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Review Article

Correlation of Peri-Implant Bone Loss and Occlusal Trauma: A Literature Review

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Abstract

Implants were discovered by Professor Branemark back in the 1950's. As we stand today in the 21st century, we still haven't completely figured out the dynamics of an implant and its association and effect on the periodontium. Controversy still exists regarding the role of excessive occlusal overload on peri-implantitis or implant failure. Animal studies shows conflicting results and human clinical trials are inadequate to draw a conclusion whether loss of osseointegration is caused by undue occlusal load or just leads to marginal bone loss. There are no set rules or measurements which would guide a clinician in planning an implant keeping the periodontal as well as prosthetic component balanced. Hence this review paper aims to compile the evidence present currently and help understand the complex relationship biomechanical stress and its effect on bone loss around implants, in a concise manner.

Keywords: Occlusion; Occlusal Trauma; Dental Implants; Peri-Implantitis; Peri-Implant Bone Loss

Introduction

"Occlusion is the sustaining force in the life of the periodontium" has been rightly stated by Sir Erwin Glickman. It emphasises on the fact that occlusion greatly affects the functionality of oral cavity and plays a crucial role in clinical dentistry. Thus, attaining a balanced occlusion becomes a mandatory requirement for normal physiologic oral functions [1].

It is said to be the Era of Dental Implants as they have brought about a renaissance in the field of dentistry and is increasingly becoming a preferred treatment approach [2]. But despite of a good survival and success rate, implants are still not considered 99% successful. They do come with a possibility of complications [3]. Thus, it is essential to point out the factors that play a role in pathobiology of peri-implant disease, thereby improving the health of peri-implant tissues for an extended period.

"Excessive occlusal force is defined as a force that exceeds the regenerative capacity of the periodontal attachment apparatus, which results in occlusal trauma and/or causes excessive tooth wear (loss)." [4]. But when talking about osseointegrated implants, they react differently to biomechanical forces compared to natural teeth, due to lack of the periodontal ligament [5]. When osseointegrated implants are loaded mechanically, a sensory function, often stated as "osseoperception", is induced which is nothing but a patient's occlusal perception [6]. Since, tactile sensations or motor reflex functions are associated with mechanoreceptors present in the periodontal ligament [7], this sort of perception decreases in patients having dental implants. Therefore, a good prosthesis with a balanced occlusion on dental implant becomes critical which would respect the biological and mechanical components of the implant and peri-implant tissues, without overloading it, for its the long-term survival.

There is no consensus reached about the type of effect occlusal overload has on dental implants. Till date, there is disagreement as to whether or not heavy occlusal load is one of the aetiology behind a failing implant or is it just sort of a stimulus which when

removed, will cause the bone to repair and be healthy again. Some researchers believe that excessive occlusal load could be a probable aetiology of peri-implant bone loss or failure of the implant/implant prosthesis [8]. However, another school of thought state that peri-implant bone loss is a repercussion of biological elements and not related to occlusal load [9]. The reason for such disparity in opinion is due to (a, Humans love conflict and b,) the limited number of controlled clinical studies being conducted on humans. This is because any sort of prospective study to assess the outcome without treating the occlusal problems would not be ethical and against the Helsinki accords. Thus, all human clinical trials on the effect of occlusion on implants are retrospective in nature and are thus subjected to a good amount of examiner biases. Despite the fact that animal studies can be controlled clinically, they do not imitate how occlusion affects implant outcomes in people per say. The evidence on this subject is both diverse and varied. Hence, the purpose of this article is to help cater to the perception of complex relationship of bone loss and biomechanical stress, by reviewing the available literature on animal studies and a few human clinical studies in a concise manner.

Reaction of bone cells to occlusal overload

The amount of stress put on the bone, or the mechanical environment around it dictates the level of strain transmitted to the bone. That, in turn influence bone remodelling at the cellular level. Cow in, back in 1991, demonstrated the effect of mechanical loading which causes bone cells to deposit or resorb bone tissue. He concluded that there are certain mechanosensory receptors in bone which react to negligible amounts of strain, almost hundred times less than the ultimate strength of the bone, triggering bone remodelling. Therefore, any amount of strain exceeding the capacity of bone cells to withstand load, will trigger cytokine production and lead to bone resorption [10]. Frost illustrated that the bone behaves like a shock absorbing mechanostat and that it has a range within which it can withstand certain amount of forces. He further elaborated that 4,000 microstrain unit would trigger a bone resorption cascade and a microstrain unit more than 25,000 is supposed to cause pathological fracture of bone [11,12]. In that way, perhaps occlusal stress directed through the implant prosthesis and components may transmit stress to the bone-implant interface in similar fashion [13]. However, these hypothesis are purely based on a cellular biomechanics standpoint and hasn't been translated on a large scale in human trials, using dental implants. Hence it cannot be concluded whether excessive overload invariably causes bone resorption. If at all it does, is it loss of osseo-integration or just marginal bone loss is what needs to be evaluated.

Frost emphasized that the bone simulating a mechanostat responds to external load by adapting itself biomechanically. He proposed 4 zones which corresponds to the mechanical adaptation of the bone on receiving occlusal load. The zones represent the following: disuse atrophy, steady state, physiological overload, pathological loading (Figure 1).

Figure 2: Frost's Mechanostat theory; 4 zones corresponding to the mechanical adaption of bone on receiving occlusal load: a-disuse atrophy, b- physiologic remodelling, c-physiological fracture, d-pathological fracture. Remodelling occurs between 200-2500 microstrain units. Bone modelling aims to repair the damage caused by overload between 2500-3500, beyond which (>25000) pathological or catastrophic fracture occurs.

At both the ends of the graph, that is in case of disuse atrophy or pathologic overload the bone volume decreases. Frost's study has given values within which this phenomenon occurs. When the peak magnitude drops below 50–200 micro strains, disused atrophy is thought to occur, and when the peak loading levels exceed 3500 microstains, pathological bone resorption is initiated. Levels beyond 25000 microstrain leads to catastrophic fracture. 200-2500

microstrain allows the bone to remain in a steady state where the transition from young woven bone to a mature lamellar bone occurs. Between 2500-3500 microstrain, the bone becomes fatigued but still continues to remodel until it reaches back to the steady state or accommodates itself by physically conforming to receive the load rather comfortably. Although this finding may not be fully translated in case of implants as the cyclic impact of chewing in natural dentition cannot be simulated in bone-implant interface, it can be assumed that implants would have a predictable course like that of a natural tooth on bone. Large scale in-vitro studies are required to add on to the existing evidence which would make sure that a clinician doesn't exceed the upper limit of the given standard range while placing implant and prosthesis.

Studies showing association of occlusal overload around dental implants

Animal studies

There are quite a number of animal studies supporting or disregarding the role of excessive overload on implants and loss of osseointegration (Table 1).

Sr no.	Study	Study type	Samples	Method	Results
1.	Isidor et al - 1996	Retrospective, split-mouth design; Time period: 18 months	Four Monkeys (Macaca fascularis)	Test group: Mandibular first molar, premolar, incisor extracted. 5 Astra Implants placed 8 months post extraction. 2 implants subjected to dynamic loading at excess occlusion. Control site: Remaining 3 implants No abutments received	Clinical evaluation done at 3, 6, 9, 12 ,18 months. 6/8 implants were lost osseointegration with little or no marginal bone loss.
2.	Miyata et a - 1998	Retrospective, split mouth design. Time period:	Four monkeys	Test group: dynamic loading of (100,180,250)m on 3 monkeys for 4 weeks Control group: oral hygiene only	No difference between control and test group; and 100m group and control; bone resorption was observed under excess occlusal load of 180m or higher.
3.	Heitz-Mayfield et al - 2004	Retrospective; split mouth design	6 Beagle Dogs	Test group: dynamic loading high in occlusion in each dog. Control group: no prosthesis given	No statistically significant difference in bone height or bone density between control (72.6%) and test (73.9%) group seen.
4.	Kozlovsky - 2007	Retrospective; split mouth design	4 Beagle Dogs	Test group: 2 implants placed; 1 loaded with supraocclusion, 1 unloaded; cotton floss ligatures placed to promote plaque accumulation in both. Control group: 1 implant loaded with supraoccluded prosthesis and 1 unloaded, routine oral prophylaxis done.	Clinical parameters evaluated at baseline and every 3 months; loaded inflamed and unloaded inflamed implants showed considerable bone loss exposing implant thread, loaded uninflamed, unloaded uninflamed didn't show statistical difference from baseline

Table 1: List of animal studies included in the review.

Back in 1996, Isidor [14]. reported that heavy occlusal loading in Macaca Fascularis species (Monkey) caused loss of osseointegration. In the retrospective study, four monkeys got their Mandibular first molars, premolars and incisors extracted. Eight months post extraction, 5 (Astra - machined as well as TiO2 blasted surface) implants were placed in each monkey. Two were placed in premolar regions bilaterally, and one placed in the incisor region. It was a split mouth design where the contralateral side did not receive any abutments. Six months after the surgical implant placement, the test sites were uncovered and prosthesis were given which were kept high in occlusion causing a dynamic lateral displacement of the mandible during occlusion.

Both the sites received thorough plaque control which included tooth brushing once a week, and subgingival cleaning once in a month. The clinical and radiographic evaluation was made when the prosthesis were inserted and at 3, 6, 9, 12 and 18 months later. The results showed that four overloaded implants out of eight presented with considerable mobility and discrete radiolucency around the implant and 2 of them showed complete loss of osseointegration with "none or little marginal bone loss". These observation lead to the conclusion that an implant which is overloaded could be the main cause for the loss of osseointegration around a previously osseointegrated dental implant, whereas the presence of plaque can be the main etiological factor for progressive marginal bone loss height.

The results were quite the contrary for Miyata., *et al*. in their study conducted two years later in 1998 and 2000 [15,16]. They tried simulating occlusal overload by supra-occlusal contacts acting on a healthy peri-implant environment on Macaca Monkeys, in a retrospective study. Overload did not cause loss of osseointegration, in fact induced tissue build-up around the implant surface. They however, in another follow up study, measured the effect of occlusal overload in 3 different levels of superstructure heights (100, 180 and >250). It was observed that there was loss of osseointegration above 180. It was also observed that presence of plaque around implant combined with functional overload lead to marginal bone loss and loss of osseointegration. Hence, the authors concluded that both occlusion and inflammation need to be controlled around implants.

Heitz-Mayfield in 2004 [9] conducted experiment on 6 Labrador dogs. Each dogs bilateral Mandibular premolar and molar teeth were extracted. 3 months later, two differently coated implants were placed bilaterally in Mandibular jaw in each dog. Prosthesis which was high in occlusion were delivered after 6 months in the test site whereas control site implants were not loaded. Oral prophylaxis was routinely done on both the sites in each dog. Histological results didn't show statistical difference between control and test sites (72.6% and 73.9%).

In yet another split-mouth study conducted on beagle dogs by Kozlovsky., *et al*. in 2007 [17] assessed the abutments on implants which were kept in supra-occlusion or infraocclusion. They observed that there was no loss of osseointegration or marginal loss of bone in absence of any inflammatory component, even though the prosthesis is placed supraocclusally. Interestingly they found that there was a surge in osteoblastic activity which lead to an increase in bone to implant contact in an overloaded implant.

The drawback of all these animal studies is the lack of standardisation. The samples used are not the same and are used under different loading strain, and protocols. Nevertheless, what can be concluded is that the bone can withstand occlusal load up till a certain threshold beyond which the implant may start to show signs of loss of osseointegration.

Human studies

The literature on human clinical trials are mainly based on Case reports and Retrospective Cohort studies and thus are subjective in nature.

Merin [18] in the year 2014, documented a case report where he observed repair of the peri-implant bone loss after doing occlusal adjustment. The patient was a 63-year-old female, bruxer who had reported to the clinic for routine periodontal examination after 3 years. The patient had no bleeding on probing or Probing depths more than 4mm. Radiographic picture revealed considerable bone loss. Minimal occlusal adjustment was performed on the implant experiencing heavy occlusal load and was reviewed after 5 months. The peri-implant bone loss was repaired thus indicating that peri-implant bone loss due to heavy occlusal load is reversible in nature. It also emphasizes on the fact that routine follow-ups should be made to avoid peri-implantitis and it must include occlusal findings along with periodontal and radiographic findings.

Mattheos [19], an year earlier (2013) had described two cases where the patients presented with loss of osseointegration around

the implant without marginal bone loss. There were no signs of inflammation on either of the cases. In the first case, one year after placement of implant and the prosthesis, the patient complained of implant crown mobility. No marginal bone loss was seen radiographically however, a radiolucent halo was observed around the implant. The prosthesis was removed, and cover screw was replaced on the implant. Three months later, the implant was stable without any signs of inflammation or pockets, and the radiographs showed no loss of bone height or density. The second case showed similar presentation and outcomes.

Tawil in 2008 [20]. published a few case reports which reported marginal bone loss on previously well osseo-integrated implants, 6 months after placement of unstable prosthesis. The patient reported to the periodontist with complaint of uncomfortable denture and presented with marginal bone loss around the implants which extended till the 6^{th} thread of the implants. A new prosthesis was fabricated and delivered, and the bone lesions began to heal within 3 months after elimination of the traumatic condition. The author concluded that the marginal bone loss could only be attributed to occlusal overload as the patient was on regular periodontal maintenance over the years.

Uribe [21] in 2004 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. The patient presented with erythema and pocket depth of 6mm around the implant. It was also showed premature contacts with the opposing dentition. The sequence of treatment included occlusal adjustment followed by surgical therapy. The implants remained stable, Twelve months after treatment. The Case report emphasizes on the importance of occlusal adjustment for attainment of a successful surgical treatment. They also highlighted the need for histologic evaluation of the tissue around the implant to determine the cause for implant failure.

Quirynen [22] in 1998 assessed ninety-three implant patients with several implant restorations over a period of 3 years. They observed that the amount of crestal bone loss was associated with occlusal loading or presence of parafunctional activity. They however didn't mention the association of plaque around implant and crestal bone loss.

It is interesting to note that a case of peri-implantitis will also have a similar presentation like mobility, except there will be considerable amount of plaque-induced inflammation of the marginal soft tissue associated with it [23]. Radiographically, Plaque-induced peri-implantitis is being described as "saucer-shaped bone loss", in which the bone loss occurs within the limitation of the inflamed tissue. The type of implant mobility mentioned in the case reports seem like the "functional mobility" or "fremitus" reported in human teeth, which were reported as cardinal signs of "trauma from occlusion" in human teeth [24-26].

Current concepts of occlusion in implants

Misch [27] in his various articles and books has used the term "implant-protected occlusion" to refer to an occlusal scheme that is designed for the restoration of endosteal dental implants. Along with that it also emphasises on an improved clinical long term stability of the implant and the prosthesis. Some important facts to remember when placing an implant are

- An implant differs from a natural tooth in that it lacks a periodontal ligament which acts as viscoelastic "shock absorber". Thus an occlusal load subjected on the implant is directly transferred to the bone rather than absorbing and dissipating in itself. Thus bone-implant biomechanics should be given due consideration when planning a prosthesis [19].

- The diameter of nearly all the natural tooth is wider than the diameter of the implant to be used to substitute that tooth. The greater the width (of a tooth or an implant), the lesser the degree of stress into the surrounding bone.
- Implants should be placed along the long axis, respecting the angulations of the adjacent natural teeth. Shear (lateral/sliding) load should be eliminated as much as possible as cortical bone is strongest in compression (stress directed at long axis) and 65% weak in shear stress.
- A regular or wider implant is always indicated than a mini or a narrow implant as the stress is more in the later. This is because lesser the area that receive a force, greater is the stress produced. In case a narrow diameter implant is indicated or when the angle of load is not axial to the implant body, it should be supplemented with additional implants.

Conclusion

Occlusion is the medium which brings all the branches of dentistry together. It is also the main factor affecting the behaviour of the supportive periodontium. Hence, whether or not it is a causative factor for progression of periodontal disease, the importance of identifying the occlusal discrepancies which may affect the periodontium cannot be disregarded. The above-mentioned studies, if not completely, but somewhat tries to clear the controversy regarding excessive occlusal overload around implants. As the current notion stands vis-à-vis occlusal trauma and the periodontium, wherein it is considered that occlusal trauma may not be an etiological factor in causing periodontal breakdown, but is certainly a supporting factor, the presence of plaque or microbial component being the primary cause. Likewise, the tissue around implants can also be thought to react in a similar way.

It can be inferred that re-osseointegration appears achievable once the occlusal load is removed; provided that the peri-implant tissues are devoid of any inflammation, the marginal soft tissue seal is not compromised and the duration and the intensity of the applied load have not overwhelmed the repair potential of the bone. While there is no question about the fact that more studies are needed to help understand the mechanisms by which occlusion can have an effect on the dental implant and peri-implant condition, a clinician should strive to provide a balanced and an optimum occlusion in and around implants which would enhance the periodontal tissue around it and also increase the longevity of the implant.

Conflict of Interest

None.

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