

# Occlusion: Reflections on science and clinical reality

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The last 50 years have seen progress in emphasizing scientific evidence as a basis for dental practice, including occlusal therapy. Although a proper understanding of the contributory role of occlusion to temporomandibular disorders should not be minimized, the importance of occlusion in other areas of dental education and practice should not be overlooked. The primary objective of this article is to discuss the nature of this problem as it relates to the duality of science and clinical reality in the evidence-based paradigm, information transfer, quality of evidence, clinical trials, and clinical aspects of occlusion. Some suggested solutions for the problem and thoughts on past and future perspectives of occlusion are expressed in context of inquiry. (J Prosthet Dent 2003;90:373-84.)

The literature on temporomandibular disorders (TMD) is extensive,<sup>1</sup> with more philosophical types of reviews<sup>2,3</sup> being replaced with evidence-driven systematic reviews of occlusal therapy.<sup>4</sup> For the practitioner to critically evaluate the evidence from qualitative, let alone quantitative, reviews requires more educational background than is generally found in most areas of predoctoral dental education. The gap between what is known and unknown between science and clinical reality is in part a problem in the transfer of information from teachers to students and from research to clinical practice. The link between science and clinical reality is information transfer, but the uncertainty of that linkage is reflected in debates about conflicting conclusions and implications set forth by research data, and by the absence of an educational foundation for determining what research evidence is best, both scientifically and clinically. One way to address this paradigmatic duality is to make certain that the dental curriculum contains practical experience in research design, evidence-based research methodologies, qualitative and quantitative systematic reviews, statistical analyses, and how to practice evidence-based occlusal therapy for the individual patient. In that way, a bidirectional link between science and clinical reality for all aspects of occlusion could be enhanced.

The term *occlusion* in this review will be used conceptually to encompass a multifactorial relationship between the teeth and other components of the masticatory system, including their direct or indirect relationship with function, parafunction, and dysfunction. A testable systems analysis of occlusion<sup>5</sup> to evaluate the biomechanical unity of the components of the masticatory system is needed.

## EVIDENCE-BASED PARADIGM

It is unlikely that a significant number of dentists disagree with the concept of an evidence-based practice being “the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients,” including “integrating individual clinical expertise with the best available external clinical evidence.”<sup>6</sup> However, from the standpoint of occlusion and clinical reality, attention should be directed toward “best”, “individual patients”, “clinical expertise”, and “external evidence”. It is around these terms that the meaning of “evidence-based” may be problematic if applied rigidly to clinical practice or research methodologies when an agreed upon basis for that evidence is not yet available. Evidence-based dentistry is an ongoing process wherein it is necessary to determine at a particular point in time what constitutes “best evidence” from all credible sources for the treatment of the individual patient. External evidence refers to evidence from sources other than a single study, as well as knowledge based on past treatment outcomes of patients with the same disorders. The methods of evaluating external evidence from several studies may involve some form of extrapolation based on causal reasoning, or quantitative statistical summation of the results from similar clinical trials. Practical methods of determining “best evidence” and methods of summarizing the results of several clinical trials should not be outside the scope of the dental curriculum using computer-driven simulations.

## Statistics

The rise of evidence-based dentistry, which focuses on the use of clinical trials for empirical demonstration of the efficacy of treatments and procedures, may be viewed as reflecting a paradigmatic shift away from the balance in authority of the practitioner with primary knowledge of the biological basis of dentistry toward those with knowledge of quantitative methods, or toward the quantitative results alone, as though the numbers spoke for themselves.<sup>7</sup> In effect, the statistical-

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driven shift to the evidence-based paradigm has not been without contention regarding inherent problems with what qualifies as evidence,<sup>8,9</sup> and whether some current methods of statistical inference are “evidence-based” in fact.<sup>7</sup> Because a small effect in a clinical trial with a large number of subjects can have the same *P* value as a large effect in a study with a small sample size, there is an emphasis on confidence level rather than *P* values.<sup>10-12</sup> Problems with using the *P* value as a measure of evidence include internal inconsistencies of the combined hypothesis *P*-test value method, and inhibitions on combining experimental results with background information. One solution to the problem of facilitating the integration of statistical summaries for dental knowledge points to the use of the Bayes factor rather than the *P* value,<sup>7</sup> keeping in mind that when the *P* value becomes very small, the disparity between it and the minimum Bayes factor is essentially negligible; therefore, strong evidence will look strong by either of the measurements.<sup>13</sup> Focusing again on the objective aspects of Bayesian inference, the statistical evidence against the null hypothesis is usually weaker when the data are interpreted by the Bayes factor than when the same data are interpreted using the *P*-value approach.<sup>14</sup> The weight of evidence against the null hypothesis is not nearly as strong as the magnitude of the *P* value suggests.<sup>13</sup> For example, reanalysis of some clinical trials by Bayesian statistics showed that observed differences were unlikely to be true.<sup>15</sup> It has been suggested that researchers include a Bayesian interpretation with their results<sup>14</sup>; however, Bayes may not be for beginners.<sup>16</sup> Even so, the Federal Drug Administration (FDA) permits and encourages Bayesian designs and analysis in applications seeking approval for medical devices for which large clinical trials are not feasible but directly relevant historical evidence is available.<sup>17</sup>

In addition to the *P*-value fallacy, “the mistaken idea that a single number can capture both the long-run outcomes of an experiment and the evidential meaning of a single result,”<sup>7</sup> experienced meta-analysts have suggested that the threshold for significance in a meta-analysis should be a result more than 2 standard errors from the null effect rather than just 2 standard errors.<sup>18</sup> Meta-analysis is a statistical method for combining summary information from related but independent studies,<sup>19</sup> in which each study is treated as an experimental unit.<sup>20</sup> Meta-analysis has not been common to the dental literature<sup>21</sup>; however, the use of meta-analysis with randomized controlled trials is considered to lead to the highest quality of evidence<sup>22</sup> for addressing sharply defined clinical questions.<sup>23</sup> It should not be concluded that meta-analysis is not without validity issues.<sup>19,24</sup> Odds ratios<sup>25</sup> and regression analysis, which are essentially synonyms for regression modeling,<sup>26</sup> may have problems in their clinical application. Using odds ratios for estimating the

significance of occlusion in TMD is based on the assumption that etiologic factors are additive and interchangeable in relation to different composite causes. Therefore, odds ratios should not be used in risk estimation if the factor under study is a necessary causal factor.<sup>27</sup> In effect, the use of odds ratios may be problematic for estimating the significance of occlusal factors in temporomandibular disorders.<sup>27</sup> Concepts such as sensitivity, specificity, and positive and negative predictive value may lead to misunderstandings; therefore, their use in dentistry should be clearly understood.<sup>28</sup>

The observation that many individuals have occlusal interferences is a problem for studies of association when it is assumed that samples represent a target population. Therefore, because of the lack of variation in the presences of interferences, a researcher may believe incorrectly that he/she has shown empirically that there is no association present.<sup>28</sup> Also, selection of patients with a minimum or maximum number of interferences may not provide for an efficient analysis either.<sup>29</sup> The validity of statistical analyses has to be considered in context when considering well-designed and conducted studies.<sup>30</sup>

Statistics is a science that progressively finds new truths in the ways of evaluating data from clinical trials. The researcher and the clinician who read reports of either primary research or systematic reviews should be aware of the validity of statistical methods applied to data from clinical trials. The clinician with knowledge of the limitations and application of statistics to clinical trials may be in a better position to critically evaluate the results of primary research or systematic reviews of the literature.

### Clinical trials

The elements of the design of clinical trials include comparisons, randomization, blinding, patients' rights and confidentiality, treatment intentions, and statistical methodologies.<sup>31,32</sup> The present inquiry will consider only briefly some of these elements. A clinical trial is generally both comparative (active intervention group compared to a nonintervention group); and randomized (subjects randomly allocated by chance to the active intervention group or the control group). A control group may receive treatment that has already been shown to be effective, or no-treatment, or a placebo. A controlled clinical trial is one in which a comparative group is used for the purpose of making certain that the effect of the intervention is due solely to the treatment and not to some other factor. Allocation of subjects to different groups by random number generation or tables is done to reduce the chance of allocation bias that might ensue because of gender, age, disorder severity, and other

variables. There are several methods of randomization; therefore, it is important for the practitioner who is critiquing a clinical trial to be aware of what constitutes proper allocation of subjects.<sup>33</sup>

The randomized controlled trial (RCT) is said to constitute the gold standard<sup>34</sup> for the evaluation of treatment methods because it tends to balance measured and unmeasured characteristics<sup>35</sup> and increase the reliability of the trials.<sup>1,36</sup> Compared to RCTs, it is commonly believed that the size of treatment effect is exaggerated in nonrandomized studies; however, where is the empirical evidence that this is so?<sup>37</sup> A criticism of RCTs is that they are based on highly selected individuals, raising the question of whether there are systematic differences between patients that are included in these kind of trials, and whether these influence the treatment effect.<sup>37</sup>

Although RCTs are considered to be the standard for clinical trials, only recently have qualitative systematic assessments of randomly controlled clinical trials of occlusal treatments in temporomandibular disorders been reported.<sup>4</sup> Because of methodological problems in a recent randomized controlled clinical trial, only suggestive conclusions were drawn: the use of occlusal splints may be of some benefit in the treatment of TMD, but evidence for occlusal adjustment was lacking.<sup>4</sup> However, the authors<sup>4</sup> did conclude that there was a need for well-designed controlled studies to analyze current occlusal practices. Occlusal adjustment has been found to cause changes in headache<sup>38</sup> and changes in symptoms of chronic cervicobrachial pain<sup>39</sup>; however, the nature of such changes requires clarification. From the results of a prospective, long-term, controlled trial that compared repeated occlusal adjustment every 6 months with mock adjustment beginning at a young age, it was concluded that the removal of the presumed risk from dental occlusion appeared to significantly reduce the incidence of demand for treatment of temporomandibular disorders in a select group of young subjects.<sup>40</sup> The conclusions and implications drawn from this prospective, long-term study,<sup>40</sup> and other longitudinal randomized controlled studies,<sup>41</sup> suggest that occlusal adjustment remains a selective evidence-driven option in occlusal therapy.

Objections to occlusal adjustment<sup>42</sup> have been couched in such terms as “irreversible”, which is true but applicable to many procedures in health care, perhaps including those with psychological implications. Objections also rest on observational and epidemiologic studies that call attention to the seemingly almost universal presence of naturally occurring “occlusal interferences” in a high number of patients who do not have TMD at some moment in time.<sup>43,44</sup> Studies that do not make certain that no occlusal interferences exist when attempting to compare occlusions free from interferences with those with occlusal interferences may not provide a strong statistical case for a lack of associa-

tion.<sup>45</sup> Occlusal factors have been suggested to be cofactors in the identification of patients with TMD, but their role should not be overstated.<sup>46</sup> On the basis of supporting evidence and absence of results clearly rejecting the hypothesis concerning the role of occlusal factors in temporomandibular disorders, occlusal therapy appears to remain a select option for a large percentage of practitioners.<sup>47</sup>

Another element of the clinical trial is blinding (masking) or double-blinding to prevent the investigators (assessors) from knowing to which group (treatment, control, placebo) subjects have been assigned. Double-blinding may be problematic or not possible because of ethical reasons or practicality, including the requirement for informing patients of possible untoward effects as part of the informed consent process.<sup>48</sup>

It should not be concluded that all clinical trials designated as RCTs meet the scientific rationale for collective equipoise.<sup>49</sup> The quality of RCTs in most areas of health care should be evaluated by rigorous review standards to detect any inadequacies in methods of randomization, allocation concealment and blinding,<sup>32,50</sup> and ethics.<sup>49</sup> The clinician must consider all methodological aspects of RCTs in accepting or rejecting research findings.

### Alternatives to RCTs

It is not possible to answer all clinical questions with randomized controlled trials; these trials may not be feasible, necessary, ethical, or appropriate. While possible RCTs, including meta-analysis, are best for answering questions about treatment, observational or epidemiologic studies are best for answering questions about diagnosis, prognosis, and causation.<sup>51</sup> Even so, the validity of these studies requires an appropriate appraisal; for example, diagnostic tests should have appropriate sensitivity and specificity, effective blinding, an appropriate reference or “gold standard”, and a range of patients that represent what is found in clinical reality.<sup>52,53</sup>

Alternatives to RCTs are observational studies, including cohort and case-control methods, in which patients are allocated treatment on a nonrandom basis. However, in such studies it is usually not possible to consider unknown confounders, nonblinding, and the preferences for treatment by patients and clinicians.<sup>54</sup>

Single patient trials (SPTs) or N-of-1 trials are used to identify the best treatment for the individual patient using a formalized treatment procedure in which blinding and multiple crossover periods are used. Such trials are used to improve decision-making about long-term medications for chronic diseases or disorders. Combining SPTs has been used to estimate population treat-

ment effects and to evaluate the response of individual patients to treatment.<sup>55</sup>

### Quality of evidence

The quality of evidence for clinical guidelines is usually based on a hierarchy of increasing vulnerability to bias in the way that the evidence is obtained in a decreasing hierarchy: random allocation, cohort studies, case-control studies, case series and registries, and case reports and expert opinion.<sup>34</sup> There is a similar descending hierarchy for the quality of evidence from: meta-analysis of RCTs; at least one RCT; at least 1 well-designed controlled study without randomization; at least 1 other quasi-experimental study; well-designed nonexperimental descriptive studies such as comparative studies, correlation studies; case control studies; and expert committee reports or opinions and/or clinical experience of respected authorities.<sup>22,56</sup> A significant problem with basic-evidence hierarchal categories<sup>22,34</sup> is the lack of precise definitions of what constitutes a well-designed study that is sufficiently valid to be included in the evidence base. In effect, most, if not all, taxonomies of methodological flaws for validating study design have some limitations in reducing subjectivity; however, it is possible to identify design features that are reasonably likely to affect the validity of study results.<sup>34</sup>

### Systematic reviews

The strategy for obtaining the best evidence for making clinical decisions consists of systematically reviewing the literature using explicit and rigorous methods to identify, critically appraise, and synthesize studies that are thought to answer a specific question. The result of systematically reviewing the literature using evidence-based methods should be concise summaries of the best available evidence that addresses sharply defined clinical questions.<sup>23</sup> However, the validity of the methodological processes is not always evidence-based<sup>7</sup> inasmuch as the review process itself is like any other type of research; it is subject to bias.<sup>57</sup>

The practitioner has the option of accepting evidence from primary sources of evidence derived from basic, clinical, and epidemiologic research, or from the synthesis of multiple studies using strategies to limit bias and random error. The latter, which can be either a qualitative or quantitative systematic review, can be accomplished efficiently if an answer to a specific question exists by using one of the initiatives to help prepare, maintain, and disseminate the results of systemic reviews of health care, such as Cochrane Collaboration.<sup>58</sup> Although the Cochrane reviews may fulfill most of the criteria listed in the Cochrane handbook,<sup>59</sup> errors do occur and unsuspected biases do emerge; for example, partitioning of effects of treatment and prevention rather than that which is the best representation of the

total impact of the symptoms attributable to a disorder such as TMD.<sup>40</sup> In effect, defining outcome measures appropriately for inclusion in a review is critical for demonstrating the presence or absence of true differences between experimental and control groups. The literature may be unintentionally searched in a biased way even with systematic overviews if reviewers do not guard against interpreting studies in a way that is colored by their own perceptual and ideologic presuppositions. Thus, all scientific endeavors, including Cochrane reviews, should be interpreted cautiously and read critically. Some methodologies might not be appropriate for some types of studies.<sup>27,60</sup> Randomized controlled trials often disagree because of the complexity of the design of the trial, including eligibility and selection of study groups and baseline differences in available populations.<sup>61</sup>

If practitioners evaluate the methodologies used and the results of clinical trials for themselves in order to apply them to clinical practice with confidence, it is necessary to understand the issues in designing, conducting, and interpreting randomized clinical trials (RCTs), as well as observational and epidemiologic methodologies.<sup>31,32</sup> It would appear to be ideal if the treatment or procedure (intervention) to be studied were based on causal hypotheses that indicate specifically the ways in which changes will occur. However, that is not always possible, for instance, when the cause of a disorder is said to be unknown or multifactorial, as is said to be the case with "TMD" or bruxism.

A quantitative systematic review that uses meta-analysis is much more easily accomplished now with available software programs, such as the RevMan by the Cochrane Collaboration 2000,<sup>59</sup> as well as general application software for the integration of both data management and analysis.<sup>62</sup>

Practical guidelines for undertaking systematic reviews are complex<sup>63</sup> and are beyond the scope of this review. Systematic reviews may be located in MEDLINE, a multipurpose database produced by the US National Library, and other electronic databases such as the Cochrane Library.<sup>64</sup> Assessing the quality of a systematic review can be undertaken by using published criteria.<sup>65,66</sup>

### INFORMATION TRANSFER

Providing various forms of evidence for a profession that has a biological as well as a mechanical basis has been remarkably successful. The literature of the past several decades illustrates how communication technology could cause significant alterations in the practice of dentistry.<sup>67</sup> Even so, problems of information transfer remain between the researcher and the clinician. Such delays have led to concerns for the success of the application of the evidence-based paradigm.<sup>68,69</sup> The prac-

tice of evidence-based dentistry is an ongoing process wherein it is necessary to determine at a particular point in time what constitutes the “best evidence” from all credible sources to apply to practice at that time.

When it is necessary to transfer available evidence to resolve immediate clinical problems, the practitioner must be able to identify the problem specifically, efficiently determine and appraise relevant published evidence, and synthesize it for clinical application with some measure of confidence that the evidence is relevant to the patient’s problem. These abilities require more than a passing interest in information transfer; what is needed is a commitment by academia to actualize these abilities in dental education without undermining that part of the curriculum consistent with the biomechanical precision necessary for resolving problems at the biological/technique interface. Thus, from the standpoint of dental education, the problem of actuating the process of evidence-based dentistry is how to provide the educational basis for determining what constitutes the “best evidence” at a given time, and how to transfer that information efficiently to clinical practice using clinical experience and judgement. It should be understandable that many practitioners would conclude that evidence is “best” when it is directly applicable to clinical decision-making about individual patients, especially when it deals with occlusal therapy.

### Approaches to information transfer

In order to convert information about cause, diagnosis, interventions, and treatment into answers for questions about clinical reality, there must be a transfer of scientific evidence to the clinician. To find the “best” current evidence, the clinician should ask answerable questions and be able to obtain answers from a reliable source that he/she can filter through experience and clinical judgement free of personal bias or ideology. A commonly used strategy to obtain evidence is by searching electronic databases such as MEDLINE, which provides access to large amounts of literature. Although searching electronic databases may superficially appear to be straightforward, some experience and guidelines are necessary for efficient searches. In order for a practitioner to perform his own critical evaluation of primary clinical trials or even published systematic reviews, perhaps she/he should think initially of research as being driven by biases and ideologies of researchers and funders.<sup>70</sup> It should also be perceived that systematic reviews are a form of research that can vary in methodologic quality and, as such, may lead to erroneous conclusions.<sup>71</sup> Even so, properly conducted systematic reviews are considered to be a way of controlling bias. Changing from opinion-based to evidence-based occlusal practice is an ongoing process, considering that today’s facts may be tomorrow’s artifact.

### Problems in information transfer

A significant difficulty in information transfer revolves around what the researcher thinks has been proved, and what the clinician accepts as truth and believes can be implemented into practice. In that sense, both sides of the issue may be invested with a strong component of subjective rationalization. The reality of clinical practice reflects the duality of extracting the “best evidence” from clinical trials versus the immediacy of making decisions about individual patients based on clinical best guesses tempered with clinical judgment and experience.<sup>72</sup> This time-dependent duality of science and clinical reality is also seen in assessing the difference between what is “statistically” significant and what is “biologically” significant.<sup>73</sup> Quantifying and transferring the meaning of the difference between statistical significance and clinical reality into practice can be problematic.

Making science clinically relevant<sup>74</sup> is not a matter of simply closing the gaps between what is known and what is practiced.<sup>69</sup> It is necessary that “science” be able to predict with studied probability that treatment based on newer evidence-based knowledge will have a successful outcome. In some instances, uncertainty has led to the premature application of new but unverified research findings; in other instances, a new technology may appear far in advance of clear implications for its utility.<sup>75,76</sup>

When scientific evidence for or against a concept is clearly applicable to clinical practice using the best estimate of a time-dependent cost-risk-benefit formula, there will be no controversy, at least for that time period. To not apply this evidence would appear to be the same as applying rigid evidence-based criteria without considering the probability of new evidence becoming available over time.<sup>77</sup> All formulas and paradigms require constant review to demonstrate their adequacy in relation to the results of clinical trials and the experience of practitioners who apply research findings in their practice.

Clinicians have concerns when “science” does not seem to match the clinical reality of a cost-risk-benefit formula for the clinician who is faced with using treatment alternatives that have not been shown to be more efficacious than placebo,<sup>42,78,79</sup> or only apparently efficacious,<sup>80</sup> for example, physical therapy and physical modalities for relief of chronic musculoskeletal pain. It has been reported that oral splint treatment for TMD is only apparently efficacious in that it has not been shown to affect the unknown or multifarious causes of these disorders; however, controlled clinical trials support the effectiveness of oral splints. For example, patients appreciate the positive changes associated with their use.<sup>80</sup> The application of the difference in the meaning of these terms has not been in general use. Effectiveness of treat-

ment may be couched in terms of patient-centered assessment,<sup>81</sup> or demand for follow-up treatment after initial therapy.<sup>40</sup>

What seems to be obvious is the need for more effective transfer and constant updating of information that flows bi-directionally between researcher and clinician. Clinicians should be sufficiently knowledgeable in research methodologies, principles for qualitative and quantitative systematic reviews with meta-analysis,<sup>82-84</sup> to be able to recognize that primary research and reviews are reasonably free of methodologic errors.<sup>27,85</sup> The epistemologic foundation for evaluation of research findings should be laid in predoctoral dental education. The better clinicians understand the evidence-based paradigm and its strengths and limitations, the more discriminating a 2-way transfer might be expected to become; for example, practitioners with basic knowledge of research methodologies will be able to evaluate whether research findings are evidence-based and applicable to clinical practice.

If valid evidence-based concepts of occlusion are to be developed fully, practitioners, academicians, and researchers who are most familiar with the problems of systematically evaluating research data on occlusion and its transfer to the clinical practice must seek to complement evidence-based research with evidence-based implementation. In effect, the dimensions of the problems of information transfer and eventual change to evidence-based clinical practices may well involve a spectrum of scientific, epistemologic, societal, and economic considerations.

### Practitioners' uncertainty

Patients' satisfaction and attitudes about the technical competence of their health care provider is of importance to the practitioner.<sup>86</sup> In the absence of conclusive scientific evidence for or against a particular treatment or procedure, clinical reality must be considered in light of the uncertainty among practitioners about the effects of evidence-based treatment on patients' consent and their professional autonomy<sup>87,88</sup>; how relevant the evidence-based research findings are perceived to be for their specialty<sup>89</sup>; their level of knowledge of evidence-based methodologies<sup>86</sup>; their awareness of quality defects in both randomized and nonrandomized studies<sup>90-92</sup>; their knowledge that research is limited to determining the likelihood of particular outcomes, and is not necessarily focused on the attitudes or conditions of patients<sup>93</sup>; the extent to which experimental findings can be generalized across different individuals, settings and times<sup>94</sup>; their ability to evaluate conflicting data from one or more randomized clinical trials rather than making decisions based solely on expert opinion or clinical best guesses<sup>34,72,95</sup>; their response to demands for empirically validated treatment by insurance companies,

managed care, and other institutions<sup>96-98</sup>; and their ability to evaluate what the effect might be of the impossibility or necessity of including all relevant studies even in recognized good systematic reviews.<sup>4,83</sup> These epistemologic uncertainties may be present because in order for the clinician to assess what is the best, most relevant, and useful evidence from all sources, it is necessary to have some familiarity with the broad spectrum of research methodologies. These range from meta-analysis of randomized clinical trials, which is considered to provide the highest level of evidence, to expert committee reports or opinions and/or clinical experience of respected authorities, which are considered the lowest level of evidence.<sup>22</sup> To not familiarize oneself with these methodologies is to accept or reject research data without being able to critique its validity for application to practice and to individual patients.

The extent of the gap between science and clinical practice can be measured to a certain extent by the number (majority) of practitioners who think that there is sufficient research data and clinical experience to show that occlusion has an association with TMD.<sup>47</sup>

### Solutions in dental education

From the standpoint of dental education, it would seem reasonable to include specific courses in the curriculum that would provide more experience in exploring the concepts of evidence-based health care,<sup>99</sup> "problem-based learning"<sup>100</sup> or "learning by inquiry", and decision analysis or clinical decision making.<sup>101,102</sup> Learning critical appraisal of evidence-based methodologies, including systematic reviews, meta-analysis, and randomized trials, by performing simulated clinical trials in class is a hands-on-experience for students. In this way it may be possible to provide dental students with methods of how to find the best evidence, an understanding of what constitutes good primary research, and knowledge of how to do systematic reviews using explicit standards for evidence retrieval, assessment, and synthesis. It should be kept in mind that the search for current best evidence is an ongoing process. The word "current" is extremely important, for to paraphrase one sage, half of what students are taught now will in 10 years have been shown to be wrong, or at least outdated; and, unfortunately, none of the teachers know which half.<sup>103</sup> However, teaching evidence-based methodologies is teaching for the future.

### Biomechanical precision and dental curricular change

Attempts to change dental curricula both structurally and philosophically are not new.<sup>104</sup> However, solutions for change in an already dense curriculum, especially those that would appear to de-emphasize significantly the skills needed for biomechanical precision in favor of

a broader concept of health care, have not been widely accepted. Biomechanical precision means the use of clinical procedures that are technique-sensitive and require biological/technique interfaces to be sufficiently accurate to treat or prevent further diseases or disorders, such as good marginal seals of restorations, removal of all dental decay, precise tooth root instrumentation, and freedom from occlusal trauma. Although not always a reality, biomechanical precision integrated with a broad concept of dental health care that focuses on educational skills for the diagnosis and the prevention of diseases and disorders has been the hallmark of the best in dental education.

To a considerable extent the duality reflected in the balance between the goals of biomechanical precision and goals related to a broader role of the dentist in the health care arena is often determined outside academia by the clinical reality that there remains a significant incidence of dental caries, both primary and secondary, despite the availability of recognized preventive measures.<sup>105</sup> Secondary caries can be related in part to a lack of biomechanical precision in the placement and quality of the margins of restorations involving occlusal surfaces,<sup>106</sup> as well as the familiar triad of host, microflora, and diet. Secondary caries is not a universal attack along the entire tooth-restorative interface but most often involves local areas of plaque, usually in stagnant areas of plaque accumulation along the margin of a restoration. There has been success in the diagnosis, prevention, and control of periodontal diseases using precise biomechanical periodontal instrumentation for calculus removal and root planing, and stress on home care methods; however, refractory periodontal diseases still remain a significant problem.<sup>76</sup>

It is quite likely that as biomechanical interfaces become better understood, the restorative biological interface will require better diagnostic methods and more sophisticated, precise, and technique-sensitive procedures, such as proper design, placement, loading, and maintenance of dental implants. Even where dental schools attempt to accommodate the duality of skills in biomechanical precision and diagnostic and preventive health care in the already crowded curriculum, time for specific courses teaching the skills needed to evaluate the results of primary research and its application to clinical practice may not be available if the same level of requirements for biomechanical skills is to be maintained. Resolution may be possible by appropriate predoctoral requirements in biostatistics.

In clinical reality, the building blocks of evidence-based practice<sup>99</sup> reflect a process of evolving science and its progressive application to clinical practice. How do educators prepare students for situations where there is an absence of rigorous evidence?<sup>107</sup> This remains a challenge.

In order for information transfer to occur, more evidence of the highest quality is needed in many areas, including selective occlusal adjustment, etiology of bruxism, tooth fractures, periodontal trauma from occlusion, abfraction, adaptation, patient centered treatment responses, use of devices for obstructive sleep apnea, competency-based education in occlusion, implant occlusion, representative sampling in occlusal studies, adaptation and plasticity of the masticatory system, anxiety, depression and drugs in occlusal therapy, and more sensitive and specific diagnostic procedures.

## CONCEPTS OF OCCLUSION

Controversies about concepts of occlusion seem to suggest that perhaps all observations are theory-laden, either because they are colored by perceptual and ideological differences, or because attempts to differentiate between observation, theory, and clinical reality have not been successful because of 1 or more of the problems already considered in the bidirectional transfer of information between researcher and clinician. More specifically, the importance of occlusal contact relations that interfere with occlusal function has largely been overshadowed by the emphasis on occlusal contact relations as some form of causal factor in TMD. Such an emphasis has validity; however, the significance of occlusion in other areas of clinical reality has not received attention commensurate with its importance.

### Occlusal interferences

It has been a generally accepted concept in clinical practice that the contact relations of the teeth in the maxilla and mandible are important for function and stability and not simply for descriptive clinical convenience. In this respect, occlusal contacts can be described in terms of "normal", optimal, esthetic, stable, and functional relationships. Assuming that a term such as *canine-protected articulation*<sup>108</sup> (canine guidance) has evidence-based functional significance, any occlusal contact relation that interferes with that protection may be viewed as an interference to functional articulation. Perhaps a more obvious interference is the situation in which occlusal contact relations interfere in some way with the contact function of the canine teeth for tearing or shredding food. Less straightforward is the presence of recent iatrogenic interferences on the nonworking side that interfere with an established pattern of bruxism (past or present) located on the canines. Although clinicians may see its effects (for example, fracture of the iatrogenic interference) if adaptation does not occur, there is no research to validate the concept that iatrogenic occlusal interferences to canine bruxing can aggravate bruxism. Even without such evidence, the clinician should not knowingly introduce into the occlusion

interferences to canine function and parafunction. The adaptability of the normal masticatory system does have limits, perhaps even less in the presence of disorders. From the standpoint of clinical reality, the effects of iatrogenic occlusal interferences on function and parafunction may be considered as one of the gray zones or current limitations of the evidence-based paradigm.

To establish the validity of increasing or re-establishing canine-guided occlusion by “canine risers” to help control excessive loading of the teeth, limit further tooth wear, and assist in the management of temporomandibular disorders and dysfunction,<sup>109</sup> requires more evidence to substantiate the concept of canine-protected occlusion than is now available.

If, in excursive movements of the mandible, there is a loss of contact of canines because of an iatrogenic occlusal contact relation elsewhere in the occlusion, that occlusal contact relationship should be considered by definition to be an occlusal interference—in other words, a tooth contact that inhibits the remaining occlusal surfaces from achieving stable and harmonious contacts, as well as an interference to function of the canine teeth.<sup>108</sup> Therefore, it seems reasonable to accept and teach the concept that occlusal interferences should not be introduced into the occlusion iatrogenically, whether or not occlusal interferences are considered paradigmatically to be associated with TMD, because they can interfere with function.

For naturally occurring interferences to the functional contact relations of canine guidance, removal of the interference by reasonable and judicious selective occlusal adjustment to obtain contact may be clinically indicated if the problem does not require orthodontics. Eliminating such interferences to facilitate canine-protected articulation should be considered in light of evidence-based individual patient needs, such as efficient grasping of food, distributing loading on the periodontium, esthetics, and stability, at least until there is sufficient evidence to establish the concept of canine-protected occlusion as evidence-based.

### Experimental occlusal interferences

Short-term clinical symptoms and signs, such as jaw muscle fatigue and pains, headache pain, and clicking in the joints, do occur in response to experimental occlusal interferences; however, the responses vary according to the placement of the interferences (anteriorly, posteriorly, and position on a tooth), psychological adaptability of the patient, functional and structural adaptability of the masticatory system, past or present history of TMD, and whether the patient is free of interferences before the interferences are placed.<sup>110-112</sup> In clinical reality, patients who complain of “high fillings” may do so because of pain and

discomfort in the tooth and/or the muscles and joints. The complaints generally continue until the interference to closure into the intercuspal position is relieved by occlusal adjustment. Interferences involving the maxillary incisors that prevent closure into the intercuspal position may gain relief of signs and symptoms if the involved tooth moves anteriorly before the dentist can examine the patient. These types of responses fit into the effects of experimental occlusal interferences, and the offending occlusal interferences should be removed whether or not they are considered to be a causal factor in TMD.

Because of the adaptability of the normal masticatory system to the placement of experimental interferences,<sup>113</sup> studies that select subjects without a past history of TMD are less likely to demonstrate a consistent untoward response to occlusal interferences. As indicated in one study,<sup>110</sup> new paradigms involving experimental occlusal interferences should be introduced to clarify the nature of the TMD-like responses that occur with experimental occlusal interferences. Although there has been controversy over the relationship between experimental occlusal interferences and TMD and whether their effects may appear to be short lived because of adaptation, overlooking iatrogenic occlusal interferences is not good dental practice; if nothing else, they can interfere with function, considering the significant potential for functional and structural adaptation. Adaptation should not be overlooked in research design and in clinical practice.<sup>113</sup> There is no evidence from RCTs that iatrogenic occlusal interferences cause an exacerbation of TMD; however, that does not mean that such occlusal interferences do not. In effect, empirical evidence is needed from well-designed clinical trials to specifically answer that question. Occlusal adjustment of occlusal interferences in patients with progressive periodontal disease appears beneficial,<sup>114</sup> and when indicated, an adjunct to periodontal therapy.<sup>115</sup> There are currently few controlled studies examining the benefits of occlusal adjustment for patients with mandibular dysfunction.<sup>4,38,39,116</sup> Methodological errors in studies that are for or against occlusal adjustment for mandibular disorders have been considered briefly throughout this review. The same can be said for occlusal interferences acting as an etiologic factor for TMD. In the absence of convincing evidence, many clinicians<sup>47</sup> will continue to use occlusal adjustment judiciously for the treatment of trauma from occlusion, including some of the temporomandibular disorders. Methods of occlusal adjustment are found in textbooks on occlusion.

On the basis of the evidence presented here on occlusal interferences, and considering the adaptability of the masticatory system, the following conclusions are made: 1) some iatrogenic occlusal contact relations may interfere with function, and some with parafunction; 2) dependence on system adaptability to avoid iatrogenic in-

terferences to function should not be a passive strategy in quality dental care; 3) iatrogenic interferences should be avoided in making restorations, or if present, should be removed by occlusal adjustment; and 4) because they may not be perceived to be some form of causal factor in TMD or of significance in the treatment of periodontitis, these perceptions should not be the basis for overlooking the introduction of iatrogenic occlusal interferences into the occlusion. Natural occlusal interferences usually have been present for a long period of time and adaptation has occurred. Whether there are set limitations to such adaptation, or associated additive microstructural changes in the joint structures, has not been determined. Gross occlusal interferences to functional contact relations such as prevention of canine guidance are usually obvious; however, smaller posterior interferences may not be so apparent and may require the use of articulated casts. Questions of the cost to benefit ratio are necessary.

## BRUXISM

Bruxism is defined as diurnal and nocturnal parafunctional activity, including bracing, clenching, gnashing, and grinding of the teeth.<sup>117</sup> Bruxism that occurs during sleep in a laboratory setting can be diagnosed with reasonable accuracy; however, evidence from a clinical examination is needed in that nighttime bruxism varies considerably.<sup>118</sup> The presumptive diagnosis of bruxism in clinical practice has been based on a number of approaches: admitted bruxism, self-report questionnaires, observation of degree and location of dental attrition, and observation of the patient bruxing in the dental chair. However, there is considerable variation in these methods of diagnosis. No claim need be made for a cause-and-effect relationship, either in terms of concomitant variation or the method of difference in clinical research.<sup>119</sup> Thus, in clinical practice, for the patient who appears to have bruxism because of tooth wear or tooth fractures, the design of restorations should reflect the probability of continued bruxing and clenching. The role of bruxism and clenching as etiologic factors in 1 or more of the temporomandibular disorders remains unsettled. The etiologic spectrum for a relationship between bruxism and TMD vary from being coexistent or unrelated<sup>120</sup> to having a true cause-and-effect relationship.<sup>121</sup> However, bruxism is more prevalent in patients with TMD in the general population.<sup>122</sup> Treatment for bruxism is directed towards control of loss of tooth structure and occlusal trauma by using stabilization occlusal splints; the etiology of bruxism remains undetermined.

## SUMMARY

The last 50 years have seen the rise and fall of many paradigms for the cause and treatment of occlusal

disorders that may cause orofacial pain and dysfunction. The most recent paradigm is described as "evidence-based," a term that seems to be applied to a range from clinical practice to statistical methods. Though it is a worthwhile goal to provide unequivocal evidence for clinical reality, the short-term effect has been to uncover the inadequacies of the quality of evidence used to support differences of opinion about the role of occlusion in dental education, clinical practice, and insurance programs.

Some associations among occlusion, bruxing and clenching, and temporomandibular disorders have been found. As with all studies, there are arguments about the interpretation of the data because the associations are not specific, are not consistent, or do not make epidemiological sense, and therefore exist without having a cause-and-effect relationship. Whatever an individual may conclude from such debates, until "science" finds 1 or more acceptable causal factors, the clinician is faced with the need to provide therapy that has some reasonable degree of objective and/or subjective impact on the effects of a disorder. The therapy should do no harm; be acceptable in terms of patients' criteria for success; be in keeping with the need to balance costs, benefits, and risks; and be consistent with the standard of care determined by the dental profession.

## CONCLUDING PRINCIPLES

Based on personal experience and a review of the literature, the author offers the following concluding principles:

1. Iatrogenic occlusal contact relations that interfere with function should be avoided.
2. Dental educators should emphasize the idea that iatrogenic occlusal interferences have significance even though such interferences may not always exceed the adaptive level of the masticatory system, including the temporomandibular joints.
3. Indications for occlusal adjustment and a method based on a procedure that promotes occlusal stability should be taught in dental schools.
4. Education in the treatment of temporomandibular disorders and bruxism should include adequate experience in determining the indications for stabilization occlusal splints, as well as their design, fabrication, adjustment, and maintenance.
5. The principles involved in the biomechanical aspects of all forms of dental treatment can be enhanced by better information transfer and a better understanding of the strengths and limitations of the evidence-based paradigm applied to clinical reality.

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