Biomechanical risk factors for implantosupported prostheses — literature review

Marcelo Barbosa **RAMOS***
Luiz Alves de **OLIVEIRA NETO****
Max Dória **COSTA***
Paulo Martins **FERRREIRA***
Luiz Fernando **PEGORARO*****
José Henrique **RUBO******

Abstract

Introduction: The masticatory efforts applied over the prosthesis implant-supported may compromise the success of treatment. Implants are susceptible to various risk factors, including the biomechanics of order, involving the understanding of applied occlusal loads or overloads on all components of the biological system (bone and periodontal support) and mechanical (prosthesis-implant components). **Objective:** The purpose of this review is to discuss the risk factors of order biomechanics and its influence on the success of implant prostheses. **Conclusions:** The authors concluded that the control of biomechanical loads received by the implant-prosthesis are critical to the longevity of the treatment, because they act directly on the prosthesis, screws, intermediate, implant and bone support.

Keywords: Dental implants. Risk factors. Prostheses and implants.

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Marcelo Barbosa Ramos
Al. Octávio Pinheiro Brisolla, 7-12, Ap 15 – Vila Universitária
CEP: 17.012-901 – Bauru/SP – Brazil
e.mail: marcelobr74@yahoo.com.br

* PhD Student in Oral Rehabilitation, Bauru School of Dentistry.
** Full Professor, Department of Prosthodontics, Bauru School of Dentistry.
*** PhD and Full Professor, Department of Prosthodontics, Bauru School of Dentistry.
**** PhD and Full Professor, Department of Prosthodontics, Bauru School of Dentistry.

Introduction

The success of osseointegration, stabilized over the last years, ensured to dental implants the credibility to assume the best material for root replacement. Nonetheless, the masticatory forces applied on the implantosupported prostheses can cause the peri-implant bone loss with different severity levels, depending on the site and magnitude of these forces. Biomechanical risk factors involve the understanding of load or overload applied on all components of the biological (bone-periodontal support) and mechanical (prosthesis-implant components) system.

The biomechanics of the distribution of forces on the prostheses supported by implants is highly complex, including many factors, such as: Amount, position, implant inclination and size, shape and extension of infrastructure and cantilever, physical properties of materials involved in implants, components, infrastructure and coverage, as well as the interface between prosthetic components and implants, bone-implant interface.[1,2,3]

Material and Methods

The authors, who are experts in periodontics and dental prosthesis, established a search strategy to decide the main factors related to risks in Implantology, based on best available evidence. The survey was performed through a search in MEDLINE (PubMed) database of the literature published between 1983 and 2011. Combinations of different keywords were performed, including terms dental implants, biomechanical risk factors and failures in the treatment planning. After eliminating double quotes, 30 full articles were included. Abstracts which were not available in English, as well as clinical case reports were excluded.

All relevant works related to the subject were considered for the inclusion. In addition, references of classic books and systematic review articles were included.

Literature Review

Positioning and design of the implants

During the planning step, the appropriate position for the implant should be studied. Working also the distribution of the inclination, the risk of mechanical and biological problems can be reduced, since the malposition complicates the construction of the prosthesis (Fig. 1). A higher number of implants for a particular prosthetic space supports better masticatory loads, dissipating more effectively stress on the bone. However, very

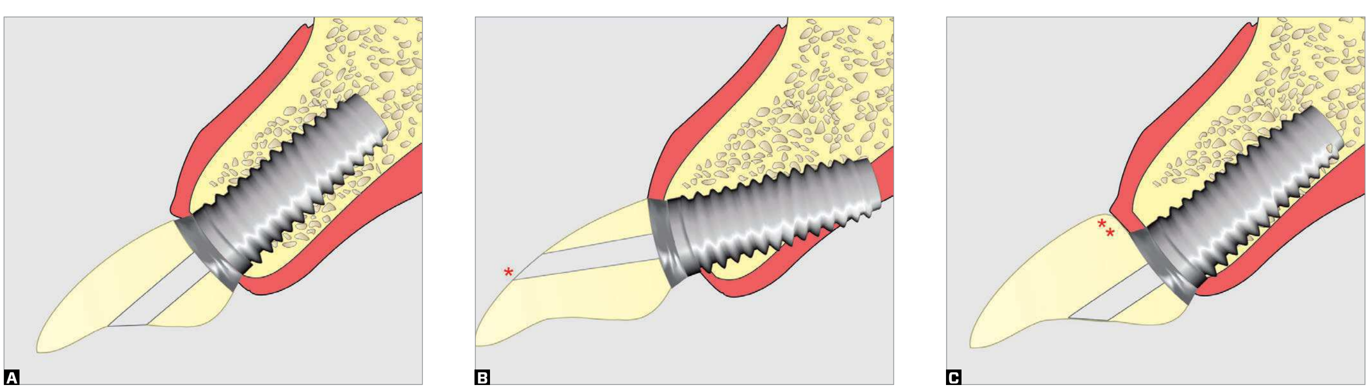

Figure 1 - Improper positioning of the implant can result in vestibularization of the access hole to the fixation screw (*), or use of overlap (**) to regularize the position of the crown.

close spaces between implants can cause biological impairment due to the poor vascularization of remaining bone among the implants, in addition to difficulty of hygiene after the construction of the prosthesis.[4]

The diameter of the implant should also be directly related to bone thickness, interdental space, esthetics and occlusion. Wide-platform short implants are more biomechanically appropriate for replacing posterior teeth due to biological contours similar to those found in cervical margin of natural teeth. However, large-diameter implants in thin bone, with less than 1 mm thickness among bone plaques (V-L), can cause the bone dehiscence due to the small irrigation.[5,6]

Space between implants is related to the number and diameter of the implants and should have approximately 3-5 mm depending on the bone type . However, between the implant and tooth, minimum space should be 2 mm (Fig. 2), allowing an adequate hygiene protocol of prostheses.[5,6]

Different sizes of implants may be found in the market, ranging between 7 mm and 20 mm. But, its use is conditioned to the height of the remaining bone. Long-term success of the implants depends on the amount of the existing bone between the bone-implant that is proportional to the length, surface and quality of bone available. On the other hand, failures may increase as the bone anchor decreases. Therefore, placing short implants in which the bone structure allows longer implants should be avoided.[5,6]

Recent data suggest implants with rough surface provide higher bone contact supporting the healing, besides providing higher fixation of the implant during the healing period. Currently, all implants practically have some type of surface treatment, and therefore many types of surfaces have been developed seeking a better clinical performance.[4]

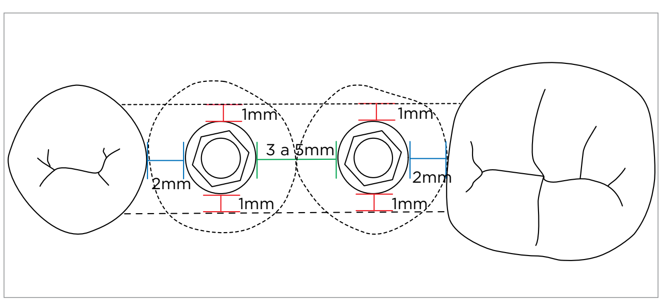

Figure 2 - Minimum measures between tooth-implant (blue), implant-implant (green) and bone implant-crest (red).

Bone-Periodontal support

Distribution of forces on dentosupported prostheses has the resiliency of the periodontal ligament. In implant prostheses, it depends on the deformation level of screws, intermediate, prosthesis, implant and bone tissue, once the osseointegration lacks the presence of periodontal ligament.[7] The connection between prosthesis and implant is an area subject to high levels of tension because it is located next to the alveolar bone crest, area in which the masticatory forces are dissipated.[1]

Bone tissue remodels its structure according to the load imposed and this bone remodeling at the cellular level occurs through a balance among the osteoclasts (resorbs bone matrix) and osteoblasts (synthesize bone matrix). Isidor[8] observed denser bone around the mechanically loaded implants when compared to implants which did not received loads. In another histomorphometric study[9] almost no osteoclast, inflammatory cells or marginal resorption were found in axially loaded implants, and the bone become denser in the cervical margin.

The mechanical overload can cause biological failures. When a pathological load occurs, stress and tension generated in the peri-implant site exceed the physiological threshold tolerated by the bone, causing microfractures in the bone-implant interface.[10] The application of repeated load can cause failure for fatigue of the interface, decreasing the peri-implant bone density and leading to formation of crater-like bone defects.[10]

The effects of mechanical loading are dependent on factors, such as direction, magnitude, duration and load rate applied. Long-term load and lower amplitude have the same effect on bone formation than the short-term load and higher amplitude. Thus, the loading should be cyclic to stimulate the formation of new bone.[11] On the other hand, prostheses with no passive adaptation can generate an additional stress on the system, accumulating tensions after the application of masticatory loads.

Occlusion in prosthesis over implant

To distribute more properly the masticatory forces, a scheme of mutually protected occlusion with low cusps and reduced occlusal platform facilitates the direction of the forces, favoring the biomechanics and minimizing the deleterious effects.[4]

When the height of the abutment-crown complex is exaggerated, the lever arm for the implant is significantly larger (Fig. 3). If lateral forces are increased, the risks of fracture of screws and components are increased. Therefore, a malocclusion in facilitated protrusive and lateral excursions is essential.[4,12]

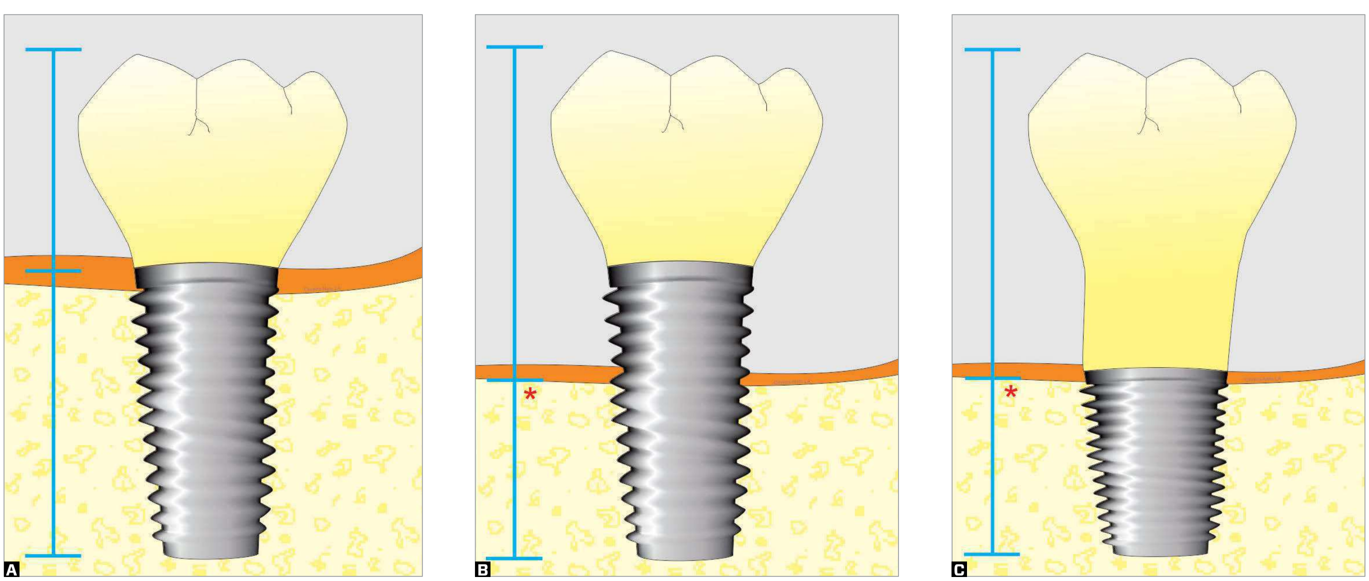

Figure 3 - Height of the abutment-crown complex should be close to ½. In cases of bone loss and short implants, the displacement of the fulcrum of the lever occurs in the apical direction.

Parafunctional habits, such as bruxism and clenching,4 may create some complications due to excessive and continuous force, affecting the prosthetic components and covering materials, and exceed the capacity of the bone to support such loads. In teeth clenching, the excessive loads are vertical, while the eccentric forces along axis are present in the bruxism, and may cause loosening or even fracture of screws.[4]

Design and adaptation of the prosthesis

In a clinical study, Kreissl et al[13] observed a higher success rate in prostheses on splinted contiguous implant (86.1%) when compared to single crowns (77.8%) and prostheses with cantilever (68.6%).

Cehreli et al[14] compared the tensions around immediate implants supporting single and splinted prostheses. Although a prosthetic design has not shown clear advantages on the other, the splinting of the implants can be considered a safety measure. In addition, Clelland et al[15] observed the attached prosthesis distribute the tensions more uniformly; however, data of tension distribution were not statistically different than that observed in non-attached prostheses.

Regarding the union between tooth and implant in the prosthesis, regardless of the type of connection used, it is considered as a risk factor, once the teeth have mobility 10X higher than implants.[4] The occlusal perception in teeth is around 20 µm, and in tooth-implant union is around 40 µm. When the occlusion occurs only among implants, the perception is approximately 64 µm. Therefore, the tooth-implant union should be avoided whenever possible.

In the work of Sallan et al[16] it was found infrastructures of three elements with cantilever they noted major deformations in simulated bone around the implants than those with suspended pontic among the abutments for the loading conditions applied. Whenever possible, prosthetic extensions should be avoided. However, when its use is required, it shall be to mesial extension of installed implant. In cases of lower protocol in which the cantilever are required and to distal extension, the approximate extension shall be, at maximum, 20 mm (Fig. 4).[3,4]

Another important point is related to the fixation type of the implant prosthesis and passive adaptation. Akça et al[17] found in cases of fixed prostheses the tension generated at the level of the bone crest is similar in both the cemented and screwed prostheses when subjected to a static load of 150N. However, in works by Guichet et al,[18] Heckmann et al,[19] in conditions without load, the cemented prostheses showed lower stress levels than screwed prostheses. According to Clelland e Van Putten[20] the association of two procedures (cementation and screwed) minimizes the stress transmission and provide a more balanced distribution. On the other hand, Duyck; Naert[21] found the combination of cementation and fixation with screws was not effective in reducing the preload on

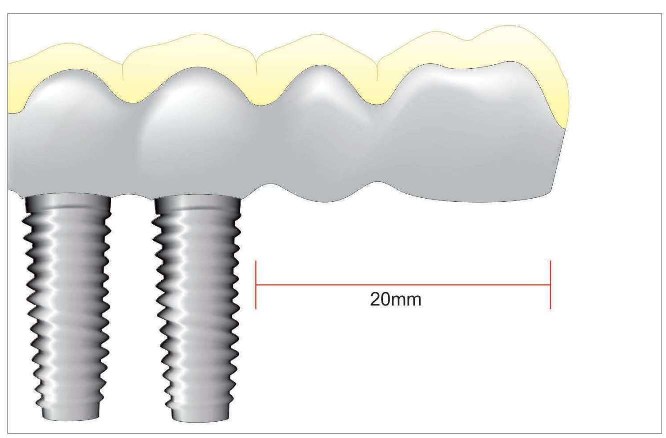

Figure 4 - Size limit to the lower protocol cantilever.

the implants caused by unadapted prosthesis, and it failed to improve the load conditions on the implants, although the cementing system could compensate the maladjustment visually.

The precision for adaptation has been questioned as a significant factor in transfer of stress, biomechanics of implant systems, occurrence of complications and response of tissues at the biological interface.[22,23] The presence or absence of a microspace between infrastructure and platform is not necessarily indicative of passivity, and micro-gap may not be clinically reliable as a measure of precision for adjustment.[23]

According to current scientific evidence, the clinical and laboratory procedures utilized in the confection of prostheses on implant are inadequate to propitiate a totally passive adaptation and it can conclude an absolute passive settlement could not be obtained.[24-27] In addition, a maladaptive prosthesis generates stress and additional tension, decreasing the longevity of the components, and the magnitude of the stress depends on the amount of maladjustment.[22,25]

However, such distortions can be camouflaged when the clenching torque is given in all screws, making the infrastructure seems to be adapted, thus causing external preload tensions on the system.[23] Furthermore, the capacity of a torque to close the clefts in the screw depends on the dimension and location of such clefts. Thus, Skalak[28] emphasized that stresses can cause failures even in the absence of external forces, although they may not be detected visually or clinically.

In screwed prostheses, there is a relationship between lack of adaptation and subsequent failure of the screw.[7] The loosening usually precedes the fracture of the fixation screw in the prosthesis, conveniently the weakness of the system, because it can easily be reset.

According to Jornéus, Jemt and Carlsson,[29] the preload should be as high as possible to provide a contact forces between the prosthesis and the implant. While materials are more rigid, the union is more stable. Furthermore, all materials have a particular elasticity and the screw suffers a stretching when subjected to tension forces during clenching. Titanium screws allow a good safety margin in most clinical situations.[29]

With respect to the materials of infrastructure, according to some authors[24] for situations in which a more predictable preload is desired, the prefabricated, machined metal cylinders provide better adaptation and higher pre-loads when compared to fusible plastic cylinders. The use of cobalt-chromium alloys for implantosupported prosthesis structures may be considered clinically acceptable as silver-palladium alloy.[30]

Different preparation techniques of the infrastructure for implant prosthesis are reported in literature. Goll[24] recommended the casting in monoblock or single piece, justifying the welding of two or more portions of the infrastructure could change the properties of the metal. However, some strategies can be used to achieve a settlement of the infrastructure,[25] such as the use of metallic alloys with low shrinkage casting, sectioning of the infrastructure and subsequent welding,[20] because no casting will present a completely passive adaptation in a micrometric form. Thus, it is impossible to predict the biological response of the implants regarding a static force when a prosthesis with no passive adaptation is screwed.

Discussion

In the planing phase, before deciding the number, size and diameter of implants, we should take into account several factors, such as: Mesiodistal space, volume, height, bone density and occlusion regarding the antagonistic dentition.[4] All these factors are essential for the biomechanics of the implant prosthesis .

The mechanical stresses applied on an implantosupported prosthesis are invariably transferred to the prosthetic components, implant and from these to the underlying bone tissue.[28] Several authors[2,9,14] agreed stress is concentrated mainly on the periosteal surface in bone crest area around the implants.

The load influences significantly both on cell turnover and bone density around implants.[8,9] Clinically, it is difficult to quantify the magnitude and direction of forces which occur naturally, making it difficult to correlate with failures of implants. Studies with animals have shown that occlusal overload can result in an increased marginal bone loss around implants, contrasting the clinical studies in which marginal bone loss was observed in relatively high stress areas, but the causal relationship with the overhead could not be established.[8]

A judicious occlusal adjustment is indispensable in implantosupported rehabilitations, particularly in cases of patients with parafunction in which excessive occlusal loads are found. This problem can be minimized with the use of acrylic occlusal plaques.[4] Occlusion should be very well distributed with forces distributed over most implants and the cantilevers reduced whenever possible.

The control of the forces is facilitated by splinting the prostheses using rigid connectors. The cantilever increases the risk of overload on implants[3,16] and the union between tooth and implant is considered as a risk factor and should be avoided.

Another frequent source of discussion in existing literature is the fixation type for prosthesis over implants and passive adaptation. However, the preparation procedures for cemented or screwed implant prostheses produce small rotational distortions, causing wide vertical clefts. The possible sources of imperfections inherent to the preparation procedures for prosthesis should be observed as follows: Casting, obtaining the model, inclusion, welding, properties of alloys and casting and coating materials, and esthetic coverage of the infrastructure, as well as finishing, polishing, characteristics of the implant components, especially intermediates, cylinders and screws.[19,24,25]

The preload should be as high as possible to provide contact force between the implant and the prosthesis or intermediate. However, when a sufficient preload and/or an appropriate adaptation are not established between the implant and prosthesis, the retention screw can suffer deformation. The shearing force generated on the screw can be higher than it can support, and it may cause metal fatigue and even its failure and fracture.[7]

After the prosthesis installation, the implant failures are observed and correlated with biomechanical complications, and mechanisms related to these failures are not fully understood yet, and the literature regarding the influences of many biomechanical factors is inconclusive.[10] We cannot ignore that the control of the biomechanical loads received by the prosthesis system, screws, intermediate, implant and bone system are fundamental factors for the longevity of the treatment, as well as the control of bacterial biofilm.

Thus, (clinical and radiographic) follow-up of the patient by the practitioner is extremely important. The cleaning with the use of interdental brushes and dental floss are indispensable. The health of the peri-implant tissue should be kept stable and healthy. The lack of detailed instructions for the patient in post-operative stage or the failure by the patient to comply with the instructions of the practitioner can cause situations of difficult resolution later. Poor communication among practitioners and between practitioner and patient can cause treatment failure.

Conclusion

The control of biomechanical loads received by the prosthesis, screws, intermediate, implant and bone support system are fundamental factors for the longevity of treatment.

The correct previous planning of the positioning, distribution, length, diameter and surface characteristics of implants support a better clinical performance. Additionally, judicious occlusal adjustment is indispensable in implantosupported rehabilitations by promoting a better distribution of masticatory forces.

Understanding the options and limitations for treatment with prosthesison implants will allow the professional to choose the most appropriate techniques, materials and prosthetic components for each case. Although there are limitations to a prosthetic design, splinting should ideally be used among implants as a measure for prevention of complications. Prosthetic extensions (cantilever) can be used with caution; however, tooth-implant union must still be avoided.

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