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REVIEW ARTICLE

# Main factors of bone loss and the processes of osseointegration for dental implant: a systematic review

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## Abstract

**Introduction:** In the cellular, molecular and structural scenario for dental implants, primary or mechanical stability in implant dentistry is considered a prerequisite for successful osseointegration. The alveolar bone architecture of the implant drilling site dictates the success of anchored endosteal implants. **Objective:** It was to carry out a systematic review to highlight the main variables that can compromise bone formation and osseointegration for dental implants. **Methods:** The systematic review rules of the PRISMA Platform were followed. The search was carried out from October to December 2022 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases, using articles from 2010 to 2022. 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 220 articles were found, and 65 articles were evaluated in full and 22 were included and developed in this systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 45 studies with a high risk of bias and 92 studies that did not meet GRADE. The success of the prosthetic restoration supported by osseointegrated implants and the health of the 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 masticatory function. It is necessary to provide a complete understanding of the biological events that occur during osseointegration. Factors that can compromise bone healing are cholesterol, hyperlipidemia, and low vitamin D intake. Furthermore, the prominent influence of osteocytes and immune cells is influenced as being the main regulators during osseointegration and maintenance of the dental implant.

**Keywords:** Dental implants. Bone loss. Saucerization. Osseointegration. Stability. Alveolar bone.

## Introduction

In the cellular, molecular and structural scenario for dental implants, primary or mechanical stability in implant dentistry is considered a prerequisite for successful osseointegration [1]. The alveolar bone architecture of the implant drilling site dictates the success of anchored endosteal implants. A series of cellular and molecular events occur where host tissues biologically integrate the alloplastic material into the native bone structure [1,2].

While cortical bone has the function of supporting torsional loads and providing greater initial stability, spongy bone is richer in vascular channels and, therefore, in vascularization to supply mesenchymal progenitor cells [3,4]. In this sense, the complex and dynamic process of osseointegration can occur via contact osteogenesis, where the surface of the implant is filled with bone cells after fixation to form new bone, or via osteogenesis, where bone formation is preceded by tissue osteoclastogenesis. existing [4].

In this sense, dental medicine besides art is a science that aims to alleviate human suffering, since its main focus of work is the entire stomatognathic system [5,6]. The diverse areas of this science act in an orchestrated way, to transform this suffering into equilibrium, within the biological and technical limits [6]. One of the factors that most fascinates the professional of Dental Medicine is the permanent evolution of the available means and techniques, capable of producing results very close to the natural, both in aesthetic and functional terms. Despite the current stage of technological evolution, there will always be the possibility of further steps [6,7].

Moreover, implantology is one of the branches of dental medicine that has evolved the most as a result of the investigations carried out in the last fifty years [3]. 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 [7].

Besides, 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 [6-8]. However, for the convergence of function and aesthetics to be possible, several processes are required, such as boneimplant integration, long-term implant stability, stable bone maintenance around the implant, and tissues healthy and aesthetically acceptable peri-implant moles [6,7].

A physiological process of perimplantar bone remodeling was observed during numerous investigations related to osseointegration and implantology [8]. 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 [9].

Also, 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 [9,10]. Knowledge of its biological and biomechanical mechanism is important to understand and, if possible, reduce or control this perimplant 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 [11].

Further, criteria were adopted for the success and survival of integrated bone implants [12]. 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 [12,13].

Afterward, studies and comparative studies of saucerization between different implant systems and types should be viewed with care and reservations [14]. It is necessary to take into account the differences between the methodologies used, the differences between surgical techniques, implant forms, implant depth to 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 [15].

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 [16].

Therefore, the present study aimed to carry out a systematic review to highlight the main variables that can compromise bone formation and osseointegration for dental implants.

## Methods

### Study Design

This was followed by a systematic literature review model on the main clinical findings of mandible fractures, according to the PRISMA rules (Transparent reporting of systematic review and meta-analysis-HTTP://www.prisma-statement.org/).

### Data sources and research strategy

The literary search process was carried out from October to December 2022 and was developed based on Scopus, PubMed, Science Direct, Scielo, and Google Scholar, using scientific articles from 20 to 2022, using the descriptors (MeSH Terms): *"Dental implants. Bone loss. Osseointegration. Saucerization. Stability. Alveolar bone"*, and using the Booleans "and" between the descriptors (MeSH Terms) and "or" between the historical findings.

### Study quality and risk of bias

The quality of the studies was based on the GRADE instrument, with randomized controlled clinical studies, prospective controlled clinical studies, and studies of systematic review and meta-analysis listed as the studies with the greatest scientific evidence. The risk of bias was analyzed according to the Cochrane instrument.

## Results and Discussion

### Summary of Literary Findings

A total of 220 articles were found. Initially, duplication of articles was excluded. After this process, the abstracts were evaluated and a new exclusion was performed, removing the articles that did not include the theme of this article, resulting in 202 articles. A total of 65 articles were evaluated in full and 22 were included and developed in this systematic review study (**Figure 1**). Considering the Cochrane tool for risk of bias, the overall assessment resulted in 45 studies with a high risk of bias and 92 studies that did not meet GRADE.

**Figure 1**. Selection of studies.

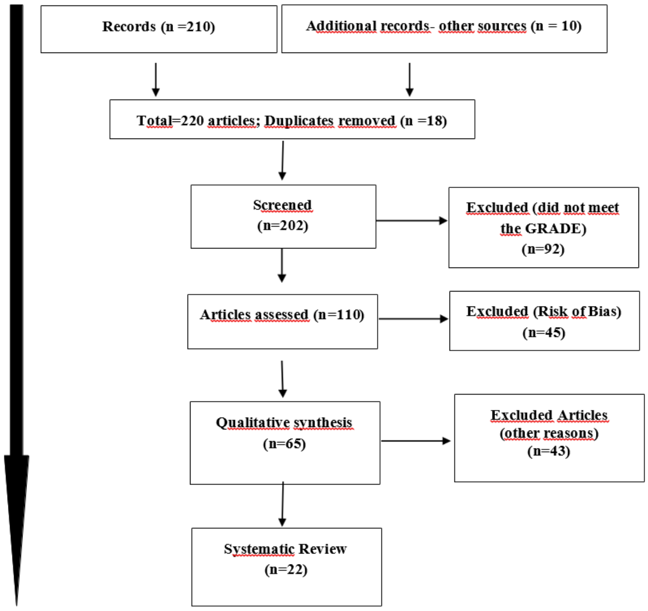
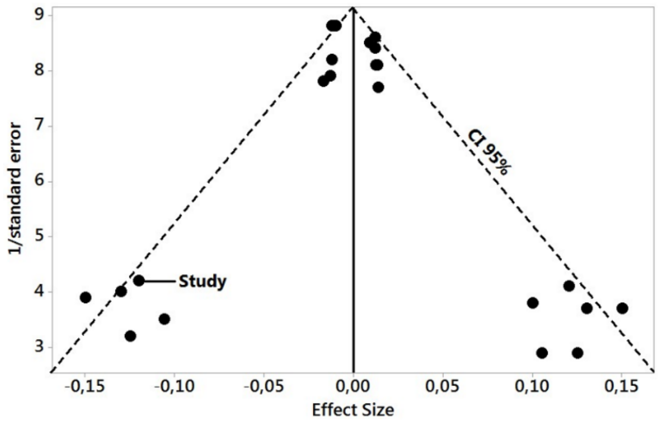



**Figure 2** presents the results of the risk of bias in the studies using the Funnel Plot, through the calculation of the Effect Size (Cohen's Test). The sample size was determined indirectly by the inverse of the standard error. The number of clinical studies evaluated was n=22. The graph showed symmetric 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 risk of bias between the small sample size studies that are shown at the bottom of the graph (N = 22 studies).




Source: Own authorship

### Major Findings

There are limited studies to date investigating the biology and metabolism of bone healing around dental implants and its implications for peri-implant marginal bone loss. It is necessary to provide a complete understanding of the biological events that occur during osseointegration and the subsequent early and late phases of bone remodeling around dental implants. Local bone metabolism is subject to signals from systemic calcium phosphate homeostasis and bone remodeling. Three areas of interest were reviewed due to recently reported impairments in bone healing, including the putative effects of (1) cholesterol, (2) hyperlipidemia, and (3) low vitamin D intake. In addition, the prominent influence of osteocytes and immune cells is discussed as being the main regulators during osseointegration and maintenance of the dental implant. These cells are of crucial importance in the presence of biofilm accumulation and its associated by-products that lead to the breakdown of hard and soft tissues, the so-called peri-implantitis. Factors that may negatively affect osteoclastogenesis or bone macrophage activation should be monitored in future research [17].

Furthermore, a systematic review study investigated the relationship between serum vitamin D levels and dental implants in terms of survival rates, marginal bone loss, and associated complications. The study included 1089 patients restored with 1984 dental implants, with follow-up periods ranging from 20 to 240 months. Cases with lower serum vitamin D levels had slightly worse results in terms of marginal bone loss. Longer follow-up periods are needed to determine whether serum vitamin D levels affect implant survival rates and osseointegration over time [18].

In this context, osseointegrated implants were initially applied in the treatment of totally edentulous patients, to reduce the negative psychological impact of the absence of dental elements [1-4]. 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 of subsequent years [7]. 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 [7].

Besides, 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 [8]. 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 [9]. This discussion promotes the scientific effort and the technological development towards the implementation of new surgical approaches and implant projects that minimize this effect, aiming at reducing the phenomenon of per-implant marginal bone loss and its potential risk of compromising the clinical results in regions aesthetic [9].

Moreover, the use of intraosseous implants is currently a treatment modality widely used in the rehabilitation of total and partial edentulous [5,7]. Obtaining a rigid fixation condition between the implant and bone around the implant site is critical [7]. Such a condition is called osseointegration [2,3]. Osseointegration was originally defined as a direct functional and structural connection between organized living bone tissue and the surface of an implant under load. Currently, it is permissible for an implant to be considered osseointegrated when there are no relative and progressive movements between this same implant and the bone in which it is in direct contact [1]. 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 of normal loads [4].

In addition, 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 implant installed [10]. In the same way, it is exposed that the surgical technique, even being extremely careful and rigorous, at the time of implantation, will occur 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 [11].

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 [16]. 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 osseointegration of a dental implant [19].

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 [13]. Johanson and Albrektsson, in 1987, showed that there is a direct relation between the bone degree in contact with the implant and the removal torque, which can reach a percentage of 90.0 % of direct bone contact, cortical level after one year of implantation [10].

Multicentric studies in the two-step procedure have predicted a predictable prognosis for the stability and longevity of the fixed prosthesis over mandible implant, 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% [11].

The success of osseointegration as a biological concept depends on careful planning, meticulous surgical technique, and specialized prosthetic work, as well as being evaluated both by clinical and radiographic parameters so that it is possible to quantify per implant osseous loss [12]. The scope of osseointegration is not restricted to dental implants, but also maxillofacial prostheses, replacement of injured joints, and placement of artificial limbs [20].

Despite the high success rate of osseointegration, initial failures during the regeneration process can occur, affecting it [21]. 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 [15,19].

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 [20,21]. On the other hand, if there is little or no compression, an unsatisfactory stimulation may occur, compromising repair in the perimplantar bone tissue [22]. 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 [1,2].

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 [22]. From the bone marrow, three differentiated types of cells act in the process of bone ossification and remodeling. They are osteoblasts, osteocytes, and osteoclasts [9]. 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 [10].

Also, bone remodeling describes a coordinated action of bone resorption by osteoclasts and the formation of new bone by osteoblasts [11]. In bone, all osteoclasts and osteoblasts belong to a Multicellular Functional Unit called BMU (Basic multicellular units). Several factors can influence bone loss as age, hormonal changes, drugs, and inflammation [12]. 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 [22].

In this context, the process of bone resorption, observed on the surface of the osseointegrated bone plane, is termed saucerization [10]. 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, shallow and superficial. Due to this analogy, the term in English is called saucer [2]. 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. The knowledge of its biological mechanism is important to understand it and, if possible, reduce or control this per implant cervical bone loss. The saucerization may also be referred to as cervical perimplantar bone remodeling [7].

Also, was reported the possibility of observing different reactions of perimplantar bone crest that can differ significantly, both in radiographic and histomorphic form under certain conditions. It further adds that such differences are dependent on the cervical edge implant 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 [11].

Several theories and explanations have been given for saucerization, however, many of them have difficulty explaining one or the other aspect. One of these theories attributes the saucerization as being the result of occlusal masticatory loading in 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 [12].

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. 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 [13].

The FCE (Epithelial Growth Factor) of saliva, as well as that of epithelial cells, stimulates perimplantar epithelial proliferation, and the formation of the perimplantar junctional epithelium begins [7]. 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 [8].

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 [8]. 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 [13].

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 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 [13].

## Conclusion

The success of the prosthetic restoration supported by osseointegrated implants and the health of the 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 masticatory function. It is necessary to provide a complete understanding of the biological events that occur during osseointegration. Factors that can compromise bone healing are cholesterol, hyperlipidemia, and low vitamin D intake. Furthermore, the prominent influence of osteocytes and immune cells is influenced as being the main regulators during osseointegration and maintenance of the dental implant.

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## Ethics approval

Not applicable.

## Informed consent

Not applicable.

## Data sharing statement

No additional data are available.

## Conflict of interest

The authors declare no conflict of interest.

## Similarity check

It was applied by Ithenticate@.



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