Evidence-based considerations for removable prosthodontic and dental implant occlusion: A literature review

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The dental literature is filled with discussions of dental occlusion, occlusal schemes, philosophies, and methods to correct and restore the diseased, worn, or damaged occlusion. Traditionally, these discussions have been empirical in nature and not based on scientific evidence. Due to the empirical nature of the literature, the study of occlusion has been extremely complex and troublesome to both pre- and post-doctoral students. The introduction of osseointegrated implants has further complicated the situation. Dentists may apply the principles of occlusion for the natural dentition directly to implant-supported and retained restorations. Although this may be successful, this rationale may result in overly complex or simplified treatment protocols and outcomes. There is an emerging body of scientific literature related to dental implant therapy that may be useful in formulating treatment protocols and prosthesis designs for implant-supported restorations. This review focuses on some of the "classic" removable prosthodontic literature and the currently available scientific literature involving removable prosthodontic occlusion and dental implant occlusion. The authors reviewed the English peer-reviewed literature prior to 1996 in as comprehensive manner as possible, and material after 1996 was reviewed electronically using MEDLINE.

Electronic searches of the literature were performed in MEDLINE using key words—animal studies, case series, clinical trials, cohort studies, complete denture occlusion, dental implant function, dental implant occlusion, dental implant occlusion research, dental implant functional loading, dental implants, dental occlusion, dental occlusion research, denture function, denture occlusion, dentures, implant function, implant functional loading, implant occlusion, occlusion, and removable partial denture occlusion—in various combinations to obtain potential references for review. A total of 5447 English language titles were obtained, many of which were duplicates due to multiple searches. Manual hand searching of the MEDLINE reference list was performed to identify any articles missed in the original search. (J Prosthet Dent 2005;94:555-60.)

The study of human occlusion has a broad and fascinating history in the dental literature. The literature, while extensive, is largely empirical in nature and based on theory and anecdote with little scientific basis. In spite of this potential shortcoming, most occlusion-related dental therapy may be deemed successful if it is assumed that results such as patient comfort, satisfaction, and restoration durability are acceptable outcomes.

The introduction of osseointegrated dental implants has dramatically altered the scope of prosthodontic treatment. The availability of predictable, stable anchorage for prosthetic tooth replacement has expanded treatment options but has also increased treatment planning and technical complexity. The extrapolation of occlusal concepts from natural teeth to dental implants has been an unavoidable progression simply because no alternative, scientific, or empirical theory has been put forward. In short, occlusion for dental implant-supported or retained restorations has largely been an extension of natural tooth occlusion and/or complete denture occlusion with a few twists.[1] This literature review was undertaken in an attempt to clarify current understanding of the scientific basis for removable prosthodontic occlusion, dental implant occlusion, and the occlusal concepts and methods currently advocated for both.

A review of the dental literature concerning occlusion was undertaken. Material appearing in the literature prior to 1996 was reviewed in as comprehensive manner as possible, and material after 1996 was reviewed electronically. Electronic searches of the literature were performed in MEDLINE using key words—animal studies, case series, clinical trials, cohort studies, complete denture occlusion, dental implant function, dental implant occlusion, dental implant occlusion research, dental implant functional loading, dental implants, dental occlusion, dental occlusion research, denture function, denture occlusion, dentures, implant function, implant functional loading, implant occlusion, occlusion, and removable partial denture occlusion—in various combinations to obtain potential references for review. A total

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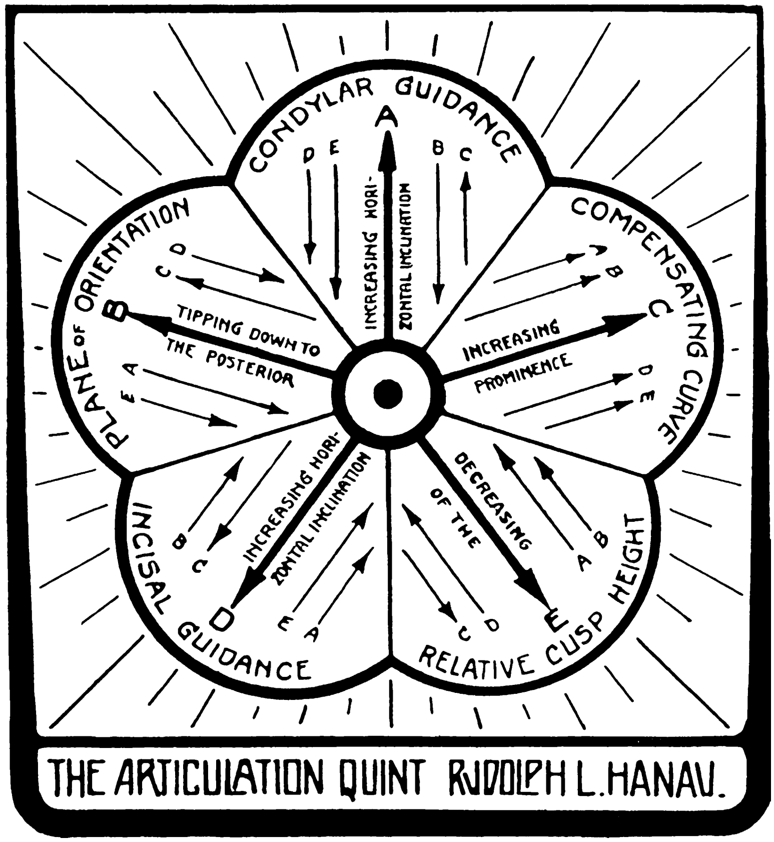

Fig. 1. Hanau's Quint. (From Hanau RL. Articulation defined, analyzed and formulated. J Am Dent Assoc 1926;13:1694-709. Copyright 1926 American Dental Association. All rights reserved. Reproduced by permission.)

of 5447 English language titles were obtained, many of which were duplicates due to multiple searches. The titles were reviewed and selected for closer examination if it appeared that the article was a study of any type. Manual hand searching of the MEDLINE reference list was performed to identify any articles missed in the original search. As the vast majority of articles reviewed were descriptive in nature, and because of the very limited number of human clinical trials found, it was decided to report findings in a descriptive manner rather than as a systematic review of the available clinical trials identified. This permitted the inclusion of in vitro and in vivo studies including nonhuman studies. Articles were included if they were thought to provide experimentally derived, objective information regarding occlusion. Completely empirical or anecdotal articles were excluded except in those instances when they were of "classic" value in describing philosophy and/or technique. Those "classic" articles are limited to the discussion of removable prosthodontic occlusion.

Removable prosthodontic occlusion

Modern theories and concepts of occlusion for implants and natural teeth have originated in complete denture construction. The Pankey-Mann concept of occlusal rehabilitation takes its origins partially from the Monson spherical theory of occlusion as it was originally conceived for complete denture construction.[2] The early gnathological approach to occlusal rehabilitation evolved from the concept of balanced articulation, which can be defined as bilateral, simultaneous, anterior and posterior occlusal contact of the teeth in centric and eccentric positions.[3] Bilateral articulation, or balance, as the occlusal scheme of choice has a long history in complete denture construction.[4]

It was believed that gliding tooth contacts in harmony with the anatomical condylar guidance and incisal guidance established to achieve esthetic and phonetic goals was most appropriate to lessen denture base instability, as well as residual ridge atrophy and possible deleterious effects of parafunctional habits. Attempts to develop a scientific basis for clinical observations and an effort to create a balanced occlusion led to geometric schemes and engineering or mathematical models (Fig. 1).[5] As a result, numerous articulators were developed to mechanically record and replicate maxillomandibular relationships, along with a variety of tooth forms to correspond to the balanced occlusal scheme theory and their prescribed formulation. The principles of balanced occlusion required the recording of the patient's condylar guidance and the establishment of the incisal guidance as predicated by esthetic and phonetic determinants, skeletal relationships, and acceptable vertical dimension of occlusion. Posterior cusp form, plane of occlusion, compensating curve and/or tooth selection became products of the end determinants. Modification in the tooth arrangement by the incorporation of a compensating curve or alteration in the plane of occlusion/orientation was further subscribed to achieve the simultaneous or bilateral occlusal tooth contact. The authors believe that the perceived confusion associated with the term ''balanced occlusion'' led to multiple interpretations in different geographical areas and at different times, making standardization nearly impossible. It should be considered that the presence of a food bolus could negate the simultaneous bilateral tooth contacts deemed so desirable[6]; however, others contended that penetration of the food bolus results in desirable tooth contacts.[7-13]

In 1972, a workshop was conducted on the subject of complete denture occlusion.[14] Eighty-nine participants met to examine the current state of knowledge of the scientific basis for complete denture occlusion. In the summary of the chapter on occlusal patterns and tooth arrangements, Kapur disassociated occlusion from denture efficiency.[15] A review of publications comparing various occlusal forms, materials, and occlusal arrangements, including studies since 1972, confirms Kapur's observation that there is no scientific evidence supporting the use of one occlusal form or arrangement over another.[16-38]

The quandary that clinicians find themselves in when searching for a scientific basis for the best technique, material, tooth design, or occlusal scheme in removable prosthodontics may be best understood by examining the literature and observing the apparent clinical success of diverse empirical methods. It is evident that there are multiple pathways to clinical success when considering occlusal concepts for removable prosthodontics. Jacob[39] noted that although the earlier observations and techniques were scientifically unproven, they remain in clinical practice today essentially unchanged as accepted parameters of care.

The effect of nonaxial load on implant function and survival

Relative to implant-supported prostheses, numerous authors have stated the need to avoid the application of nonaxial forces to dental implants whenever possible.[40-45] The reasons cited for this concern focus primarily on the absence of a periodontal ligament supporting the implants and the observation that nonaxial forces will create areas of high stress concentration instead of uniform compression along the implant to bone interface. The nonaxial loading of a mechanical device assembled with screw joints, such as dental implants, puts those components at greater risk of failure through fatigue and/or recurrent loosening of screws. The mechanical failures, primarily from clinical experience but also from in vitro and animal studies, appear to be valid.[42,46,47] Evidence is lacking, however, regarding the effect of nonaxial load (or overload) on the integrity of the osseointegrated interface between bone and implant. The shape and surface texture of cylindrical, endosseous implants make it impossible for a vertically applied load to be transmitted to the bone exclusively through compressive loading. A threaded profile, or even a rough surface on an implant, indicates that the load will be transferred to bone by compression in some areas, but also in tension and shear in other areas.[48,49] By changing the direction of load application, the location and magnitude of compressive, tensile, and shear forces will be altered, but all 3 continue to participate in the transfer of load through the implant to surrounding bone. It should be recognized that the forces of occlusion are rarely vertical. Mastication is a side-to-side action that does not lend itself to axial loading of teeth or implants in the jaws. Similarly, the damaging effects of bruxism are created through lateral friction between the occlusal surfaces of maxilla and mandible. Thus, the resultant forces are not vertical.

Two studies have specifically examined the effect of nonaxial loading on osseointegrated dental implants, one in a primate model with cyclical occlusal loading and the other in sheep with static loading.[46,50] In both studies, the authors were unable to demonstrate a negative effect on bone-to-implant anchorage after extended periods of nonaxial loading. The limited evidence available does not demonstrate that nonaxial loading is detrimental to the osseointegrated interface between the bone and implant surface.

Progressive loading and occlusal overload of dental implants

Numerous authors have written about the concept of progressive loading of dental implants.[51-53] The concept may make intuitive sense when considering the role of Wolff's Law in bone remodeling where bone mass will increase in response to stress.[54] Gradually increasing the load applied to implants in poor quality bone, thereby allowing that bone to increase in mass and density through gradually increasing function, seems logical. The evidence available, however, does not support the need for progressive loading. Several studies have examined the effects of placing restorations on previously unloaded implants in heavier than normal occlusion.[55-58] In these animal studies, restorations were placed on implants that had previously not been functionally loaded. In all situations, the occlusal overload generated at the time of abutment connection or initial functional loading was tolerated by the implants without evidence of deleterious effect. Loading previously unloaded implants by immediately subjecting the implant to extreme overload without negative effect does not support the principle of progressive loading. In a study by Isidor,[58] fixed partial dentures secured to dental implants in "supra-occlusal contact" were followed from 9 to 15 months. When the natural teeth erupted back into occlusion, the prostheses were replaced (in some situations replaced twice) with prostheses that further increased the occlusal contact on the implant-supported restorations. This also generated a "lateral displacement" to the loading pattern of the implants. Unfortunately, the author failed to describe in a quantitative manner how much of a supra-occlusal contact was created or the magnitude of the lateral displacement. In this study, the original hypothesis of creating occlusal overload to cause implant failure was not successful, and only by further increasing the magnitude and changing the direction of the overload was an effect demonstrated. Although the second (or third) increase in occlusal overload on the implants did ultimately result in loss of some implants, the extent of additional increase in vertical dimension of occlusion created by the secondary increase in occlusal height does not necessarily reflect any comparable normal clinical situation and should be interpreted with caution. This is particularly true in light of the fact that the results of this study are not consistent with those published by others[55-57,59,60] in which excessive occlusal load did not create adverse responses with implants.

It may also be argued that the concept of progressive loading is, in fact, unlikely to be attained. In 1985, Skalak[61] hypothesized that the selection of occlusal material would affect the survival of the underlying implant and its osseointegrated interface. Although the hypothesis was easily understood, it did not reflect normal masticatory function but, rather, was dependent on the assumption that occlusal movements involved impact type contacts between the arches. Several studies have examined the effect of occlusal material on load transfer to dental implants.[62-64] The findings indicate that occlusal material does not affect the force transmitted through the prosthesis/implant to the surrounding bone, nor does prosthesis material affect the tissues adjacent to the implant(s). Similarly, there is no published evidence that modifications to the dimensions and occlusal contacts/anatomy of provisional restorations reduce loading of implant prostheses. The presence of parafunctional habits and mastication of food can generate high forces on implant-supported restorations, potentially negating prosthesis design aspects intended to reduce functional loads during the progressive loading period.[65,66] The previously cited evidence does not support the contention that the osseointegrated interface may be damaged by full occlusal loading at the time the implant is brought into function.[55-60] When coupled with the likelihood that performing a graduated loading protocol may be unlikely to be realized, the value of progressive loading as a treatment concept must be questioned. Similarly, the literature available at this time concerning occlusal overload in animal models does not reveal a direct cause-effect relationship between occlusal loading and implant failure (exclusive of implant fracture).[55-60]

Proprioception and dental implants

The role of proprioceptive nerve endings in the periodontal ligament has been documented.[67] Loss of periodontal ligament proprioception that occurs when the natural teeth are lost has been described as an important consideration in the replacement of natural teeth with dental implants. Studies that have examined tactile sensibility have demonstrated extreme differences between natural teeth and implants (average 3.8-g pressure for natural teeth tested horizontally vs. 580-g horizontal force for implants in the anterior mandible).[68-70] In spite of these findings, patients with extensive implant-supported restorations seem, clinically, to function well without the benefit of periodontal proprioceptive nerve endings. The presence of proprioceptive nerve endings in periosteum, muscles of mastication, oral mucosa, and the temporomandibular joints may somewhat compensate for those lost from the missing periodontal ligament. There is, in fact, extensive discussion on the topic of "osseoperception" in the literature,[71-74] including a textbook on the subject.[75]

SUMMARY

Little scientific evidence supports a direct cause-effect relationship between occlusal factors and deleterious biological outcomes for osseointegrated implants. To the contrary, the limited evidence available at this time supports the position that there is no direct cause-effect relationship between occlusion and disease processes. Evidence supporting specific occlusal theories for removable prostheses is primarily based on expert opinion and in vitro studies. Evidence supporting specific occlusal theories for implant-supported prostheses is based on expert opinion, in vitro studies, and animal studies.

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Noteworthy Abstracts of the Current Literature

Clinical case reports of injectable tissue-engineered bone for alveolar augmentation with simultaneous implant placement
Ueda M, Yamada Y, Ozawa R, Okazaki Y. *Int J Periodontics Restorative Dent* 2005;25:129-37.

This clinical study was undertaken to evaluate the use of tissue-engineered bone, mesenchymal stem cells, platelet-rich plasma, and beta-tricalcium phosphate as grafting materials for maxillary sinus floor augmentation or onlay plasty with simultaneous implant placement in six patients with 3- to 5-mm alveolar crestal bone height. All 20 implants were clinically stable at second-stage surgery and 12 months postloading. A mean increase in mineralized tissue height of 7.3 ± 4.6 mm was evident when comparing the pre- and postsurgical radiographs. Injectable tissue-engineered bone provided stable and predictable results in terms of implant success.—*Reprinted with permission of Quintessence Publishing.*