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State of the art of occlusion in dental implants: a systematic review

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Abstract

Introduction: Dental implants are a regular feature in daily clinical practice and there is a need to perform routine evaluation and maintenance of implants and their restorations. Occlusal checks form an important part of the maintenance regimen to preserve the integrity of implants, their restorations, and the health of peri-implant tissues. The risks attributable to occlusal forces mainly affect implant restorations and are elevated in the presence of bruxism. **Objective:** This study presented the main clinical considerations of occlusions in dental implants. **Methods:** The PRISMA Platform systematic review rules were followed. The search was conducted from October to November 2024 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** 102 articles were found, 45 were evaluated in full and 24 were included and developed in the present systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 15 studies with a high risk of bias and 22 studies that did not meet GRADE and AMSTAR-2. Most studies did not show homogeneity in their results, with X^2=82.2%>50%. It was concluded that occlusion is a factor directly responsible for the success or failure of treatments performed with dental implants. It directly interferes with the distribution and absorption of loads resulting from mandibular movement. Understanding how these loads work requires the clinician to seek multiple knowledge, mechanical and biological so that prosthesis planning is well executed.

Keywords: Dental implant. Occlusion. Peri-implant tissues. Occlusal forces.

Introduction

With the evolution of implants, studies are needed on techniques and procedures that facilitate and make implant placement surgeries feasible. Prosthetic planning with the correct distribution of masticatory forces through adequate occlusal adjustment is a key factor in planning prosthetic rehabilitation with implants [1,2].

Before the implants are installed, the patient must receive prior prosthetic preparation and, based on this, the implants are installed and the definitive prosthesis is made. This work philosophy is called Reverse Planning. Visualizing the rehabilitated case, the surgeon and prosthetist must talk to outline the treatment plan, so that it can be passed on to the patient [2,3].

For the correct planning of prostheses on implants, some factors must be taken into consideration, among which are the differences between teeth and implants related to mobility, proprioception, wear, etc., importance of the periodontal ligament, arrangement and number of implants, size of the prosthetic crown; parafunction; overload and direction of the load; biomechanics; occlusion itself [1-4]. All these factors complement each other, as they involve the forces that are generated during the masticatory movement, how these forces are transmitted, and what the effects of this transmission of forces are on biological tissues [5].

The number of implants performed has increased alarmingly nowadays, and the simplification of surgical methods and the advancement of technology have made implant surgery a success in dentistry. Therefore, further studies are needed to develop occlusal adjustment techniques that aid in the success of oral rehabilitation with implants [1-4].

Therefore, the present study aims to present the main clinical considerations of occlusions in dental implants.

Methods

Study Design

The present study followed the international systematic review model, following the rules of PRISMA (preferred reporting items for systematic reviews and meta-analysis). Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed on: 11/10/2024. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: https://amstar.ca/. Accessed on: 11/10/2024.

Data Sources and Research Strategy

The literary search process was carried out from October to November 2024 and was developed based on Scopus, PubMed, Lilacs, Ebsco, Scielo, and Google Scholar, covering scientific articles from various eras to the present. The descriptors (DeCS /MeSH Terms) were used: *"Dental implant. Occlusion. Peri-implant tissues. Occlusal forces"*, and using the Boolean "and" between the *MeSH* terms and "or" between historical discoveries.

Study Quality and Risk of Bias

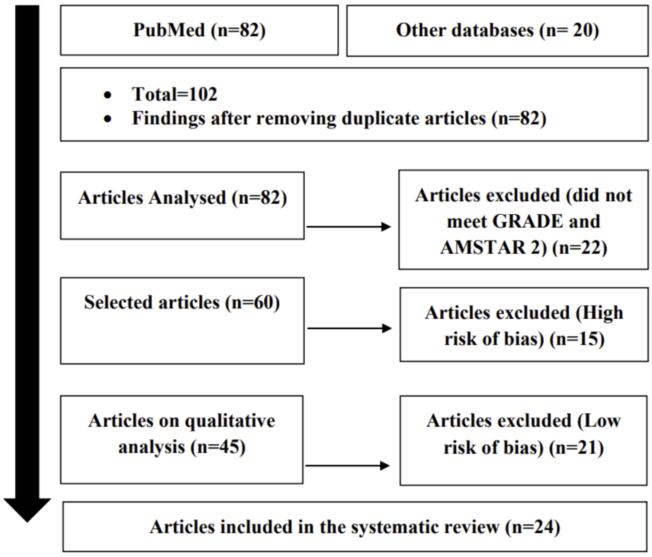
Quality was classified as high, moderate, low, or very low in terms of risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. The low quality of evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument by analyzing the Funnel Plot graph (Sample size versus Effect size), using the Cohen test (d).

Results and Discussion

Summary of Findings

A total of 102 articles were found that were subjected to eligibility analysis, with 24 final studies being selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. The biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies showed homogeneity in their results, with X^2=82.2%>50%. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 15 studies with a high risk of bias and 22 studies that did not meet GRADE and AMSTAR-2.

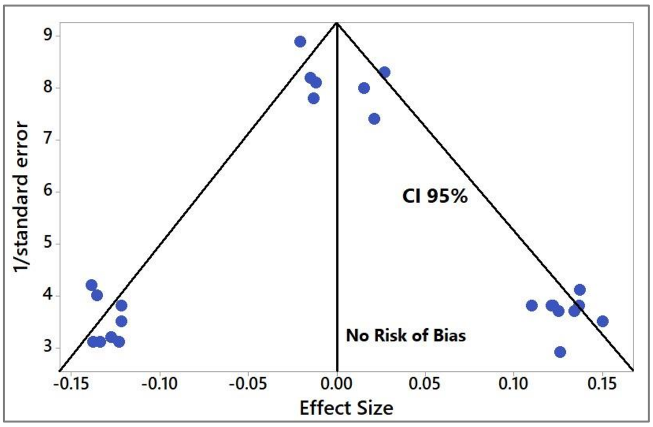
Figure 1. Articles eligibility process.



Source: Own authorship.

Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using the Cohen Test (d). Precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph had a symmetrical behavior, not suggesting a significant risk of bias, both between studies with a small sample size (lower precision) that are shown at the bottom of the graph and in studies with a large sample size that are presented at the top.

Figure 2. The symmetric funnel plot suggests no risk of bias among the small sample size studies that are shown at the bottom of the graph. High confidence and high recommendation studies are shown above the graph (n=24 studies).



Source: Own authorship.

Main Findings

The harmful effect of occlusal overloads is known, as it can cause cervical bone loss, implant fracture, and component loosening. Alternatives to minimize the forces transmitted by implants have been studied, including variations in the arrangement of implants, their shape and size, the shape of prostheses, occlusal requirements, prosthetic components, and the materials of implant-supported prostheses [1-3].

From 1994 to the present day, authors have agreed that a natural tooth can move in an apical direction 28 μm with an axial load. An implant subjected to the same load moves approximately 5 μm. A lateral force on a natural tooth is quickly dissipated, moving away from the bone crest towards the apex of the tooth. The healthy natural tooth moves 56 to 108 μm and makes a pivotal movement of two-thirds toward the conical axis. This action reduces the loads on the bone crest [2-4].

An implant moves 10 to 50 μm under similar lateral loads and does not have as much pivotal movement toward the apex as a tooth, but instead concentrates the greater forces on the crest of the surrounding bone. Therefore, if an initial load of equal magnitude and direction is applied to an implant and a natural tooth, the implant will receive a greater proportion of the load. Hence the importance of the implant being protected [4,5]. Thus, when a joint is made through natural teeth, the combined intrusive movement of the elements in contact can be 56 μm (28 μm + 28 μm). When a tooth has an implant as an antagonist, the combined intrusive movement is 33 μm (28 μm of the tooth and 5 μm of the implant). When a joint is made using implants, the combined intrusive movement of the elements can be 10 μm, compared with 56 μm in the rest of the mouth, in the case of a partially edentulous patient. Unlike teeth that move immediately, even with light loads, implants only move this amount with a stronger load [4-7].

Attempts have been made to compensate for the lack of the periodontal ligament, using materials with low rigidity between the prosthetic components and as an occlusal coating, it was proposed to use an implant system containing an intermediate plastic component, which would imitate the properties of the periodontal ligament. Some studies that studied this system were not able to demonstrate the benefits of its use [8].

Proprioception in the tooth is carried out by the mechanoreceptors of the periodontal ligament, leading to a very high tactile perception; in the implant, proprioception is provided by the bone, which is very low, and can be up to 5 times lower than in the ligament. Thanks to proprioception, in the presence of trauma, the arch of closure or occlusion can be modified to avoid trauma. Since the implant does not present this perception, it does not allow the adaptation of the occlusion and, despite the tooth being overloaded, the patient does not notice it, leading to excessive stress on the implant [9-11].

Authors describe that the forces generated by an implant-supported fixed total prosthesis are similar to the forces generated in the natural dentition [2,3,12]. This suggests that the longitudinal strength of the implant and the strong integration with the bone influence the neuromuscular feedback mechanisms that control the occlusal force. In patients with extensive rehabilitations, purely supported by implants, there is normal clinical function, since the absence of proprioception of the ligaments is compensated (with sensory deficit) by the nerve endings of the periosteum, masticatory muscles, oral mucosa, temporomandibular joints (TMJ), among others. These data have generated a great discussion of concepts in the literature with the creation of a term called osseoperception [13-15].

Understanding occlusion in natural dentition is essential to developing optimal occlusion in prostheses on osseointegrated implants. An ideal occlusion can be defined as an occlusion compatible with the patient's masticatory movements, developing efficient mastication associated with good aesthetics and phonetics [3,4,16]. When the prosthesis is inadequately planned in terms of the number of implants, even if the occlusion principle is correct, excess load can fracture or compromise the work. It is ideal to place a sufficient number of implants to support the prostheses. Complementing this statement, it has been stated that the greater the length of the implant, the better its behavior under occlusal forces [17,18].

Ideally, the implant would have the same surface area as the root of the tooth to be replaced. And despite the current trend of reducing the number of implants used in rehabilitations, the forces suffered by these implants are certainly much higher than those that would be supported by a greater number of implants for the same type of prosthetic piece. The reduction in the number of implants requires great care with the force angle since increasing this angle greatly increases the resulting force. When more than two consecutive implants are placed to better distribute forces, they should not be placed in a straight line [2,4,19].

Implant splinting increases resistance to occlusal forces. In the case of multiple implants, and to better absorb horizontal forces, the geometric arrangement of the implants is indicated, since we are reducing the rotation axes of the prosthesis. Therefore, posterior prostheses on multiple implants should ideally be joined. Some research on the absorption of masticatory load has shown that: for the replacement of a molar with two or three roots, the best solution for absorbing vertical forces is a wide-platform implant and not two narrow-platform or regular-platform implants, which would lead to the inconvenience of determining an increased occlusal surface or even difficulty in hygiene between the implants [20,21].

The height of the crown in the implant prosthesis is greater than the crown of the natural tooth, due to bone loss. Thus, the height of the crown will function as a vertical cantilever, meaning that the angled load applied to the crown will have a force component that will be multiplied by the height of this crown. The greater the height of the crown, the greater the resulting load on the crest in lateral movements, this is a consequence of angled load. Angulated abutments with crowns of greater height increase the moment loads on the bone crest [23]. The wider the occlusal table, the greater the number of contacts during chewing or parafunction.

The narrower the implant surface, the greater the influence of the width of the occlusal table with compensatory loads. The height of the crown has a very large influence on the amount of force distributed in the prosthesis-implant system. The larger the crown, the greater the moment of force, especially under lateral forces. Increasing the crown can multiply this stress quickly. For every 1um of crown increase, a force can increase by 20.0 % [24].

A narrowing of the width of the occlusal surface by 30.0% causes a significant reduction in the lateral force components. Regarding food consistency, soft food is suggested when immediately loading implants. Irregular occlusal forces, such as those caused by bruxism or clenching, also contribute to complications with the prosthesis. These interferences are often detected late, compromising the design of the new prosthesis. Regarding bruxism, it has been stated that the best way to protect implants from occlusal overload is to use an occlusal splint, normally worn during sleep [5].

Still regarding bruxism and clenching, it has been described that some parafunctional habits such as bruxism and dental clenching create mechanical and biological complications, since they compromise components and coating materials, in addition to exceeding the bone's capacity to support such loads. In dental clenching, the excessive loads are vertical, while in cases of bruxism, the friction causes eccentric forces along the axis of the implants, responsible for loosening or even fracture of screws. However, bruxism does not present a contraindication for implants, but it greatly influences planning. However, the literature points to bruxism as a contraindication factor for rehabilitation with implants. However, few welldesigned studies have systematically addressed the cause-and-effect relationship between bruxism and implants and have failed to establish this relationship [5]. In studies carried out to quantify occlusal forces, prematurity up to 200um did not cause overload at the level of the implants [3-5]. Several authors agree that the relative stiffness of titanium and alveolar bone (compared to the flexure allowed by the periodontal ligament) concentrates the maximum force in the area of the third implant thread. And a three-dimensional finite element stress analysis also indicates that the force applied to the implant results in a concentration of force in the bone crest, rather than distribution across the entire implant surface [1-4].

Occlusal forces directed at the intercuspal inclinations of the posterior teeth during excessive movements can be destructive due to their high intensity. In contrast, the bite force of the anterior teeth corresponds to 1/8 of the force generated in the second molar. The reduced occlusion force in the anterior teeth region allows them to guide excursions. For this reason, anterior guidance with posterior disocclusion and reduced cuspal inclinations are preferable for prostheses with osseointegrated fixation. Confirming that the occlusion force is greater in the posterior region [3-5].

Authors are unanimous in stating that to the pattern of force distribution in implantsupported prostheses, we must observe the magnitude, duration, frequency, distribution, and direction of occlusal forces during function and parafunction, which decisively determines the survival of both the prosthesis components and the implants. Occlusion is an important factor in determining the direction of the load. Compressive forces should predominate in the occlusion of implant-supported prostheses, as they are less harmful than tension forces. They also agree that the occlusal force should also be transmitted through the long axis of the implant to eliminate the destructive lateral torque forces, which may result in implant failure [1-3].

The cusp-fossa occlusal relationship is accepted as biomechanically favorable, as the buccal and lingual force line components produce a resultant vertical force line that is biomechanically favorable. However, the precision of this contact is clinically unattainable, as the occlusal contact is a small area and not an immutable point. This as a result of a physiological assessment of the muscle will result in only an inclined contact, producing a laterally inclined line of force. The anatomy of the occlusal surfaces, or area of impact, determines the direction of the resulting line of force, relative to the implant or natural tooth root, and supported bone will determine the character of the applied force [5].

It is important to understand simply that if the cusp occludes in a flat fossa, the resultant force line passes vertically close to or in line with the supported bone. Therefore, when the cusp contact is inclined, the resultant force line passes obliquely away from the supported bone. This creates a lateral force component that is more deleterious to the supporting bone than the vertical force. A simple laboratory technique was described and created to produce a modified occlusion anatomy containing a 1.5 mm horizontal fossa. With this configuration, a mandibular cusp will produce a resultant vertical force line within the expected spectrum of physiological variation [4,5].

Given this, there are four clinical variants (cusp inclination, implant inclination, horizontal implant compensation, and vertical implant compensation) that were compared mathematically to torque production (moment) and the following conclusion was made: for each 10-degree increase in cusp inclination, there is an average increase of 30.0% in torque production: a 10-degree increase in implant inclination produced only a 5.0% increase in torque; for every 1 mm of horizontal offset, there is an average change of 15.0% in torque production; for every 1 mm of vertical offset of the implant, there is only an average of 5.0% in torque production [3-5].

Implant-protected occlusion dictates that the width of the occlusal table is directly related to the width of the implant body. The width of the crown is reduced to favor axial loads on the implant in non-aesthetic regions. For example, in the posterior region of the mandible, the occlusal table is reduced in the buccal direction, increasing the overjet. No premature contact or interference. The lingual contour remains the same and out of contact. The first centric contact is over the implant region, which corresponds to the central fossa of the lower posterior teeth. An occlusal contact on the buccal cusp is not indicated because it can result in compensatory loads [5].

Occlusion in Single Implants

Single teeth on implants in the posterior region should be left without occlusal contact. When adjacent natural teeth come into contact during masticatory function, they suffer a small intrusion. In the anterior region, the single prosthesis on implants participates in the anterior guide, disoccluding the posterior teeth in the protrusive movement [1,2]. For the placement of implants with immediate loading, occlusion in a single prosthesis with immediate loading, in the case of teeth in the anterior region and premolars, a temporary tooth with only an aesthetic function should be placed, without contact with the antagonist. If a permanent porcelain tooth is placed, the contact will be in maximum intercuspation, avoiding lateral contact. In the case of upper premolars, the temporary tooth should be made with a canine shape, avoiding the palatine cusp; posterior fixed prostheses on implants with immediate loading, stronger contacts should be maintained on the natural teeth and very soft on prostheses on implants, with the intensity decreasing from premolars to molars. In the definitive prosthesis, the contacts should be the same as the natural teeth in cases where an entire quadrant is to be re-established. Promote disocclusion in the posterior teeth; upper or lower protocol on implants, when four to six implants are placed in the anterior region with fixed rehabilitation, the occlusion should be re-established with maximum intercuspation coinciding with the centric relationship [2-5].

The occlusal scheme is that of mutual protection. With a vertical dimension of occlusion that allows a free functional space of approximately 3.0 mm, observing principles of aesthetics and phonetics. Upper and lower fixed rehabilitation on implants: we rarely perform this type of protocol simultaneously. However, if it is performed, it is preferable to adopt the Mutual Protection School, avoiding contact with the posterior teeth in lateral movements. When making definitive porcelain prostheses, it is advisable to make a night protection plate to protect against parafunction events, should these occur [5,6].

Because of proprioception, an initial premature contact on a tooth always affects jaw closure, resulting in a centric occlusion that is different from the centric occlusion relationship. Premature contact on an implant crown does not benefit from such protective features and results in an increased risk. The occlusal contact on the crown of an implant should ideally be on a flat surface perpendicular to the implant body, with an increased central groove (2 to 3 mm) and the antagonist cusp should be adjusted to occlude in the central fossa directly over the implant body [4].

Biomechanical factors and physiological processes are interrelated and thus reactive, i.e. they produce a cumulative effect that can lead to implant overload. Given this fact, therapeutic biomechanics uses the principles to be followed to dissipate deleterious forces during occlusion: a) Implant placed as close to the midline of the prosthesis as possible, in addition to using the inclination of the implant, producing less torque than the horizontal compensation of the implant; b) Whenever possible, use posterior cross occlusion to reduce the horizontal compensation of the implant; c) Angled or re-angled abutments that result in parallelism or access; d) The posterior inclination of the cusp produces maximum torque and should be reduced considerably; e) Due to physiological variability, a modified centric occlusal anatomy with 1.5 mm of horizontal fossa is recommended to maintain the resulting vertical forces within the spectrum of physiological variation [6-10]. It is important to note that in the anterior region, post-extraction bone loss produces a marked vertical overlap, resulting in a biomechanical reactivity of high torque level in centric occlusion. To reduce the problem, it is recommended to place a horizontal stop point on the lingual surface of the maxilla, redirecting the damaging lateral forces, and verticalizing them towards the supporting bone [10-12].

The implant-supported prosthesis must be made to transmit the chewing forces only along the long axis of the implant. To do this, the occlusal anatomy must be reduced with a shallow occlusal anatomy and wide grooves and fossae, thus preventing the food itself from generating lateral forces when being crushed. Transforming the fossa into a smooth surface (1.0 mm to 1.5 mm) ensures that the occlusal force is directed apically and allows greater freedom in occlusion [5,8,10].

The occlusal table must be as narrow as possible, leaving the implant well-centered. Sometimes the bite must be crossed over the implant to prevent the prosthesis from extending in the vestibular-lingual direction. The advantage of this occlusal anatomy only works if the opposing cusp is also modified. When the cusps come into cusp-fossa contact, occlusal stability is produced and consistent with the physiological variation of the masticatory muscles, producing vertical lines of force with a contact area in centric occlusion [5]. Posterior cross occlusion should be used whenever possible. The inclination of the posterior cusp should be considerably reduced. When a vertical overlap is present in the anterior part, a horizontal stop on the lingual surface of the maxilla redirects the damaging lateral force, so that it is vertical to the implant and the supporting bone. This occlusal pattern has the advantage of eliminating the cutting function of the lower buccal cusp, eliminating the potential for lateral forces; the short lower buccal cusp avoids any interference with excursive movements; and finally, the number of contacts decreases, thus making adjustment easier. The disadvantage is the reduction in masticatory efficiency and aesthetics [6].

In the occlusal adjustment of a single crown, the initial difference in vertical movement of the teeth and implant in the same arch may be 28 μm; the initial occlusal contact should take this difference into account. The dentist should use thin articular paper (less than 25 μm thick) for the initial adjustment in centric occlusion under a light torque force. The implant-supported prosthesis should barely make contact, and the surrounding teeth in the arch should exhibit more initial contact. After adjustment with a light occlusal force, a more pronounced centric occlusal force is applied, as this presses the natural teeth closer to the depressed position of the implants, thus sharing equal loads. A similar adjustment should be used when anterior implants and teeth are not coercive and dis occlude the posterior dentition during excursive movements of the mandible, ensuring that no contact occurs during the initial movement of the teeth in the occlusal or lateral direction. Then, a strong force is used during centric occlusion and excursive movements, as this will create similar occlusal contacts between the anterior implants and the natural teeth [2,5,6,23,24].

Conclusion

It was concluded that occlusion is a factor directly responsible for the success or failure of treatments performed with dental implants. It directly interferes with the distribution and absorption of loads resulting from mandibular movement. Understanding how these loads work requires the clinician to seek multiple mechanical and biological knowledge so that prosthesis planning is well executed.

CRediT

Author contributions: **Conceptualization -** Luis Andrés Palacios Tito, Josué Enmanuel Jiménez Reyna, Mario Coronel Olivera, Alvaro José Cicareli, Fábio Alarcon Idalgo; **Data curation-** Luis Andrés Palacios Tito, Josué Enmanuel Jiménez Reyna, Mario Coronel Olivera; **Formal Analysis-** Luis Andrés Palacios Tito, Josué Enmanuel Jiménez Reyna, Mario Coronel Olivera; **Investigation-** Luis Andrés Palacios Tito, Josué Enmanuel Jiménez Reyna, Mario Coronel Olivera; **Methodology-** Luis Andrés Palacios Tito, Josué Enmanuel Jiménez Reyna, Mario Coronel Olivera; **Project administration-** Luis Andrés Palacios Tito, Josué Enmanuel Jiménez Reyna, Mario Coronel Olivera, Alvaro José Cicareli, Fábio Alarcon Idalgo; **Supervision-**Alvaro José Cicareli, Fábio Alarcon Idalgo; **Writing - original draft-** Luis Andrés Palacios Tito, Josué Enmanuel Jiménez Reyna, Mario Coronel Olivera, Alvaro José Cicareli, Fábio Alarcon Idalgo ; **Writing-review & editing-** Luis Andrés Palacios Tito, Josué Enmanuel Jiménez Reyna, Mario Coronel Olivera, Alvaro José Cicareli, Fábio Alarcon Idalgo.

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