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Review Article

Occlusal Considerations in Dental Implantology

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Abstract

Introduction: Since endosseous implants differ from natural teeth in relation to the surrounding bone, forces resulting from occlusal overloading may cause mechanical and/or biological complications. Hence, multiple occlusal considerations should be thought about in order to provide optimum treatment for patients.

Aim: to discuss the influence of occlusion on the success and survival of dental implants in different clinical scenarios based on scientific evidence.

Methodology: comprehensive search of the dental literature via PUBMED, MEDLINE and Scopus databases using the following keywords: "dental implants", "dental occlusion", "implant success", "implant longevity", "overloading", "implant complications", "occlusal design", "occlusal load". In addition, references of the selected articles were searched for further information.

Conclusion: multiple factors can cause occlusal overload on dental implants. With careful planning, mechanical and biological complications can be avoided. At the scientific evidence level, the relation between occlusal overload and implants longevity is controversial, further randomized clinical trials are needed to clarify this issue.

Keywords: *Fixed Prosthodontics; Dental Implantology; Occlusion; Complications; Forces*

Introduction

The use of dental implants in the treatment of complete and partially edentulous patients has evolved over time. With predictable long term success rate, endosseous-type implants have revolutionized patient care [1-3]. The extension of occlusal schemes from natural teeth, removable or fixed dentures to dental implants has been certain to happen because no scientific concepts have been introduced [4]. The role of occlusion in peri-implant bone loss has been controversial, many studies suggested that occlusal overload may cause peri-implant disease and therefore should be avoided [5-8]. In contrast, other studies propose tm io0hat biological complications such as infections are the main contributors to peri-implant bone loss [9,10]. Although there are different opinions of how occlusal overload can biologically affect the dental implant and the surrounding bone, it is necessary to mention that occlusal overload can have negative mechanical influences on the dental implant and the restoration such as screw loosening, screw fracture or implant texture fracture [11]. In addition, many literatures reported that the success and survival of osseointegrated implants can be determined by the occlusion [12-14]. Thus, the aim of this paper is to discuss how the occlusion can affect the success and survival of dental implants in different clinical scenarios based on scientific evidences.

Differences between natural teeth and dental implant

In order to understand how osseointegrated implants absorb the occlusal forces, it is essential to the clinician to appreciate the anatomical differences between natural teeth and dental implants [15]. Endosseous implants are in direct contact with the surrounding bone without intervening soft or fibrous tissue, this connection is known as osseointegration [16]. In contrast, natural teeth are separated by the periodontal ligaments (PDL). As a result of the proximity to the bone, endosseous implants have axial mobility of about 3 - 5 µm, while natural teeth have a range of 25 - 100 µm of axial mobility [17,18]. In addition, the presence of PDL in natural teeth leads to physiological and functional adjustments when there is an occlusal overload, this is because the PDL are well oriented toward an axial force. Therefore, an adaptation to the variable masticatory forces can occur [19].

Furthermore, unlike natural teeth, the movement of a loaded implant depends on the elastic deformation of the bone, and the implant deflects in a linear and elastic pattern. In contrast, the movement of a natural tooth upon loading begins with a periodontal compliance phase that is non-linear and complex, followed by a linear and elastic phase of the alveolar bone [17].

A further difference between teeth and implants is the movement pattern during stress. Natural teeth move rapidly during lateral forces at 56 - 108 µm, and the apical third of the root is the fulcrum point to the lateral force which disappear immediately from the crest of the bone [20]. The implant on the other hand moves gradually to similar lateral forces 5 - 10 µm, and the forces will accumulate at the level of the crestal bone without any rotation of the implant [17]. Moreover, heavy forcers in centric occlusion such as clenching is reported to cause highest stress on the surrounding bone [21].

Furthermore, many studies suggested that the threshold value of tactile sensation is significantly higher in implants than natural teeth, this is due to the presence of neurophysiological receptors in PDL which transmit information from nerves end to the central nervous system, thus, natural teeth can exhibit pain caused by occlusal stress substantially faster than osseointegrated implants [22-24].

The anatomical differences mentioned above and the absence of PDL in endosseous implants suggest that implants are more susceptible to occlusal overload. (Table 1) summarize the differences between natural teeth and osseointegrated implant.

	Tooth	Implant	Study
Anatomical connection	Periodontal ligaments	Osseointegration, absence of PDL	(Branemark*., et al.* 2001) [16]
Proprioception	Periodontal mechanoreceptors	Osseoperception	
Tactile sensibility	High (average 3.8-g of horizontal pressure)	Low (average 580-g of horizontal pressure)	(Hämmerle*., et al.* 1995) [23]
Axial mobility	25-100 µm	3-5 µm	(Sekine*., et al.* 1986, Schulte 1995) [17,18]
Movement phases	Primary: non-linear and periodontally complex phase Secondary: linear and elastic	Only one phase: linear and elastic	(Sekine*., et al.* 1986) [17]
Movement patterns	Two patterns: Primary: immediate Secondary: gradually	One pattern: gradually	(Schulte 1995) [18]
Fulcrum point to lateral stress	Apical third of the root	Crestal bone	(Parfitt 1960, Sekine*., et al.* 1986) [20,17]
Load-bearing tendency	Stress distribution	Stress concentration at the level of crestal bone	(Sekine*., et al.* 1986) [17]
Signs and symptoms of occlusal over load	Mobility, widening of the PDL, pain, tooth surface loss, fremitus	Restorative complication such like: screw fracture, screw loosening, restoration fracture Implant fracture Bone loss	(Zarb & Schmitt 1990, Schwarz 2000) [72,11]

Table 1: *comparison between natural teeth and osseointegrated implants.*

Factors affecting occlusal load on dental implants

There are numbers of factors and clinical scenarios that may possibly cause occlusal overload such as: length of cantilever, parafunctional habits, time of loading, quality of bone, numbers of implants, occlusal scheme and more (Table 2) [15,25]. It is essential for the clinician to consider and appreciate these factors prior to placing dental implants in order to have a more predictable outcome.

Length of cantilever extension
Parafunctional habits
Premature contacts
Time of loading and quality of bone
Location of the implant
Morphology of the prosthesis
Design of occlusal scheme

Table 2: Factors and occlusal considerations in dental implantology.

Length of cantilever extension

Cantilever extension is a factor which can cause occlusal over load on osseointegrated implants, it is suggested that the extension part may cause a hinging effect which induce a significant compressive strength on the implants especially the closest one to the extension [26]. Therefore, peri-implant disease and/or restorative complications can be observed when inadequate cantilever extension is present [27,28].

There are two factors that is related to a cantilever extension; the length of the cantilever extension and the distribution of the occlusal stress on the implants which support the prosthesis with cantilever, hence, the number and location of implants supporting the prosthesis.

Knowing a specific number for the maximum length of the cantilever can be very useful for the clinician in certain situations. A clinical study done by hackleton., *et al.* (1994) examined the survival rate of prosthesis with cantilever of different length and location (mesial or distal) supported by osseointegrated implant. The result shows that implants supporting prosthesis (ISP) with shorter cantilevers have better outcome and longevity than ISP with longer cantilever, the maximum recommended length of cantilever was 15 mm, a cantilever longer than that can significantly increase the failure rate. In addition, mesial cantilevers were significantly favorable than distal cantilevers. However, the sample in the study was mainly in the mandible (85%) rather than the maxilla (15%), thus, it is reasonable to consider the result of this study in mandibular implants unlike maxillary ones [28]. Taylor (1990) suggested that for a fixed ISP in the edentulous maxilla, the length of the cantilever should not exceed 10-12 mm in order to ovoid occlusal overload to the implants [29]. On the other hand, Naert., *et al.* (1992) suggest that the length of cantilever does not significantly affect the bone surrounding the implants, however, the average length of the cantilever extension of the mandible was 14.4mm and in the maxilla 10.9mm, hence, there is no conflict between the result of this study and the previously mentioned ones. In addition, the author advised to properly spread the implants, shorter the cantilever and maximum length of the implant should be provided to reduce the possibility of any complications [30]. Moreover, a study done by Cicciù., *et al.* (2018) using a model that mimic the human mandible for reproduction of screwed overdenture. four trials were done using a different cantilever lengths and implants numbers. The trials with hort cantilever lengths (5.5-8.5mm) and six-screw implants, showed the least stresses on the cantilever parts and screws, comparing to trials with cantilever lengths up to 18.5mm and four-screw implants [31].

The distribution and the number of implants supporting the prosthesis is another factor that need to be considered. A study done by Duyck., *et al*. (2000) showed that under controlled load of 50 N in different position on fixed prosthesis supported by different numbers

of implants (3, 4, 5 and 6 implants), less number of implants showed higher bending forces and the usage of three implants had the highest bending force [26].

Parafunctional habits

Parafunctional habits such as bruxism, clenching, ice chewing, etc. have been considered as an important factor for occlusal overload by many studies and through the literature. One retrospective study reported that marginal bone loss around implants and restorative complications were observed in patients with parafunctional habits and in cases where posterior ISP is present but there is no anterior contact [5]. In a different study, fractured implants were evaluated, the study reported that 90% of the fractured implants occurred in cases having both parafunctional habit and cantilever prosthesis [6]. In contrast, a 1 - 10 years prospective clinical study showed no significant relation between implant supported posterior single crown failure, and parafunctional habits [32]. However, in a 15 years' prospective study attributed marginal bone loss to bad oral hygiene rather than occlusal overload [33].

Nevertheless, it is essential to stress that there is a great variation in the design of each prosthesis and occlusion in the previous studies, this can explain the different conclusions because it is suggested that different occlusal designs can significantly increase the forces on the implant and thus, increase the possibility of complications of the treatment [34].

Premature contacts

Loss of marginal bone surrounding the implant and prosthetic complications due to premature contact has been controversial. Several *in vitro* studies showed direct relation between premature contact and biological and mechanical complications of the osseointegrated implants [7,35-37]. In contrast other studies didn't find a relation between premature contact and marginal bone loss [38,39] (Table 3). Nonetheless, almost all studies reported that premature contact in the presence of an active inflammation surrounding the implant can exaggerate the inflammation and possibly increase the rate of bone loss.

Study	Type	Methodology	Load approach	Microbial control	Result	Conclusion
(Isidor 1997) [36]	mandible of monkeys	Four monkeys, five implants/monkey bilateral design, • Two implants with premature contact • Three implants with ligature induced peri-implant disease Loading / infecting time: 18 months	High contact point (dynamic)	Yes, for the overload segment (brushing: 1x / week, subgingival cleaning: 1x / month)	• 6 out of 8 (75%) overload implants were loose • Implants with plaque accumulation were osseointegrated, however marginal bone loss was observed	Implants with cclusal over load can completely or artially loose sseointegration. While implant with plaque accumulation can exhibit peri-implant disease with marginal bone loss
(Hürzeler., *et al.* 1998) [38]	mandible of monkeys	Five monkeys, 8 implants/monkey, bilateral design, • Fur implants with ligature induced peri-implantitis , two of them with occlusal over load, other two physiologically loaded • Four implants: without peri-implantitis, two of them overloaded, other two physiologically loaded • Loading / infecting time: 16 weeks	Premature contact + static load device (dynamic / static)	Yes for the segment w/o pre-implantitis(brushing + pumice with 2% chlorhexidine 3x/ week)	• All implants remained osseointegrated • No clear histological different between the two groups • Significant more bone loss when peri-implantitis is present	No clear role of occlusal overload on the marginal bone loss, further investigation is needed

(Miyata., *et al.* 2000) [7]	mandible of monkeys	1. Four monkeys, one implant/monkey 2. No occlusal over load 3. 100 µm supraoccluded prosthesis 4. 180 µm supraoccluded prosthesis 5. 250 µm supraoccluded prosthesis 6. (Un)loading time: 4 weeks	High contact points (dynamic)	Yes, for all	Bone resorption increase significantly with 180 µm of supraoccluded prosthesis or more	Occlusal trauma may cause pathologic bone loss around the implants even when inflammation is absent
(Gotfredsen., *et al.* 2001) [39]	mandible of dogs	Three dogs, eight implants/dog, bilateral design Implants were grouped as pairs: 1. No activation of expansion screw 2. 0.2 mm expansion 3. .04 mm expansion 4. .06 mm expansion (Un)loading time: 24 weeks	Expansion screw device (static)	Yes, for all (1x/day)	No evidence of marginal bone loss in all of the groups	Static load in a lateral direction can increase the adaptation of the surrounding bone
(Kozlovsky., *et al.* 2007) [37]	mandible of dogs	Four dogs, four implants/dog, bilateral design, different condition/implant: 1. Peri-implantitis + occlusal overload 2. No peri-implant disease + occlusal over load 3. Peri-implantitis + no occlusal overload 4. No prei-implantitis + no occlusal over load (control group) (Un)loading/infecting time: 12 months	High contact point (dynamic)	Yes, for inflammation-free segments (brushing 3x/week)	• Overloading per se slightly increased marginal bone resorption • Inflamed groups showed significant bone loss around the implants • When inflammation is present, overloading significantly increased the bone loss	Overloading can affect the surrounding bone when peri-implantitis is present

Table 3: *In vitro studies that investigated the influence of premature contact on implant.*

Bone quality and time of loading

Bone quality has been considered as a critical factor in the success of the implant treatment. Multiple studies reported that implants failure in posterior maxilla is connected to the quality of that area [5,40-42]. In addition, the combination of occlusal overloading and poor quality of the bone has been considered as a leading factor of late implant failure [43] (Table 4). Thus, it is important that the clinician appreciate the variety of bone quality and the common site for each type.

Site	Anterior mandible	Anterior mandible, posterior mandible, anterior maxilla	Posterior mandible, anterior maxilla, posterior maxilla	Anterior maxilla, posterior maxilla
discerption	Consist mainly of homogenous, compact bone	Has a thick layer of compact bone with a dense layer of trabecular bone	Has a thin layer of compact bone surrounding a large core of trabecular bone	Has a very thin layer of compact bone surrounding a low-density trabecular bone
Type	Type I 	Type II 	Type III 	Type IV 

Table 4: *classification of bone quality [44].*

A classical classification of bone quality which is well recognized in the literatures has been made by Zarb., *et al.* (1985), bone quality is categorized into four types, with bone type I is the densest bone and type IV is the least [44]. It is suggested that bone types I and II promise the most successful implants due to their ability to withstand occlusal loads [45]. Truhlar., *et al.* (1997) reported that type I and IV are the least common, and the densest bone is found in the anterior mandible, followed by posterior mandible, then anterior maxilla and lastly posterior maxilla [46]. A 20 years' retrospective clinical study showed that, implants placed in type I bone have the least failure rate among other types of bone quality [47].

The loading time might affect the success of the implant, especially with poor quality of bone. It is suggested that a gradual bone loading will reduce the possibility of over loading the implant. In addition, less crestal bone loss and better bone density were noticed with progressive loading of the implant [48]. The time suggested to reach the full loading force is 5 to 7 months [14].

Location of the implant

The location of the implant is considered to be a critical factor to avoid occlusal overload, it is recommended that horizontal load should be reduced as much as possible and implants should mainly be vertically loaded [49]. In order to achieve this principle, the implant should be positioned so that it is in a straight line with the opposing antagonist [50]. The utilization of surgical guides, radiographic examination and diagnostic wax up can help to establish a favorable location of the implant.

Morphology of the prosthesis

The morphology of the prosthesis is considered to be an important factor to prevent occlusal overload. It is suggested that having a flat cusps and shallow anatomy will direct the forces axially, in contrast, cuspal inclination can create an unfavorable bending movement, in addition, inclined cusps can transmit more force to the implants compared with flat cusps [51,52]. This is recommended in implants with an increased crown-implant ratio with history of periodontal problems [53].

Furthermore, the design of the occlusal table is considered to be an important factor. A narrow occlusal table is suggested to reduce cantilever effect on the implant and direct the forces apically better than a large occlusal table, in addition, less porcelain fractures and better oral hygiene were reported with narrow occlusal table [14,54].

Effect of occlusal schemes

Occlusal concepts of dental implants have been derived mainly from occlusion of natural teeth, however, due to the previously mentioned differences between natural teeth and dental implants, efforts have been made through *in vivo* or *in vitro* studies to reach a suitable occlusal scheme for endosseous implant.

It is suggested that in order to reduce occlusal over load on dental implants, the occlusal criteria may include; (1) simulations bilateral contact, (2) no premature contacts in centric occlusion and retruded contact position, (3) lateral excursive movements should be smooth, even and without any interferences, (4) presence of anterior guidance, (5) equal distribution of occlusal forces and contacts [55].

It is controversial wither the occlusal scheme has an effect on the treatment outcome or not. Bilateral balanced occlusal has been considered for many years as the optimum occlusal scheme that can be provided for patients with complete prosthesis, however, recent

study that included 109 patients showed that there is no significant different between different occlusal schemes regarding patient's satisfaction and treatment outcome in case of mandibular implants supported fixed prosthesis and opposed by maxillary complete dentures [56]. In addition, [57] found that complete edentulous patients treated with complete dentures with different occlusal scheme including bilateral balanced occlusion reported no treatment outcome differences.

The rationale behind these results might be due to the following reasons; (1) it is estimated that teeth are in contact in case of the absence of parafunctional habits for 17.5 minutes only [58], (2) whenever the patient is eating on one side, the other side will be non-functional. Therefore, it is believed that the occlusal scheme may not be an essential factor of implants overloading.

Clinical applications

Restorations supported by implants in different clinical scenarios should be planned in advanced using an articulated model, diagnostic wax up and radiographic evaluation [25]. Multiple clinical factors should be considered to fabricate prosthesis supported by single implant, implants supporting fixed prosthesis in fully edentulous arch and overdentures supported by implants. Table 5 summarize the recommended occlusal factors according to each clinical scenario.

Clinical scenario	Recommendations
prosthesis supported by single implant	• Reduce inclination of cusps • Exclusion of anterior guidance and lateral movement • Increase proximal contact • Centrally positioned contact • Posteriorly: axial positioning with the opposing antagonist and at right angle to the occlusal table • Cantilevers as short as possible
full arch fixed prosthesis supported by implants	• Infraoccluded cantilevers (100 μm) • Cantilevers no longer than 15mm in the mandible and 10-12 mm in the maxilla • Number of implants: 4-8 in mandible, 6-8 in maxilla • Avoid canine guidance if abutments in the canine area • Narrow occlusal table • (1mm - 1.5mm) freedom from centric relation to maximum intercuspation
removable over denture supported by implants	• Attachment height reduced as possible • Magnets shows more masticatory problems than other attachments • Favourable occlusal scheme is controversial • Achieving three points balanced on lateral and protrusive movement is advisable • Number of implants: 2-4

Table 5: *The recommended occlusal factors for different clinical scenarios.*

Occlusion in prosthesis supported by single implant

Designing the occlusion in single implant should be aimed to reduce the occlusal forces onto the implant, this can be accomplished by excluding the implant from any anterior and lateral guidance [59,60]. In addition, according to Misch (1999), an increased proximal contact can help to improve the stability of the restoration [14]. Furthermore, reduced inclination of cusps in posterior area and having a centrally positioned contact is considered to be one of the critical factors to reduce bending forces on the implant [56].

One more factor that is considered to be important with all clinical situations is that the posterior implants should be placed axially in relation to the opposing antagonist, this can help to reduce occlusal overload on the implant [50,61].

Occlusion in full arch fixed prosthesis supported by implants

The occlusion for full arch fixed implants prosthesis depends on the opposing arch; in case it is opposed by full denture, the design of the occlusion should be aimed to stabilize the denture primarily, while if the prosthesis is opposed by natural dentition, the occlusion should be designed to reduce occlusal over load on the implants [15].

If a cantilever extension is present, it is suggested to have it infraoccluded (100 μm) and with a maximum length of 15 mm [34,28]. Moreover, it is recommended to avoid canine guidance if one of the abutments is in the canine area as this might lead to occlusal overload and possibly biological and/or mechanical complication of that abutment [62].

Another factor that need to be consider in this clinical situation is the number of implants supporting the prosthesis, it is suggested that 6 - 8 implants in the maxilla and 4 - 8 implants in the mandible are considered acceptable to support the prosthesis [63,25].

Occlusion in removable over denture supported by implants

Many literatures have suggested to replicate the occlusal concept of conventional overdentures in this situation, bilateral balanced occlusion and lingualized occlusion are recommended occlusal schemes in these literatures, another advisable design especially where bilateral balanced occlusion is difficult to achieve is to have three balanced points in protrusive and lateral movements [25,50]. However, clinical studies showed that different occlusal schemes are comparable to each other and there is no significant difference in relation to patient's satisfaction among them [56,57,64].

Type of attachments is consider to be a controversial factor to the success of the overdenture, most of attachment types show promising success of the treatment [65-69]. However, some clinical studies showed that most of the masticatory problems are associated with magnets [70,71]. in addition, Gross (2008), recommended to reduce the height of the attachment as much as possible in order to reduce any horizontal forces [25].

Conclusion

Good understanding of the differences between occlusal loading on natural teeth and dental implants should be well understood by the clinician. This can help to place and restore the implant in a favorable way and reduce mechanical or biological complications that might happen subsequently. Currently, the effect of overloading and occlusal scheme on the longevity of dental implants is controversial and further well designed clinical trials are needed clarify this controversy.

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