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Main clinical findings on the osseointegration in dental implants: a systematic review

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Abstract

Introduction: In the dental implant and osseointegration scenario, the treatment of oral rehabilitation with implants obtained a substantial evolution. At the time when the concept of osseointegration was pioneered by Branemark, the primary focus was directed toward functional rehabilitation. **Objective:** The present study aimed to carry out a systematic review of the main considerations of dental implants in osseointegration, as well as to emphasize all the processes involved. **Methods:** The rules of the Systematic Review-PRISMA Platform were followed. The research was carried out in June to July 2026 and developed based on Scopus, PubMed, Science Direct, Scielo, and Google Scholar. 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:** A total of 152 articles were found. A total of 72 articles were fully evaluated and 22 were included in the systematic review. A total of 44 studies were excluded because they did not meet the GRADE and AMSTAR-2 criteria, and 6 studies were excluded because they had a high risk of bias. It was concluded that to maintain osseointegration and prevent bone loss from implants, a better understanding of the osteoimmunology of the peri-implant environment would lead to the development of new therapeutic approaches. It is necessary to discuss immunomodulatory strategies to improve and preserve a long-term functional integration between dental implants and the human body. It is concluded that the bone saucerization around osseointegrated implants represents one of those specific concepts that are part of the implant dentist jargon.

Keywords: Dental implants. Bone loss. Osseointegration. Saucerization.

Introduction

In the dental implant and osseointegration scenario, dental medicine, besides being an art, is a science that aims to alleviate human suffering, since its main focus is the entire stomatognathic system [1]. The diverse areas of this science act in an orchestrated way to transform this suffering into equilibrium, within the biological and technical limits [2,3].

One of the factors that most fascinates professionals in Dental Medicine is the ongoing evolution of available means and techniques, capable of producing results very close to natural ones, both aesthetically and functionally [4]. Despite the current stage of technological evolution, there will always be the possibility of further steps [5,6].

In this sense, implantology is one of the branches of dental medicine that has evolved most as a result of the investigations carried out in the last fifty years [6]. The treatment of oral rehabilitation with implants has undergone substantial evolution. At the time when the concept of osseointegration was pioneered by Branemark, the primary focus was directed toward functional rehabilitation [1,6].

Over the years, patients and professionals have begun to perform implant treatments not only to restore masticatory function but also to acquire prostheses that are aesthetically pleasing, easy to clean, and fixed [5-7]. However, for the convergence of function and aesthetics to be possible, several processes are required, such as bone-implant integration, long-term implant stability, stable bone maintenance around the implant, and healthy tissue and aesthetically acceptable peri-implant moles [5,6].

A physiological process of perimplantar bone remodeling was observed during numerous investigations related to osseointegration and implantology [7]. This process is characterized macroscopically as loss of bone support around the implant, in the cervical portion, with or without osseointegration. Initially, acceptable standards and loss levels were adopted to frame the case as successful. With the development of techniques and materials, ie, increased static requirement and higher longevity expectancy, such acceptable levels have also changed [8].

Peri-implant cervical remodeling or pericervical bone remodeling, also known as pericervical saucerization or simply saucerization, is present in almost all osseointegrated implants [1,2]. The presence of the saucerization is inexorable and does not depend on the macro and micro implant design, the surface type, the form of connection of the prosthetic abutment and implant, the trademark, and the local and general conditions of the patient [8,9]. Knowledge of its biological and biomechanical mechanism is important to understand and, if possible, reduce or control this peri-implant cervical bone loss, and also provide guidance when acquiring, using, and evaluating this behavior in a particular implant system. It is important to distinguish it from peri-implantitis because it is pathological, progressive, and requires treatment [10].

In 1981, criteria were adopted for the success and survival of integrated bone implants [11]. Among these criteria is pericervical bone loss, which could occur up to 2.0 mm in the first year depending on the implant and up to 0.2 mm per year in subsequent years. With the technological, clinical, and scientific evolution of integrated bone implants, these criteria were reviewed. For current implants, this cervical bone loss should not be greater than 1 mm in the first year and 0.1 mm every year [11,12].

Studies and comparative studies of saucerization between different implant systems and types should be viewed with care and reservations [13]. It is necessary to take into account the differences between the methodologies used, the differences between surgical techniques, implant forms, and implant depth concerning the bone level, and many other factors. In the studies that intend to carefully evaluate the degree of saucerization in osseointegrated implants, all these variables should be considered in the evaluation of the results. Many theories and explanations have sought to explain the occurrence of saucerization but find it difficult to explain one aspect or another [14].

In the context of the question of saucerization related to osseointegrated implants, we aim to present, in an objective way, the main deductions about the evaluated elements, hoping that this work can provide the desired subsidies to serve as an indicator for other investigations on the subject [15].

Based on this context, the present study aimed to carry out a systematic review of the main considerations of dental implants in osseointegration, as well as to emphasize all the processes involved.

Methods

Study Design

This study followed the international systematic review model, following the PRISMA (preferred reporting items for systematic reviews and meta-analysis) rules. Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed at: 06/25/2026. The AMSTAR 2 (Assessing the methodological quality of systematic reviews) methodological quality standards were also followed. Available at: https://amstar.ca/. Accessed at: 06/25/2026.

Data sources and research strategy

The search strategies for this systematic review were based on the descriptors (DeCS /MeSH Terms): *"Dental implants. Bone loss. Osseointegration. Saucerization".* The research was carried out in June to July 2026 and developed based on Scopus, PubMed, Science Direct, Scielo, and Google Scholar. Also, a combination of the keywords with the booleans "OR", "AND", and the operator "NOT" were used to target the scientific articles of interest.

Study Quality and Bias Risk

Quality was classified as high, moderate, low, or very low regarding the 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. 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 Cohen's test (d).

Results and Discussion

A total of 152 articles were found. Initially, the duplication of articles was excluded. After this process, the abstracts were evaluated and a new exclusion was performed. A total of 72 articles were fully evaluated and 22 were included in the systematic review. A total of 44 studies were excluded because they did not meet the GRADE criteria, and 6 studies were excluded because they had a high risk of bias (Figure 1). Most studies presented homogeneity in their results, with Chi-Square (X^2)=78.5%>50%. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 06 studies with a high risk of bias and 44 studies that did not meet GRADE and AMSTAR-2.

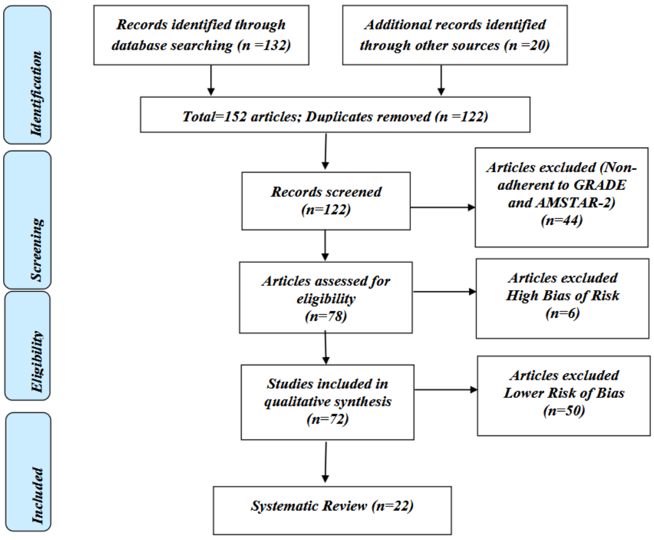

Figure 1. Study Eligibility (Systematic Review). Source: Own authorship.

Figure 2 presents the results of the risk of bias in the studies using the Funnel Plot, through the calculation of the Effect Size (Cohen's Test). The sample size was determined indirectly by the inverse of the standard error. The number of studies evaluated was n=22. The graph showed symmetric behavior, not suggesting a significant risk of bias in studies with small sample sizes, which are shown at the bottom of the graph.

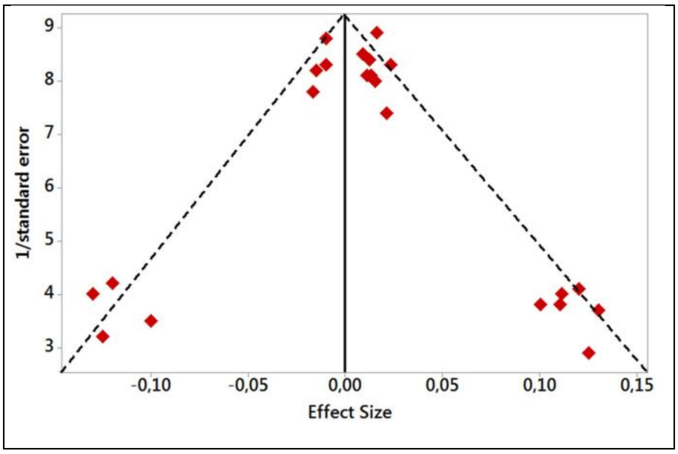

Figure 2. The symmetric funnel plot does not suggest a significant risk of bias between the small sample size studies that are shown at the bottom of the graph. N=22 studies. Source: Own authorship.

Results and Discussion

In the context of osseointegration and dental implants, there is a complex interaction between dental implants, bone, and the immune system. Among them, specific immune cells and macrophages play a crucial role in the dynamics of osseointegration. Macrophages contribute to achieving an early pro-regenerative peri-implant environment. In addition, multinucleated giant cells at the bone-implant interface and their polarization capacity maintain a peri-implant immunological balance to preserve the integrity of osseointegration. However, dental implants can present cumulative levels of antigens such as ions, nano- and microparticles, and bacterial antigens at the tissue-implant interface, activating an immune-inflammatory response. If the inflammation is not resolved or reactivated due to stress signals and the immunogenicity of the elements present, this can lead to aseptic loosening of implants, infections, and consequent bone loss [16].

Besides, osseointegrated implants were initially applied in the treatment of totally edentulous patients to reduce the negative psychological impact of the absence of dental elements [4-6]. Within this context, the purpose of the treatment was to give the patient adequate masticatory function. In the longitudinal clinical study of the follow-up of treatment with osseointegrated implants, greater bone loss was observed in the first year of prosthetic function, when compared to the mean bone loss in subsequent years [6]. This report measured bone loss using the first implant thread as a starting point (0 mm) and not the original level of the bone crest at the time of insertion [6].

With the evolution of the technique and with the good results obtained in the use of osseointegrated implants, the clinical need for implants fell on the rehabilitation of cases of partial edentulism [7]. Some theories seek to explain the phenomenon of peri-implant bone loss. Among them, it is worth mentioning the effect of bacterial biofilm accumulation at the interface between the implant and the prosthetic abutment [8]. This discussion promotes scientific effort and technological development toward the implementation of new surgical approaches and implant projects that minimize this effect, aiming at reducing the phenomenon of peri-implant marginal bone loss and its potential risk of compromising the clinical results in aesthetic regions [8].

The use of intraosseous implants is currently a treatment modality widely used in the rehabilitation of total and partial edentulous [1,2]. Obtaining a rigid fixation condition between the implant and bone around the implant site is critical. Such a condition is called osseointegration. Osseointegration was originally defined as a direct functional and structural connection between organized living bone tissue and the surface of an implant under load [3]. Currently, it is permissible for an implant to be considered as osseointegrated when there are no relative and progressive movements between this same implant and the bone in which it is in direct contact [7]. Moreover, it is possible to cite that in practice, in osseointegration, there is an anchoring mechanism in which non-vital components can be reliably and predictably incorporated into living bone, and from that anchorage can remain under all conditions and normal loads [8].

Besides, osseointegration is also described as a series of remodeling phenomena and/or bone regeneration, which will result in the formation of new bone, organized around the installed implant [9]. In the same way, it is shown that the surgical technique, even being extremely careful and rigorous, at the time of implantation, will result in bone necrosis. The tissue repair of this necrotic portion can occur in three ways: formation of fibrous tissue, formation of bone sequestration, and bone regeneration. The latter is the most desired hypothesis [10].

For osseointegration to occur, basic requirements are specific cells (osteoblasts, osteocytes, and osteoclasts) and an adequate vascular network, as well as the presence of a stimulus of adequate frequency and intensity [11]. Factors such as volume and bone structure, bone involvement, and vascular and cellular conditions should be taken into account when there is an intention to achieve osseointegration of a dental implant [12].

Osseointegration is not a process with a specific term or a final phase of the bone regeneration process attached to the implant surface [13]. It is a dynamic process that lasts throughout the maintenance of the per-implant bone. Therefore, the longevity of the process, as well as the clinical success of implantation, will depend not only on the initial surgical steps and bone regeneration but also on other factors that may affect the implant throughout its useful life [13]. The process of osseointegration depends not only on the characteristics of the implants but also on the cellular and matrix condition of the surface of the surgical bed [5]. Other factors influence the healing of bone around the implant, such as the extent of surgical trauma and bone deformations related to functional loads [7].

The main function of the interface between the bone and the implant is to provide, effectively and safely, the transfer of the occlusal loads through the implant and from there to the bone tissue [8]. Authors showed that there is a direct relationship between the degree of bone in contact with the implant and the removal torque, which can reach a percentage of 90.0 % of direct bone contact, and cortical level after one year of implantation [9].

Multicentric studies in the two-step procedure have predicted a predictable prognosis for the stability and longevity of the fixed prosthesis over mandible implants, with a success rate of 95 to 99.0% for 10 years of use. However, in the maxilla, this percentage, for the same time of evaluation and use, is 85.0% [10]. The success of osseointegration as a biological concept depends on careful planning, meticulous surgical technique, and specialized prosthetic work, as well as being evaluated by both clinical and radiographic parameters so that it is possible to quantify per-implant osseous loss [11]. The scope of osseointegration is not restricted to dental implants, but also maxillofacial prostheses, replacement of injured joints, and placement of artificial limbs [12].

Despite the high success rate of osseointegration, initial failures during the regeneration process can occur, affecting it [12]. Such defects may have biological causes, such as peri-implantitis and/or systemic diseases, or biochemical factors, which may negatively influence regeneration/healing, as well as physical factors such as bone overheating during the surgical procedure, occlusal overload, shearing and compression under the perimplantar bone tissue [14-17].

The process of osseointegration requires an adequate amount of force for normal bone repair. If there is excessive pressure, irreversible damage to peri-implant bone tissue may occur [18,19]. On the other hand, if there is little or no compression, an unsatisfactory stimulation may occur, compromising repair in the perimplantar bone tissue [20].

Embryonic bone development is a highly regulated process and occurs in two ways: intramembranous or endochondral. During intramembranous ossification, mesenchymal progenitor cells migrate through vascularized areas rich in collagen, in which condensation occurs [4-7]. The formation of the membranous bone weft is the model that occurs during the repair processes of bone fractures and in the healing of the perimplantar bone [7]. From the bone marrow, three differentiated types of cells act in the process of bone ossification and remodeling. They are osteoblasts, osteocytes, and osteoclasts [8].

Osteoblasts are the only cell types capable of producing bone matrix. Osteoclasts are the main, if not exclusive, cells derived from the hematopoietic lineage responsible for bone resorption [9]. Bone remodeling describes a coordinated action of bone resorption by osteoclasts and the formation of new bone by osteoblasts [10]. In bone, all osteoclasts and osteoblasts belong to a Multicellular Functional Unit called BMU (Basic multicellular units).

Several factors can influence bone loss, such as age, hormonal changes, drugs, and inflammation [11]. In implantology, osteoclastic action due to local inflammation is desired to reabsorb necrotic bone formed in the early stages of dental implant integration. However, bone resorption may persist due to chronic inflammation resulting from bacterial contamination or autoimmune diseases, leading to prolonged action of osteoclasts [12].

Also, the process of bone resorption, observed on the surface of the osseointegrated bone plane, is termed saucerization [13]. This cervical bone resorption - observed in all types of osseointegrated implants, irrespective of their design, surface type, platform and connection, trademark, and patient conditions - takes the form of a saucer, ie, is shallow and superficial. Due to this analogy, the term in English is called saucer [1]. Its velocity may be higher or lower, but its occurrence is part of the integration of the implants with the epithelium and gingival connective tissue [2]. The knowledge of its biological mechanism is important to understand it and, if possible, reduce or control this perimplant cervical bone loss. The saucerization may also be referred to as cervical perimplantar bone remodeling [3].

It has been reported that different reactions of perimplantar bone crest and that can differ significantly, both in radiographic and histomorphic form under certain conditions [10]. It further adds that such differences are dependent on the cervical edge implant being rough/smooth in single-body implants, and dependent on the location of the micro-gap between the implant and the prosthetic component in two-piece implants. Several theories and explanations have been given for saucerization; however, many of them have difficulty explaining one or the other aspect [11]. One of these theories attributes the saucerization to occlusal masticatory loading to which the implants are submitted. However, when osseointegrated implants are out of occlusion or only with the gingival cicatrister for many months or even years, and have never entered into occlusion, they also present saucerization.

On the other hand, when implants remain submerged for a few months/years, the bone tissue advances toward the more cervical surface and may even cover the cover screw. This bone gain often requires osteotomy maneuvers for the placement of the healing or prosthetic intermediate [12]. When an epithelium is ulcerated, its cells are left with the membranes exposed to external mediators so that they interact with their receptors, as occurs in oral ulcers and surgical wounds, including perimplanar [12].

The Epithelial Growth Factor (EGF) of saliva, as well as that of epithelial cells, stimulates perimplantar epithelial proliferation, and the formation of the perimplantar junctional epithelium begins [6]. The perimplantar junctional epithelium gains more layers of cells and assumes a conformation similar to the junctional epithelium of natural teeth. This new conformation of the perimplantar junctional epithelium approximates it to the osseointegrated surface, increasing the local concentration of EGF and, consequently, accelerating the bone resorption, beginning the saucerization [7].

Once the perimplantar junctional epithelium and the saucerization are formed, which occurs after a few weeks or months, a stable biological space is established between the implant-integrated cervical bone and the perimplantar junctional epithelium, as occurs in natural teeth [11]. The gingival tissue thickness seems to have a considerable influence on the bone loss of the alveolar ridge. When this thickness is 2 mm or less, cervical bone loss tends to be significantly greater. The thicker the gingival tissues at the time of implant placement, the greater the distance between the implant junctional epithelium to be formed and the bone tissue; that is, the EGF molecules will arrive in a lower concentration at the bone surface [12].

The success of prosthetic restoration supported by osseointegrated implants and the health of surrounding tissues, such as the reduction of bone loss, are closely related to the precision and adaptation of the components, the stability of the implant/abutment interface, as well as the resistance of this interface when it is subjected to loads during the masticatory function. The mismatch between the prosthetic component and the implant platform may lead to treatment failure, mainly due to the induction of stress concentration, bacterial infiltration, and biofilm formation [12].

In this context, some theories try to explain this phenomenon, which was even described decades ago, is a current topic, contradictory, and extremely important in Oral Implantology [5]. Displacement of the periosteum in the long bones, 90.0% of the arterial blood supply and 100.0% of the venous return being performed by the periosteum. When the periosteum is displaced, blood supply at the bone level is reduced drastically, causing necrosis and non-viability of osteoprogenitor cells. Such observations support the theory of the effect of the displacement of the periosteum on bone resorption [8].

The result of the periosteal displacement would be a uniform horizontal loss, rather than the usual pattern of vertical bone loss. In addition, in the second-stage surgery, this loss would be noticed, a fact not observed [11]. Osteotomy for implant installation: The osteotomy procedure performed for the installation of osseointegrated implants has been pointed out as one of the probable agents causing the initial perimplantar bone loss, due to the creation of a devitalized zone around the implant [13].

This devitalized zone is attributed to the interruption of the blood supply and the heat generated during the osteotomy, especially in the cortical region. Following the reasoning presented in the previous example, this theory may not be directly responsible for marginal bone loss, since most implants do not present such conditions under a clinical and visual inspection during reopening surgery [1,2].

Host autoimmune response: This hypothesis is based on the possibility that bacteria are the primary agents causing per-implant marginal bone loss. Occlusal traumatism would thus constitute a secondary and accelerating factor in this process [5]. However, a good portion of per-implant marginal bone loss occurs in the first year, reaching clinically insignificant values in subsequent years. Thus, the hypothesis of bacteria being the primary cause of perimplantar bone loss cannot be substantiated [6].

Biological distance: The gingival and peri-implant groove environments are similar in some respects. In natural teeth, there is a mean biological space of 2.04 mm between the base of the gingival sulcus and the alveolar bone crest. It is composed of inserted connective tissue (measuring 1.07 mm on average) and the junctional epithelium just below the base of the groove (0.97 mm on average) [7].

Eleven types of gingival fibers are present around the teeth, and of these, at least six are directly inserted into the cementum root. Perimplant tissues exhibit areas of the sulcular and junctional epithelium histologically similar to the natural tooth. The basic differences are the lack of conjunctive insertion and the presence of gingival fibers surrounding only the region of the cervical area of the implants [7].

This theory does not fully explain the phenomenon of per-implant marginal bone loss, which has also been observed in single-stage and single-body implants. In this situation, the establishment of the biological space occurs before the complete maturation of the mucosal tissues. There are questions in the literature about the relationship between the macro effect and micro geometry of implants in the biological space [8].

Tension factors: Osseointegrated implants consist of commercially pure titanium or a titanium alloy whose modulus of elasticity is five to ten times greater than the cortical bone. According to mechanical principles, when two materials with moduli of elasticity are joined without any interposing material, a tension is generated in the region where the first contact between them occurs [8,9].

The occurrence of stresses in the region of the bone crest can cause microfractures, deformations, and bone resorption. Decreased blood supply becomes unavoidable, making the environment conducive to secondary colonization by opportunistic microorganisms [10,11]. Space between the implant platform and the prosthetic abutment: Two-stage implants result in residual spaces and gaps between the implant platform and the prosthetic abutment, which in turn may facilitate colonization by periodontopathogens, enabling the establishment of perimplant inflammatory reactions perimplanar [11].

Through an in vitro study, they evaluated bacterial infiltration in 13 possible combinations between implants and prosthetic components produced by nine different manufacturers [12-14]. To this end, the authors experimented to observe the penetration capacity of Escherichia coli bacteria through the contact area between implant and prosthetic abutment [15,17]. The authors concluded that good adaptation between prosthetic components and implants did not prevent bacterial infiltration [18-21].

Finally, titanium (Ti) offers favorable biocompatibility, mechanical properties, and corrosion resistance for dental implants. However, the long-term success of Ti-based dental implants may be challenged due to implant-related infections and inadequate osseointegration. With the development of nanotechnology, research into dental implants has increased, and surface modifications and the use of various coatings, as well as the development of controlled release of antibiotics or proteins, have improved osseointegration and soft tissue integration of dental implants, as well as their antibacterial and immunomodulatory functions. However, the comparison between these nanoengineering attempts reveals that there are still research gaps that must be addressed for their clinical translation [2].

Conclusion

It was concluded that to maintain osseointegration and prevent bone loss from implants, a better understanding of the osteoimmunology of the peri-implant environment would lead to the development of new therapeutic approaches. It is necessary to discuss immunomodulatory strategies to improve and preserve long-term functional integration between dental implants and the human body. It is concluded that the bone saucerization around osseointegrated implants represents one of those specific concepts that are part of the implant dentist jargon.

CRediT

Author contributions: **Conceptualization -** All authors; **Investigation-**All authors; **Methodology-** All authors; **Project administration-** All authors; **Supervision-** José Augusto Parola da Cruz; **Writing - original draft-** All authors; **Writing-review & editing-** All authors.

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