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# Occlusal Schemes for Implant Restorations: Best Evidence Consensus Statement

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**Keywords**
Dental implants; occlusal schemes; occlusion; restoration.

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Accepted December 17, 2020

doi: 10.1111/jopr.13319

## Abstract

**Purpose:** Numerous studies have focused on the various complications with implant-retained restorations and a common thread in these publications is the potential for occlusal overload. The purpose of this Best Evidence Consensus Statement on implant occlusal schemes was to review the literature to determine the level of scientific evidence upon which the articles are based.
**Materials and Methods:** Limiting the search to Clinical trials, Randomized Controlled Trials, Systematic Reviews, Meta-analyses, the key words: dental implants, occlusion, found no citations. Expanding the search to Journal articles found 1,483 results, 20 of which pertained to the question. Doing a similar search including Journal Articles, the key words: dental implants and occlusal scheme found 47 citations, 17 of which were pertinent to the question.
**Results:** After eliminating duplicates and non-relevant articles, 15 were included in the review. Nineteen additional articles were culled by going through the reference lists in the aforementioned articles.
**Conclusions:** There is a lack of scientific evidence regarding the occlusal scheme utilized with implant restorations that will minimize or eliminate complications. In light of this lack of scientific evidence, the style of occlusion a practitioner utilizes with tooth or mucosal supported prostheses may be used with implant-supported restorations until compelling evidence dictates otherwise.

There are numerous theories relative to the occlusal scheme used in a complete denture, a tooth supported removable partial denture, and tooth supported restoration. An implant replaces a tooth, but biologically is not a tooth, which poses the question as to whether the existing tooth paradigms are transferrable to the implant.

The development of osseointegrated implants caused a number of new concepts to emerge in dentistry. One such concept involved the occlusal relationships present on implants due to the lack of a periodontal ligament and its proprioceptive capabilities.[1] It was "speculated that osseointegrated implants without periodontal receptors would be more susceptible to occlusal overloading because the load-sharing ability, adaptation to occlusal force, and mechanoperception are significantly reduced in dental implants."[2] These concerns about overloading had roots in the early years of using osseointegrated implants.

In 1983 Skalak[3] discussed biomechanical considerations with osseointegrated prostheses. He stated that since implants having a direct contact with bone, they "will transmit any stress waves or shocks applied to the fixtures." The recommendation was made "to use a shock-absorbing material such as acrylic resin in the form of acrylic resin artificial teeth in the fixed partial denture" so as to produce a stiff, strong substructure with "adequate shock protection on its outer surface."

This shock protection concept caused concerns amongst clinicians regarding the potential of overloading the bone surrounding implants and was part of early implant prosthesis design considerations.

In 1997, Rangert et al[4] discussed occlusal load factors associated with implants in posterior partially edentulous arches. The article stated that mastication and parafunctional activities affect the load applied to implants and when these activities are greater than normal, the implant will be subjected to a higher load. The authors went on to discuss the importance of minimizing or completely removing the "risk that the stiffer implants will take a disproportionately higher percentage of the total load" than teeth. The authors indicated occlusal contact on implant prostheses should be adjusted for compatibility with the mobility of adjacent teeth by means of "centered contacts, flattened cusps, and reduction of the size of the occlusal table." When discussing the replacement of single molars, it

was stated, "ensuring light centric occlusion in these situations may compensate for the potential overload."

The above concerns about occlusal overload led to concepts of occlusion for implant prostheses as well as studies involving force measurements on implants. Using strain gauges on the implant abutments of patients, one such force measurement study[5] was published in 2002 with the purpose of testing the hypothesis that shock generation on implant-supported prostheses would produce higher implant loads if the veneering material were porcelain rather than acrylic resin. However, regardless of whether the veneering material was porcelain or acrylic resin, the study failed to demonstrate different forces being generated to the implants. They went on to say, "Therefore, from a practical point of view, the choice of occlusal material apparently has no bearing per se on force generation to the implants."

Other force measurement studies examined differences in the perception of occlusal contact between implants and natural teeth. It was 1993 when Jacobs and van Steenberghe[6] published the results of their study comparing the passive threshold level for perception of occlusal contact of implant-supported prostheses and teeth. They studied 31 implant patients that were divided into complete arch prostheses (10 subjects), partial arch fixed prostheses (6 subjects), single crowns (5 subjects), and overdentures (10 subjects) with a control group of 10 patients with natural teeth. Forces were generated by a solenoid-driven stimulating device placed in contact with the implants or tooth prior to the rise in force application. The threshold level for tactile perception of force was 50 times higher with implants compared with natural teeth. The authors proposed that the perception of contact with implants "could be related to rapid bone deformation that triggers periosteal mechanoreceptors, which remained less sensitive than the periodontal ligament receptors."

In 1995, Mericske-Stern et al [7] measured the oral tactile sensibility (threshold of minimal pressure perception) of 21 partially dentate implant patients using miniature force transducers placed between antagonistic implant to tooth pairs in a test group and a control group of 20 subjects. They also recorded maximal occlusal force and determined that force was significantly lower in patients with implants than fully dentate subjects. The implants had been in function from 1.5 to 6 years. The threshold for minimal pressure perceived by implants was significantly higher in both vertical and horizontal directions than recorded for natural teeth. In addition to maximal force and minimal pressure, the ability to detect thin steel-foil strips was examined with the results showing only a minimal difference between the implant group and dentate group.

Also, in 1996, Hämmerle et al[8] determined the tactile perception of implants and teeth by attaching a strain gauge to an amalgam plugger and using the plugger to apply a continuously increasing force until the first sensation of touch was indicated by the 21 subjects in the study. The implants had been in place for a minimum of one year. The mean threshold value for implants was 8.75 times higher than for teeth.

A 2007 randomized split-mouth study of 62 subjects by Enkling et al[9] examined tactile sensibility of both anterior and posterior single implants with opposing natural teeth. The implants had been restored between 1995 and 2001. They determined the tactile sensibility of implants opposing natural teeth was similar to natural teeth opposing each other. Another split-mouth double blinded trial by Kazemi et al[10] was performed on 25 subjects with single implants that had been in function for at least 6 months. The authors found a slight but significant difference between implants and natural teeth with implants having slightly less perception of occlusal contact.

A 2014 systematic review and meta-analysis[11] of sensation differences between implants and teeth examined studies of "tactile sensibility (minimum load that can be perceived)" and "thickness discrimination (minimum thickness that can be perceived)." The authors determined the threshold level for tactile sensibility of implants was 4 to 20 times that of natural teeth and the thickness discrimination threshold on implants was about 1.2 to 2.3 times higher than natural teeth, a difference that was determined to be significant.

Another systematic review[12] was published in 2016 with the purpose of evaluating the available literature regarding osseoperception, a term coined by Professor P-I Branemark.[13] This review[12] concluded that "it becomes apparent that with the loss of teeth and periodontal structure, other peripheral receptors dominate and transmit the afferent projections to the sensorimotor cortex and compensate by providing stimulations in the area of bone-anchored implant restorations." In support of the ability of other receptors to compensate for loss of teeth and periodontal structures, one study[14] reported a noticeable improvement in tactile function (termed osseoperception) on implants after 3 months of healing. However, since the study tested edentulous subjects, there was no simultaneous testing of dentate subjects to determine if the improvement in tactile function matched that of natural teeth during the 3-month time period of the study.

Multiple literature reviews have discussed the differences in perception between implants and teeth and the clinical implications of this difference. In 2005, Taylor et al[15] published a review of the literature related to evidence-based considerations for dental implant occlusion. They stated that in spite of tactile sensibility differences between implants and teeth, "patients with extensive implant-supported restorations seem, clinically, to function well without the benefit of periodontal proprioceptive nerve endings." They proposed that nerve endings in the periosteum, muscles of mastication, oral mucosa, and temporomandibular joints might compensate to some degree for the receptors lost from the missing periodontal ligament. A 2006 publication by Abarca et al[16] reviewed the neurophysiological aspects of osseointegrated implants and determined oral functions do not appear to be impaired with implants and therefore there must be some peripheral feedback to the sensory cortex. The feedback may be activation of receptors in the peri-implant environment (bone and periosteum), a process called osseoperception. Similarly, Carlsson[17] cited other references that indicated the lost perception from the periodontal ligament appears to be taken over by other mechanisms, apparently indicated his agreement with the change in perception.

It was a 2006 publication by Jacobs and van Steenberghe[18] that proposed clinical applications based on the tactile function of oral implants and the physiologic integration of implants and associated prostheses in the body. These clinical implications were based on their observations that patients with

oral implants developed a special sensory perception skill some time following implant placement. They indicated that during the actual rehabilitation process with implant-supported prostheses, dentists should not rely on the patient's perception of occlusion and particularly with immediate loading protocols, presumably because the perception of occlusal contact is not as discriminating as natural teeth during the early stages of treatment. However, the gradual increase in tactile perception that occurs over time resulted in the authors stating, "implant-mediated sensory-motor interactions may offer potentials for physiological integration of the implant in the human body," allowing restoration of the peripheral feedback pathways that permit more natural functioning.

The above studies and reviews indicate there is a difference in tactile perception between implants and teeth, but the perception on implants appears to improve over time. However, it is not clear whether the level of implant perception reaches the level of natural teeth over time. It is also apparent from the above literature that there were early concerns about the perceptual difference between implants and teeth and the impact this difference would have on the peri-implant bone and prostheses. This perceptual difference and the related concerns led to concepts of occlusion on implants, some of which persist today, even though there are indications that sensory perception on implants improves over time. In addition, the question as to whether the differences are clinically relevant has not been answered.

Numerous studies have been performed that focused on the various complications with implant-retained restorations as well as biological and mechanical failures.[19–25] A common thread through all of the papers is the potential for occlusal overload, as the problems do not exist until the restorations come into occlusion. Therefore, the published concepts of implant occlusal schemes need to be reviewed to determine the level of scientific evidence upon which they are based.

## Focus question: Is there a preferred occlusal scheme for an implant retained restoration?

### Search strategy

Limiting the search to Clinical trials, Randomized Controlled Trials (RCT), Systematic Reviews (SR), and Meta-analyses (MA), the key words: dental implants, occlusion, found no citations. Expanding the search to Journal Articles found 1,483 results, 20 of which pertained to the question. Performing a similar search including Journal Articles, the key words: dental implants and occlusal scheme found 47 citations, 17 of which were pertinent to the question. After eliminating duplicates and non-relevant articles, 15 were included in the review. Nineteen additional articles were culled by going through the reference lists in the aforementioned articles.

Lindquist et al[26] in a 12- to 15-year prospective study of 47 edentulous patients concluded that "Smoking and poor oral hygiene had significant influence on bone loss, while occlusal loading factors such as maximal bite force, tooth clenching and length of cantilevers were of minor importance." Bite force measurements were made with strain gauge transducers. Only one of the 273 implants failed 6 years after placement of the prosthesis. Marginal bone loss on the cohort was small. Due to the extremely low prevalence of bone loss or implant failure, it would be hard to determine any associations between occlusion and implant complications.

Hobrik et al[27] completed a study on 6 participants with implant stabilized mandibular prostheses that were opposed by a dentate maxillary arch. Using strain gauges, they measured the forces transmitted with either a balanced or a non-balanced occlusion. They reported no difference in mean peak masticatory force or load rates between the 2 occlusal schemes when chewing bread, but did report lower forces with balanced occlusion when chewing nuts and carrots. They did note that the results "do suggest that a balanced occlusal scheme may be more appropriate."

Wennerberg and Jemt[28] in their 5-year follow-up study of 133 patients felt that bending moments, which could be attributable to implant fracture and prosthesis issues, could be minimized by developing centrally located occlusal contacts.

Esposito et al[29] performed a histopathologic evaluation of 10 implants that failed after prosthesis placement and reported that occlusal overload, and in 2 cases infection, "might have been implicated in the failure process."

Morneburg and Pröschel[30] performed a study on 10 fully dentate patients who had a 3 unit fixed partial denture supported by 2 implants. They tested 3 designs, one with steep cusps, one with flat cusps, and one with steep cusps with a narrowed occlusal surface using strain gauges that were placed into the walls of the 2 abutments. They reported lower bending moments for the test foods (gummy bears and bread) with the narrowed occlusal table.

Wiskott et al[31] reported on 7 patients with failing implants, but were unable to definitively determine causation in all of the patients. van Kampen et al[32] in a cross-over study of the effect of maximum bite force on marginal bone loss in mandibular overdenture treatment found no relationship. Participants were randomized to one of 3 designs, ball, magnet or bar-clip attachment, which was changed every 3 months. Given that marginal bone loss could be time dependent, the cross-over design and the 9-month time limit seems questionable.

Blanes et al[32] in a 10-year prospective study of 192 implants in 83 partially edentulous patients concluded that implants with a crown to implant (C/I) ratio of 2 to 3 can be successfully utilized in the posterior areas. Interestingly, they found significantly greater marginal bone loss in participants with low C/I ratios. Only 4.2% of the population had C/I ratios greater than 3% and 81.3% of those were splinted, which, as stated by the authors, could have minimized any negative effect. In addition, there were numerous potentially confounding variables.

Tawil[33] in a case report of a patient wearing an ill-fitting, unstable overdenture showed that the peri-implant defects, both soft tissue and boney, were reversed by the placement of a properly fitting prosthesis. The poorly fitting overdenture, malocclusion, history of "clenching" and questionable home care are all contributing factors that, while not ruling out, temper the authors statement that the peri-implant bone loss was caused by an occlusal overload.

Jofre´ et al[34] in an RCT to evaluate the effect of the maximum biting force on marginal bone loss in 55 patients with mandibular overdentures found no relationship. Participants had either a

ball or bar retention system on mini implant retained mandibular overdentures. All prostheses were fabricated with a bilaterally balanced occlusal scheme utilizing anatomic teeth.

Vigolo and Zaccaria[35] in a 5-year prospective study to compare the marginal bone level changes around adjacent splinted implants and non-splinted implants in the maxilla, found no difference between the cohorts. They used a split mouth design with the patient's left side restored with splinted cemented restorations, and the right side restored with non-splinted cemented restorations. All patients had a canine protected occlusion with no contacts in lateral or protrusive movements. Papaspyridakos[36] presented a case report of a successful 6-year follow-up of a maxillary and mandibular full arch restoration utilizing a mutually protected occlusion with anterior guidance.

Graves et al[37] in a study of 44 patients with 74 single unit crowns in place for one year reported on the presence or absence of occlusal contacts in maximum intercuspation during working, balancing, and protrusive movements. The type of occlusal contact was evaluated using silk ribbon and they reported that 29 implant crowns had "heavy" contact, 40 "light: contact and 5 no contact. Working side contacts were present in 20 implants and 7 had contact in protrusive excursion. They also performed a computerized analysis of the patient's occlusion using a commercially available device (T-Scan, Tekscan). Despite the fact that "only one statistically significant association was found between protrusive contact and radiographic bone loss," they concluded, "the occlusal status of single unit dental implants is not associated with the soft and hard tissue conditions around non-failing single implants."

Luo et al[38] in a prospective 3-year study on the occlusal variations of single posterior implant-supported full coverage restorations found that the occlusal force and occlusal contact time increased over time. Initially the bite force, measured with a T-Scan III system, was lower than that of the natural tooth controls. This phenomenon was not explained. Contacts were verified using 30-micron articulating paper. The position of the contacts in the author's figure 1 are not in the classically accepted positions. Of the 37 original prosthesis at the onset of the project, only 22 were left to analyze at the 3-year interval, Five participants (6 prostheses) were lost to follow-up, 6 participants (6 prostheses) had a fracture of the veneering ceramic and one implant prosthesis was lost due of screw loosening.

## Reviews

Kim et al[39] in a review of the rationale and clinical guidelines for implant occlusion concluded that due to the fact that the current evidence was limited to laboratory, animal, and retrospective studies, there is no evidence to support an implant-specific occlusion scheme. Taylor et al[15] in a literature review of occlusion for removable prosthodontic and dental implants found that the evidence for implants was built on expert opinion, in vitro and animal studies. Klineberg et al[40] in an SR of occlusal designs in tooth and implant-borne reconstructions and complete dentures, concluded that for implants, there was little scientific evidence relating to occlusal design, to indicate that a particular design was superior.

Gross[41] in a review of occlusion in implant dentistry concluded that since the studies involved did not isolate some key occlusal details, "until further research is available, clinical guidelines need to be based on biomechanical principles and the state-of-the-art of current therapeutic paradigms." Carlsson[17] in his review of dental occlusal concepts and their application to implant prosthodontics found no controlled studies on the optimal features of a harmonious restored occlusion and concluded that there was "no evidence to recommend a specific occlusal design."

Naert et al[42] carried out a review of the literature related to occlusal overload and bone/implant loss. They concluded, "the effect of implant overload on bone/implant loss in clinically well-integrated implants is poorly reported and provides little unbiased evidence to support a cause-and-effect relationship." They had a structured PICO, where P was "patients with stable implants." Despite that, most of what they reported on was based on animal studies. What is hard to accept is the rejection of clinical studies with less than 10 participants, but the acceptance of animal studies with 2 or 3 participants. Four "relevant" human clinical studies[29,31,33,43] were excluded due to an N less than 10. The following studies[26,32,34,35,44] were eliminated due to "lack of sample-size calculations" despite sizable Ns. Blanes et al[32] was eliminated due to "bias."

Chang et al[45] performed a review on the impact of occlusal load on osseo-integrated implants. They concluded that due to conflicting animal studies and the low level of evidence "the knowledge regarding the response of the peri-implant bone when the dental implant is excessively loaded is limited." Of the 14 articles included, 3 were on Labrador dogs, 4 on Beagle dogs, 3 on monkeys and one on rabbits, all with small Ns. Three publications were related to human subjects that included two case reports and one case series which reported on 1.472 molar implants over a 15-year period, with 8 of the 11 failed mandibular molar implants occurring within 3 years of function and reported to be due to the presence of detectable parafunctional movement.[46]

Ma and Felton[23] in their SR of maintenance and complications of screw and cement retained implant restorations concluded that an optimal occlusion was crucial for implant retained prostheses. Koyano and Esaki[47] performed a narrative review to look at the influence of implant occlusion on the prevalence of treatment complications and concluded that there was "insufficient evidence to establish clinical guidelines for implant occlusion." Sadowsky[48] completed a narrative review and found that while there was abundant literature on cantilevers, crown to implant ratios, prosthesis cantilevers, splinting and bruxism there was no evidence relative to the occlusal scheme used.

Sheridan et al[49] in their review found that implant occlusion recommendations were lacking, but still felt that occlusion should be carefully addressed. Their recommendations: mutually protected occlusion with anterior guidance, evenly distributed contacts, wide freedom in centric relation, narrowing the occlusal table, decreasing cuspal inclines, reducing cantilevers, increasing the number of implants, increasing contact points, and monitoring for parafunctional habits, are factors typically included in many occlusion courses for tooth-supported restorations.

## Discussion

There is a plethora of articles on implant survival and complications. The problem is few, if any, mention the occlusal scheme utilized in the restoration, as noted by Sadowsky.[48] There are reports on cantilever length, C/I ratios, immediate or delayed loading, splinting vs non-splinting, alveolar bone loss, implant fracture, crown fracture, etc. It is hard to understand why authors do not report the occlusal scheme utilized. Another understandably unreported data set is iatrogenesis. Using healthy implants that have resisted overload does not help understand why unhealthy implants are failing. An interesting follow up would be to analyze the occlusal scheme in failing implants, but even that does not necessarily prove causation. In a hypothetical scenario, where one believes that mediotrusive contacts can create harm, if a contact was now visible on a failing implant it is impossible to know if it was there prior to the implant failing or now present due to mobility of the implant. Also, if there is a restorative fracture there is no way to determine what caused the problem. Implant dentistry has proven to be a highly successful treatment modality. Occlusion is an important component, as there is significant evidence of implant fracture and prosthetic complications. When we look at those failures retrospectively, there is no definitive means of knowing the design of the occlusal scheme utilized, or how well it was performed.

Multiple publications cited above have used the term "osseoperception." This term has become widely associated with the lack of perception of occlusal contact on implant restorations with other anatomic entities assuming the role of occlusal contact perception As stated above, one of the reviews[12] concluded that "it becomes apparent that with the loss of teeth and periodontal structure, other peripheral receptors dominate and transmit the afferent projections to the sensorimotor cortex and compensate by providing stimulations in the area of bone-anchored implant restorations." It is interesting to note that from a neuroanatomy/neuroscience aspect, the perception of occlusal contact likely improves overtime because of adaptation and plasticity in the somatosensory cortex. The cortex is reorganized like when a limb is amputated. From an anatomical perspective, when a tooth is extracted "high threshold" receptors that constitute the afferent limb of the jaw opening reflex are lost. These are not proprioceptors and are designed to protect the teeth from biting into hard substances that may damage the teeth. Therefore, with implants, the threshold for activating the jaw opening reflex becomes higher but the ability to sense jaw position and interdental distance may not be significantly altered.

### Evidence-based conclusions

Most of the studies identified by the search strategy reported on bone loss or implant loss with no definitive relationship established between these complications and occlusion, either because the occlusal scheme was not described or the study was unable to determine if a relationship existed. However, a small number of studies suggested a potential relationship exists between implant failure and such factors as bending moments, occlusal overload, and occlusal table dimension but without strong evidential support. The literature review either found little or no evidence to support a specific occlusal scheme with implants or determined the implant occlusion guidelines were based on expert opinion. Therefore, it seems appropriate to conclude there is a lack of scientific evidence supporting one occlusal scheme over another when restoring implants. This conclusion is supported by a critical assessment of the included publications as noted below.

As such, we can infer that occlusion is a factor but there is no significant evidence that one type of occlusal scheme is preferable to another.

The lack of a periodontal ligament around implants led to concerns they would be more susceptible to overloading due to a lack of tactile perception of occlusal contact.

## Consensus conclusions

There is a lack of scientific evidence regarding the occlusal scheme utilized with implant restorations that will minimize or eliminate complications. In light of this lack of scientific evidence, the style of occlusion a practitioner utilizes with tooth or mucosal supported prostheses may be the same used with implant-supported restorations until compelling evidence dictates otherwise.

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