit the apical down growth of the microbial plaque. They concluded that increased tooth mobility at the control tooth did not exacerbate periodontal attachment loss in this model.

The effect of jiggling occlusal forces on probing depths in beagle dogs with normal periodontal tissues was evaluated by Neiderud et al.77 Six beagle dogs had their teeth cleaned before entering the study and 3 times each week during the study. Each dog had jiggling forces applied to a test premolar while a contralateral tooth served as a non-jiggling control. After jiggling forces had been applied for 90 days, a probe was inserted into the sulcus of the test and control teeth and stabilized in position with composite resin. Biopsies of the sites were obtained.
and used for histometric and morphometric measurements. The measurements revealed that despite clinically healthy gingival tissues, the teeth which had become mobile due to the jiggling forces had lost marginal bone. An enlarged "supracrestal connective tissue compartment" had also developed which resulted in significantly greater clinical probing depth measurements. This increased probing depth was related to a decrease in collagen density and a more vascular connective tissue that was less resistant to probing without loss of connective tissue attachment.

In a related study, Giagia et al. reported a reduction of probing depth and mobility after removal of plaque retaining ligatures in a beagle dog model.78 This study evaluated the effect of experimental periodontitis on the histologic appearance of the periodontal soft tissues, alveolar bone height, and on tooth mobility. After 120 days of experimentally induced periodontitis, plaque retaining ligatures were removed and a supragingival debridement was performed. Block sections, taken at the time of ligature removal and 15 days and 3 months later, were used for histometric and morphometric evaluation. Experimental periodontitis led to the formation of an inflammatory lesion, extensive bone loss, and markedly increased tooth mobility. Removal of the dental plaque led to reduced tooth mobility and a decrease in the inflammatory lesion, but no regeneration of lost bone. Probing depth which increased due to the experimental periodontitis was reduced after removal of the microbial plaque. The authors suggested that the reduced probing depth was a result of the soft tissue changes, due to resolution of inflammation after plaque removal and to reduced mobility of the teeth. The authors' comments on the effect of reduced mobility on probing depth changes appeared to be more related to their awareness of the results of the prior Neide-rud study than to the results of this study. This study does document an increase in mobility due to periodontal inflammation and a decrease in that mobility as inflammation is decreased. This result appeared to be independent of occlusal forces in this experimental model. It also documented that changes in mobility may persist for several months after etiologic factors are reduced and inflammation is resolving.

In a study in a rat model that evaluated the effect of experimental traumatic occlusion on periodontal blood flow, Kvinnland et al. reported an increase in blood flow to both the pulp and periodontal ligament after the initiation of heavy occlusal forces.79 In the early stages of the study the experimental "traumatized" side had an increased blood flow when compared to the control side. In the later stages of the experiment, both control and experimental sides had increased blood flow. This study did not evaluate the effects of occlusal forces on periodontitis but did demonstrate a physiologic response of the periodontal tissues to occlusal forces.

**INDIRECT EVIDENCE, LABORATORY STUDIES**

Photoelastic model and finite element model studies have evaluated the transmission of occlusal forces to the periodontium.80-81 Wylie et al. used a photoelastic model to simulate the effect of splinting a periodontally involved tooth to one or more sound teeth when placing a cantilevered fixed partial denture.80 They found that optimal stress distribution occurred when splinting the compromised tooth to 2 sound teeth. Increasing the number of splinted teeth, beyond two sound teeth, did not significantly decrease the stress transmitted to the periodontium. Cross-arch splinting did not result in a significant sharing of the occlusal forces.

Using a finite element model, Aydin et al. evaluated the stresses induced by various loading forces on a mandibular 3-unit fixed partial denture using a molar and a premolar as abutments.81 Loads of 300 N to 600 N applied in axial and nonaxial directions were analyzed. Forces applied in non-axial directions led to an increase the level of stress delivered to the alveolar bone. The premolar exhibited greater stress distribution to the bone than the molar when non-axial forces were applied. Stress levels increased, also, when periodontal support was diminished.
Studies like these can be used to demonstrate the mechanics of transmission of forces from teeth to the periodontium. They can not be used to interpolate results to broader and more involved interactions such as those involving occlusion and inflammatory periodontal disease.

**SUMMARY**

Despite decades of debate and multiple publications that discuss the theory of occlusion, occlusal design, and equilibration techniques, there have been few well-designed human studies that can help answer the question "does occlusal trauma modify the progression of attachment loss due to inflammatory periodontal disease." The articles reviewed clearly demonstrate that occlusal forces are transmitted to the periodontal attachment apparatus and those forces can cause changes in the bone and connective tissue. These changes can effect tooth mobility and clinical probing depth While occlusal forces do not initiate periodontitis, results are inconclusive on the interactions between occlusion and the progression of attachment loss due to inflammatory periodontal disease.

While some studies found a relationship between increased attachment loss and tooth mobility, others found no relationship between attachment loss and abnormal occlusal contacts. Tooth mobility can be a result of a variety of factors including loss of alveolar bone, attachment loss, disruption of the periodontal supporting tissues by inflammation, occlusal forces which lead to widening of the periodontal ligament (physiologic adaptation), periodontal ligament atrophy from disuse, or any process which affects the supporting periodontal structures. Therefore, any relationship found between tooth mobility and progressing periodontitis does not necessarily indicate or defend occlusion as a cofactor in the progression of inflammatory periodontal disease.

Periodontitis can be treated and periodontal health maintained without occlusal adjustment and despite the obvious presence of traumatic occlusal forces. However, statistically greater gains in clinical periodontal attachment level have been documented when occlusal adjustment was included as a component of periodontal therapy. The extent to which this is clinically meaningful in the treatment of periodontitis is unclear. The effects of normal occlusion, parafunctional habits, and tooth mobility on wound healing have also not been adequately evaluated.

Once periodontal health is established, occlusal therapy can be an aid to help reduce mobility, regain some bone lost due to traumatic occlusal forces, and to treat a variety of clinical problems related to occlusal instability and restorative needs. Based on the literature, it appears that a clinician's decision whether or not to use occlusal adjustment as a component of periodontal therapy should be related to an evaluation of clinical factors involving patient comfort and function and not based on the assumption that occlusal adjustment is necessary to stop the progression of periodontitis.

**FUTURE RESEARCH**

Prospective studies on the effects of occlusal forces on the progression of periodontitis are not ethically acceptable in humans. Double-blind controlled prospective human studies to determine the effects of occlusal forces and mobility on wound healing following periodontal therapy are possible and are badly needed. These studies could answer questions concerning the effects of occlusion and mobility on regenerative periodontal therapy such as guided tissue regeneration and periodontal plastic surgery.

Studies that attempt to identify risk factors for periodontitis should also include occlusal analysis in the study parameters to evaluate this variable. These studies are, however, retrospective in nature and therefore may find it difficult to establish cause and effect relationships. Animal studies could help to define the effects of occlusal forces on peri-implant bone loss and to determine if excessive occlusal forces can effect the progression of plaque induced peri-implantitis.
GLOSSARY OF TERMS

Attachment apparatus: The cementum, periodontal ligament, and alveolar bone which function as a unit to support the teeth.

Bruxism: A habit of grinding, clenching, or clamping the teeth. The forces so generated may damage both the tooth and the attachment apparatus.

Co-factor: An aspect of personal behavior or life-style, an environmental exposure, or an inborn or inherited characteristic which by itself does not cause a disease process but which can modify the course or expression of a disease process.

Disease markers: Factors that are indicative of the disease, but that are not thought to be etiologic or may be historical measures of the disease or disease progression.

Fremitus: A palpable or visible movement of a tooth when subjected to occlusal forces. (also referred to as functional mobility)

Mobility, tooth: A visually perceptible movement of the tooth away from its normal position when a light force is applied. (This movement may be within physiologic limits or beyond physiologic limits.)

Occlusion: The contact of opposing teeth.

Occlusal adjustment: Reshaping the occluding surfaces of teeth by grinding to create harmonious contact relationships between the upper and lower teeth or orthodontic movement of the teeth to create a more harmonious occlusal relationship.

Occlusal forces: Forces that are generated and transmitted to the supporting structures of the teeth when the teeth are brought into contact.

Occlusal interference: Any contact that inhibits the remaining occluding surfaces from achieving stable and harmonious contacts.

Occlusal trauma: An injury to the attachment apparatus or tooth as a result of excessive occlusal forces.

Occlusal traumatism: the overall process by which a traumatogenic occlusion produces injury in the periodontal attachment apparatus.

Parafuction: abnormal or perverted function, as in bruxism.

Premature occlusal contact: A condition of tooth contact that diverts the mandible from a normal path of closure.

Primary occlusal trauma: Injury resulting from excessive occlusal trauma to a tooth or teeth with normal periodontal support.

Secondary occlusal trauma: Injury resulting from normal occlusal forces applied to a tooth or teeth with inadequate periodontal support.

Traumatogenic occlusion: Any occlusion that produces forces that cause an injury to the attachment apparatus.

REFERENCES


