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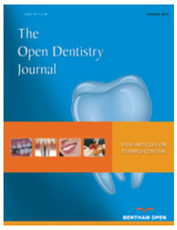

REVIEW ARTICLE

The Role of Occlusion in the Dental Implant and Peri-implant Condition: A Review

Carmen V. Graves[1], Steve K. Harrel[1,*], Jeffrey A. Rossmann[1], David Kerns[1], Jorge A. Gonzalez[2], Elias D. Kontogiorgos[3], Ibtisam Al-Hashimi[1] and Celeste Abraham[1]

[1]*Periodontics Department, Texas A&M Baylor College of Dentistry, Dallas, Texas, USA*
[2]*Center of Maxillofacial Prosthesis, Texas A&M Baylor College of Dentistry, Dallas, Texas, USA*
[3]*Restorative Science and Implant Dentistry, Texas A&M Baylor College of Dentistry, Dallas, Texas, USA*

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Abstract: Dental implants have become a widely used dental treatment approach. It is important to identify factors that can be detrimental to dental implants and the peri-implant complex. There is controversy regarding whether occlusion plays a role in the implant and peri-implant condition. The present study aims to review the scientific literature regarding this topic. Animal and human studies, and previous reviews on the topic are included and presented. There is a wide heterogeneity among study designs. Several articles demonstrated that occlusion and occlusion overload could detrimentally affect the peri-implant condition, while other articles did not support these results. More studies are needed to help understand the mechanisms by which occlusion might play a role in the peri-implant condition.

Keywords: Dental implants, Occlusion, Overload, Occlusal discrepancies, Peri-implant.

INTRODUCTION

Dental implants have become a frequent treatment approach and they have revolutionized dentistry in the last few decades [1]. They have high survival and success rates, but they are not immune to complications [2]. It is important to identify factors that can play a role in the initiation and the progression of peri-implant condition deterioration.

Dental occlusion plays a central role in clinical dentistry and is essential for normal physiologic function [3]. There is existing literature that supports the role of occlusion in periodontal disease. Harrel and Nunn [4] found that teeth that presented with initial occlusal discrepancies had deeper initial probing depths, worse prognosis and worse mobility than those teeth without initial occlusal discrepancies. However, whether occlusion plays a role in the dental implant and peri-implant condition is still in question.

As is the case with the studies of the effect of occlusion on the progression of periodontal diseases around natural teeth, there are no controlled clinical trials or prospective cohort controlled studies that evaluate the effect of occlusion on implants in humans. Again, as is the case with evaluating occlusion on natural teeth, any prospective trial of untreated occlusal discrepancies in humans would be unethical and counter to the Helsinki accords. Thus, all human studies on the effect of occlusion on implants are retrospective and subject to significant examiner biases. While animal studies can be more closely controlled, they do not reflect the effects of occlusion on implants in humans. Thus, the evidence in this topic is broad and heterogeneous. All presented human studies are considered to be at the lower scale of relevance due to the lack of controls and the potential for bias. The animal studies are of relative low impact due to the test subjects. However, because of the small body of available literature and the complete lack of controlled clinical

* Address correspondence to this author at the Periodontics Department, Texas A&M Baylor College of Dentistry, Dallas, Texas, USA; Tel: (214) 352-5304; E-mail: skharrel@gmail.com

trials in humans, the following literature review of the available literature is presented. Both animal and human studies are presented, as well as previous reviews on the topic.

OCCLUSION AND DENTAL IMPLANTS IN ANIMAL STUDIES

Isidor [5] reported that excessive occlusal loading in monkeys could cause loss of osseointegration. In this study, four Macaca Fascicularis monkeys received extractions of the first molars, premolars and incisors in the mandible. Eight months later, 5 Astra implants were placed. Two were placed in both premolar regions, and one was placed in the incisor region. In each area, one of the implants was machined, whereas the other one had a TiO_2-blasted surface. Six months after the surgical placement, the implants were uncovered and received abutments. One site received splinted restorations casted in silver-palladium alloy with supraocclusal contacts, which were high in occlusion that caused the lateral displacement of the mandible during occlusion. To ensure that supraocclusal contacts remains presented and to rule out wearing down of the prosthesis, the splinted restorations were replaced one or two times during the course of the study. The implants that received supraocclusal contacts were under a comprehensive plaque control, which included tooth brushing once a week, and subgingival cleaning once a month. In contrast, the contralateral site did not receive any prosthesis so no supraocclusal contacts were present, but were subjected to plaque accumulation by placing cotton cords around the implants. The clinical and radiographic evaluation was undertaken when the prosthesis were inserted and at 3, 6, 9, 12 and 18 months later. Their results showed that 5 out of the eight overloaded implants presented with mobility and distinct radiolucency around the extent of the implant with "none or only a small loss of height of marginal bone". The loss of integration and mobility was observed at 4.5 months and 15.5 months after loading. On the other hand, none of the implants that received plaque accumulation were mobile neither lost integration, but they presented with "increasing loss of radiographic bone height". Based on these observations, Isidor concluded that the overloading of an implant could be the main factor for the loss of osseointegration around a previously integrated dental implant, whereas plaque accumulation can be the main factor for progressive marginal bone loss height.

Miyata *et al.* studied the influence of controlled occlusal overload on peri-implant tissue in the monkey. He published a series of articles in this topic.

1. Part I [6]: This study used 5 Macaca Fascicularis monkeys in which overload was applied without inflammation *i.e.* with a good oral hygiene regimen that consisted of oral hygiene once a week under general anesthesia. Two IMZ implants that measured 2.8 mm x 8mm were placed in each monkey. After 3 months of healing, the implants received superstructures that were excessive in height by 100 µm and produced a traumatic occlusal force from the lingual to the buccal side. This traumatic occlusal force was applied from 1 to 4 weeks at which moment the animals were immediately sacrificed. The monkeys were assigned in different models in the following manner: A) control (no occlusal force), B) One week occlusal force loading, C) Two weeks occlusal force loading D) Three weeks occlusal force loading E) Four weeks occlusal loading. Their results showed that all implants were osseointegrated after the initial period of healing, and remained osseointegrated after receiving excessive occlusal force for 1 to 4 weeks without gross bone loss. None of the specimens showed inflammatory symptoms *i.e.*, redness or swelling, looseness of the implant or breakage of the superstructure. It is worth noting that this study was conducted under good oral hygiene conditions.
2. Part 2 [7]: This was a similar study as previously described but this study included experimental inflammation that was induced by using ligature wires after the second stage surgery. Their results showed that as the duration of the overload increased, the bone resorption also increased notably. This suggests that bone breakdown around the implants was accelerated when traumatic occlusion was added to inflammation around the implants.
3. Part 3 [8]: The aim of this study was to investigate different levels of traumatic occlusal force under an inflammation-free state. The prostheses were fabricated excessively high by 100 µm, 180 µm and 250 µm. The results indicated that bone resorption around the implant tended to increase with 180 µm or more excessive height. Moreover, the 180 µm and 250 µm excess height models showed a tendency to develop greater probing depths when compared to the pre-occlusal loading conditions. Histologically, the control model did not show any notable bone changes. In the 180 µm sites slight bone resorption was observed to almost one half of the implant. In the final model with 250 µm of excess height, the vertical bone resorption reached the apex of the implant, and epithelial down growth was observed in both the buccal and lingual aspects. This suggests that the threshold of excessive height of the prosthesis at which peri-implant bone breakdown starts to occur is around 180 µm. So, bone resorption around dental implants can result due to excessive occlusal trauma even when there

is no inflammatory status around the peri-implant tissue.

4. Part 4 [9]: This study intended to observe the effect of removing the occlusal trauma and introducing plaque control in monkeys. After 3 months of healing, the implants received prosthesis with excessive occlusal height of 250 μm and three models were created:
   1. Only brushing, without excessive load (for total of 8 weeks) - Model N.
   2. Only excessive load, with no brushing (for total of 8 weeks) - Model P.
   3. Excessive load with no brushing (for 4 weeks), and then no excessive load with brushing - Model E.

   Their results showed that in the model N (brushing, without excessive load) bone and implant contact was confirmed microscopically. Model P (excessive load, with no brushing) presented with bone resorption reaching the apical third of the implant with massive inflammatory cell infiltration. Model E showed bone resorption approaching the apical third indicating no difference with the model P and some evidence of inflammatory cell infiltrate. The authors concluded that both occlusion and inflammation need to be controlled around implants, and once peri-implantitis (bone loss) has progressed, the removal of the excessive overload and inflammations may not be sufficient to promote healing.

"Overload", mimicked by supra-occlusal contacts acting on an uninflamed peri-implant environment, did not negatively affect osseointegration and even led to a building up tissue response [10]. In this canine study, supra-occlusal contacts were defined as excessive height of the implant super-structure that led to an increase of the vertical dimension of around 3-4mm. The histological results of Kozlovsky *et al.* showed that supra-occlusal loading significantly increased the percentage of bone-to-implant contact. In contrast, supra-occlusal contacts produced in inflammatory conditions significantly increased the plaque-induced bone resorption around dental implants [11].

A study done by Kan [12] used bone strain analysis of dental implants following occlusal overload *in-vitro*. The study done by Kan analyzed the bone strain around implants following occlusal loading The objective of this study was to list peri-implant bone strain patterns under quantified occlusal load on metal crowns in supra-occlusal contacts and to evaluate the biological response of bone by comparison with the critical strain set points defined by Frost's theory. In this study, two greyhound dogs underwent unilateral mandibular extractions of the third premolar and molar teeth. Six weeks after, four 4.1x8mm SLA titanium implants (Straumann) were placed. Healing caps were used and a strict daily brushing protocol implemented. After 12 weeks, non-splinted, screw-retained crowns that increased the occlusal vertical dimension by 3 mm were fabricated and placed. Baseline radiographic and clinical measures were obtained. The occlusal design was oblique to ensure for functional loading in both axial and non-axial manners. An *in vivo* bite force detection device was utilized to quantify the *in vivo* occlusal load as the dogs functioned. "To encourage optimal bite force, resilient pig skin was used to cover the device during testing", a total of 75 biting cycles were recorded and averaged. After 8 weeks of function, the peri-implant tissue was assessed. Then the animals were sacrificed and the skulls and mandibles carefully disarticulated and mounted onto a loading machine. Miniature rosette strain gauges were used to record the bone strain magnitudes and directions. Each strain gauge was individually connected to a circuit. Each dog received strain gauges which were bonded on the buccal bone lying the apex of each of the four implants, the inferior border of the mandible, between the mental foramina and the lingual bone overlying the apex of the most distal implant. All implants were successfully integrated and after 8 weeks of functioning, they all showed no signs of redness, swelling, bleeding on probing, suppuration nor mobility. Radiographically, the assessment revealed minimal crestal bone change (<0.3mm), though two implants showed slightly greater bone loss (<1mm). The average *in vivo* occlusal load was 434 N ± 136 N. The peak *in vivo* occlusal load was 795 N. *In vitro*, the individually absolute bone strain was 1133 microstrains, whereas the simultaneously loaded bone strain was 753 microstrains at the implant apices. For bone strain to reach the pathological overload threshold define by Frost's mechanostat (3,000 microstrains), an occlusal load of 1,344 N is required based on linear extrapolation. The authors concluded that at *in vivo* and *in vitro* conditions, peri-implant bone was not found to be under pathological overload following supra-occlusal function.

OCCLUSION AND DENTAL IMPLANTS IN HUMAN STUDIES

Merin [13] documented a case report in which peri-implant bone loss was repaired after performing occlusal adjustment only. In this report, a 63-year-old female patient, who had a history of bruxism, presented for a regular periodontal examination after 38 months of implant crown placement on #30. The radiograph indicated considerable bone loss. The patient presented with heavy occlusion on the implant. Limited occlusal adjustment was performed on #30. Five months later, the radiograph revealed repair of the peri-implant bone loss. It is important to mention that this case of bone loss did not show the characteristic features of bleeding on probing or probing depths greater than 4mm.

Upon occlusal evaluation, the implant revealed heavy occlusion represented by “heavy markings on all occluding surfaces both in centric occlusion and in lateral excursions”. The author performed occlusal adjustment, which consisted of “grinding the areas of heavy blue markings until there was only light centric contacts”. The author of this report emphasized the need for routine periodontal examinations and maintenance in order to prevent peri-implantitis and that this routine examination should include not only periodontal and radiographic findings but should include occlusion findings.

Mattheos [14] reported two similar case reports. These two cases highlight that loss of integration can occur without inflammatory signs on the marginal tissue, such as deep probing depths or bleeding, thus attributing the loss of osseointegration to other factors, such as excessive occlusal loading. The first case was a 61-year-old female who received two Straumann implants in #2 and 3 positions. These implants were restored with single-screwed restorations with even occlusal contacts and without contacts in lateral movement and protrusion. It is worth mentioning that these implants were placed simultaneously with a lateral sinus elevation. A year after delivery of the restorations, the patient complained of implant crown mobility on #3. During the clinical evaluation, no more than 1 mm “dislocation of the crown” was observed without any signs of peri-implant inflammation or deep pockets. The patient denied any trauma to the area. When attempting to unscrew the crown with the wrench, the crown rotated without loosening of the abutment screw, which indicated “spinning of the implant in the bone socket”. The crown was removed after immobilizing it. The implant did not exhibit any mobility, however, loss of osseointegration based on the observed rotation was evident. Radiographically, no marginal bone was lost, however, a radiolucent halo was observed around the implant. A cover screw was placed and the #3 implant was left unloaded for 8 months. After this period of time, both #2 and #3 received splinted, screwed-retained crowns. Three months after, the implant was stable without any signs of inflammation or pocketing, and the radiographs revealed no loss of bone height or density. The second patient was a 56-year-old male who received two implants on #13, #14 areas. A screw retained restoration was delivered on #13 and a cemented restoration was delivered on #14. After 15 months, the patient complained of a lose crown on #14. The patient denied any trauma or injury. The exam revealed a fractured crown on #13 and #14 presented with “dislocation” of less than 1 mm. There were no signs of infection, inflammation or probing depths greater than 3mm. The treatment provided was adjusting the implant crown until it was “out of occlusion”. Eight months later, the implants were stable and both received splinted screw-retained restorations. Three months after the delivery of the new crowns, the implants were stable.

The loss of osseointegration reported in these 2 cases is different than that reported in plaque-induced peri-implantitis, in which marginal soft tissue is inflamed with concomitant marginal bone loss, which progresses in an apical direction. Plaque-induced peri-implantitis is being described radiographically as “saucer-shaped” bone loss, in which the bone loss occurs within the limitation of the inflamed tissue. Mobility will not be present until a complete osseointegration is lost. In the above cases, mobility was the only sign, without any inflammatory signs. This might resemble the “functional mobility” or “fremitus” reported in human teeth, which were reported as cardinal signs of “trauma from occlusion” in human teeth [15].

In another case report, peri-implant bone loss was apparently caused by occlusal overload, which was corrected by eliminating the traumatic occlusion [16]. In detail, this was a 57-year-old female that received three 16mm long implants in the right quadrant. These implants were stable and did not present any bone loss other than normal bone remodeling. However, 9 years later, the left tooth-supported bridge collapsed due to decay. The restorative dentist removed the left teeth and placed an overdenture. Six months after wearing the overdenture, the patient presented to the periodontist office wearing a very unstable overdenture and severe bone loss that extended to the sixth thread of two implants. A new well-fitted removable prosthesis was fabricated and delivered. The bone lesions begin to heal within 3 months after elimination of the traumatic condition. Four years after delivery of the well-fitted restoration, the bone is near the level of the first thread on the 2 implants that experienced bone loss.

Uribe [17] presented a case report in which marginal peri-implantitis was apparently associated with occlusal overload. In addition to the clinical findings, he included a histopathological analysis. In detail, this was a 46 year-old male, who received a SLA Straumann implant on #19 which was restored with a cemented crown. The implant presented with slight erythema and a pocket of 6 mm and bleeding on probing. Upon occlusal evaluation with articulating paper, a premature contact was evident. The treatment consisted of a combination of occlusal adjustment and surgical treatment. The occlusal adjustment included the reduction of the prosthetic crown. The surgical treatment included the elevation of a mucoperiosteal flap, removal of the soft tissue around the implant, decontamination with chlorhexidine and saline, and placement of bone autograft. The soft tissue biopsy result revealed dense fibrous connective tissue with few inflammatory cells, which according to previous literature is different from microbial induced peri-implantitis. After 12 months from treatment, the implant was stable. The authors emphasized the importance of occlusal adjustment for the success of the treatment. Also, they emphasized the need for histologic evaluation of the tissue around the implant to determine the cause for implant failure.

Quirynen *et al*. studied the effect of overload on Branemark fixtures [18]. From 1982 to 1989, a total of 467 consecutive edentulous patients were rehabilitated ad modum Branemark. The patients were recalled every 6 months by the same periodontist and prosthodontist. The follow up time was 3 years. The occlusal overload was evaluated in 84 patients that had fixed full prostheses. If the antagonist was a denture, balanced occlusion was attempted. In all other cases, cuspid-protected occlusion was present in 44% of the cases, groups function in 38% of the cases, and 17% of the cases presented with cuspid/anterior contact. The diagnosis of parafunctional activity was made if excessive occlusal wear or crown fractures was correlated with tooth clenching or bruxism. They found that failing or failed implants were observed if there was a lack of anterior contact, or the presence of parafunctional activity.

Escalante [19, 20] discusses the management of occlusion over implants in patients with centric bruxism (clenching). The author presents 3 cases that had centric bruxism (clenching). The implants were restored with "internally reinforced gold metal ceramic technology (Captek)" restorations. In his rationale, the author mentions that there is currently a debate in regards to the effect of harder restorations placed over implants. However, it seems that this is contradictory to nature, since the masticatory system is designed to dissipate the occlusal loads. A natural tooth presents with the hardest tissue in the human body (enamel), but it is layered with supporting dentin that is 4.7 times less hard. Additionally, the periodontal ligament functions as a shock absorber. Thus, a tooth is the perfect combination of maximum hardness along with natural flexibility, which under healthy condition can function over 90 years. The periodontal ligament works as a mechanoreceptor through which information is sent to the central nervous system, as a negative feedback mechanism, regulating the occlusal overload. In the other hand, implants are solid pieces embedded into bone and which are restored many times with harder material than enamel, and which oral tactile perception is not as sensitive as the periodontal ligament. Based on these points, it is possible to infer that dental implants are more sensitive to occlusal overload than natural teeth. In the cases that the author presents, the implants were restored with internally reinforced gold metal ceramic technology (Captek) restorations. These crowns have inner layers of gold that have the ability to be compressed, dissipating some occlusal forces. In these case series, the crowns were successfully restored with a 10 year follow up. The author recommended the following suggested occlusal scheme:

- The restoration must have a reduced occlusal buccal-lingual plane.
- It must have a "passive" occlusion, in which, only the working opposing cusp makes contact with the crown at 3 or 4 small points when the natural teeth are in active contact in maximum occlusion.
- Occlusal forces must be directed to the longitudinal axis of the implant.
- It must have immediate disclussion on any eccentric movements.

The parameters suggested by the author are based on clinical experience only, without any scientific validity. Research is warranted to evaluate the compression capacity of these reinforced gold metal ceramic copings.

The effect of maximum bite force on marginal bone loss around implants in patients was studied by Jofre in 2010 [21]. This study looked at mini implants that were supporting a mandibular overdenture. The patients were allocated randomly into two groups: one group received two single ball-type mini-implants and the other group received two mini-implants splinted with a prefabricated bar. The maximum bite force was recorded using a pressure-sensitive sheet and marginal bone loss was measured using standardized radiographs of each mini-implant at the baseline and at 5, 7, 10, and 15 months after surgery. His results showed that there was no relationship between the maximum bite force and the marginal bone loss on the mini-implants. However, this study only included patients wearing overdentures, in which most of the support lays on the mucosa while implants are mainly used to enhance retention rather than support. This could be a possible reason for their results.

OCCLUSION AND DENTAL IMPLANTS IN PREVIOUS REVIEWS

In a review of the literature in regards to current concepts in implant occlusion, Ben-Gal [22] concluded that "contact distribution between the prosthesis and opposing jaw play a substantial role in preserving the prosthesis, but have a lesser effect on implant survival and bone loss".

There are multiple reviews on the topic [23], but they appear to present the authors opinions and clinical expertise.

Naert, in a review of the effect of the occlusal load in peri-implant bone [11], mentions that although the amount of stress and strain can be defined at the exterior bone surface *via* strain gauge technology, the stress and strain produced within the implant-bone interface remains impossible to quantify today in either an in vivo animal model or clinically in a human study. Because of this difficulty it remains challenging, if not impossible, to establish an association between occlusal loading and implant failure/peri implant disease.

Misch [24] has published numerous articles and book chapters about occlusion on dental implants. He uses the term "implant-protected occlusion" to refer to an occlusal schema that is designed for the restoration of endosteal dental implants, and provides improved clinical longevity of the implant and the prosthesis. Some of the factors to consider on implant-protected occlusion are listed below:

- A natural tooth has the periodontal ligament, which serves as a viscoelastic "shock absorber" decreasing the magnitude of force and stress applied to the bone. When "trauma from occlusion" occurs in natural teeth, the tooth will respond by increasing its mobility [15]. This increase of mobility will serve to dissipate the stress and strains otherwise imposed on the bone interface. A dental implants lacks a periodontal ligament, thus the load is applied directly to the surrounding bone. It is worth noting that, it has also been reported that a dental implant can also express mobility when subjected to excessive occlusal forces [14].
- Implant and tooth movement are not similar. A tooth can move 28 μm in an apical direction with an axial load. An implant under a similar load moves approximately 5 μm. For this reason, an implant supported restoration that is surrounded by teeth must be adjusted. To achieve this, the following protocol is recommended:
    1. Biting in centric occlusion with light force utilizing a thin articulating paper (less than 25 μm) is used first to assess the occlusal contacts. The implant crown will be relieved, placing heavier forces on the contiguous teeth.
    2. A stronger bite force is then applied into the articulating paper creating contact regions on both the implant restoration and the adjacent teeth. "The greater bite force on the region can be similar between implants and teeth, because it depresses the natural teeth, positioning them closes to the depressed implant sites and equally sharing the occlusal load".
- Excursions should be evaluated after centric contacts have been corrected. The stomatognathic system produces lower forces when the posterior segments are not contacting. For this reason, all excursions on implant-protected occlusion should disclude the posterior contacts. Thus, the forces are distributed only to the anterior segments, resulting in a decrease overall occlusal force magnitude due to the diminished muscle firing.
- In the anterior region, the lateral movement of healthy teeth ranges from 68 to 108 μm, whereas, implant movement ranges from 10 to 50 μm. This means that anterior teeth will present with more apical and lateral movement in comparison to implants, creating a bigger difference. Special care should be done when adjusting the occlusion in anterior implants.
- An occlusal force should be directed mainly along the long axis of the implant body. An angle load to the implant axis would increase the compressive forces at the crest on the opposing side, while increasing tension along the same side.
- The longer the crown height, the greater the crestal movement with any lateral force.
- The width of almost every natural tooth is wider than the width of the implant to be used to replace that tooth. The greater the width (of a tooth or an implant), the lesser the magnitude of stress into the surrounding bone.
- The elastic modulus of a tooth is closer to bone, compared to that of an implant material.
- Cortical bone is strongest in compression, whereas it will be 30% weaker in tension and 65% weaker in shear. Therefore, implant-protected occlusion has the goal of eliminating or reducing all shear load to the implant. Premature occlusal contacts produce in localized lateral loading. Elimination of premature contacts is even more important when parafunctional habits are present because both the duration and magnitude of the occlusal force are augmented.
- Stress is defined as the magnitude's force divided by the cross-sectional area in which the force is applied. This means that the greater the area that receives a force, the less stress is produced. For this reason, wider implants will produce less mechanical stress at the crest than narrower implants. Additional implants are indicated when narrow diameter implants are used, or when the angle of load is not axial to the implant body.
- The wider the occlusal table, the more often non-axial contacts will occur.

CONCLUSION

The idea that occlusion affects the dental implant and peri-implant condition is plausible from a biomechanical and physiologic bone response. Evidence exists at both the animal and human levels that support the detrimental role of occlusal overload. On the other hand, there are studies that question the role of occlusion. More studies are needed to help understand the mechanisms by which occlusion can have an effect on the dental implant and peri-implant condition.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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