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Research of the osseointegration and saucerization process in bone regeneration for dental implants: a concise systematic review

Allan Carlos Marangoni[1], Carlos Eduardo Silva Campos[1], Wellington Capitelli[1], Andreia Borges Scriboni[1,2*]

[1] UNORTE - University Center of Northern São Paulo - Dentistry department, Sao Jose do Rio Preto, Sao Paulo, Brazil.
[2] UNIPOS - Post graduate and continuing education, Dentistry department, Sao Jose do Rio Preto, Sao Paulo, Brazil.

*Corresponding author: Dr. Andreia Borges Scriboni.
UNORTE/UNIPOS – Graduate and Postgraduate in dentistry, Sao Jose do Rio Preto, Sao Paulo, Brazil.
E-mail: abscriboni@hotmail.com
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Abstract

Introduction: In the context of implantology, bone regeneration is a science that aims to recover bone elevation for dental implants, with its main focus being the stomatognathic system. The treatment of oral rehabilitation with implants obtained a substantial evolution through the concept of osseointegration. A physiological process of peri-implant bone remodeling was observed during numerous investigations related to osseointegration and implantology. And, specific immune cells such as macrophages play a crucial role in the dynamics of osseointegration. **Objective:** to present the main approaches and clinical results on the process of bone regeneration, osseointegration, and saucerization in the implantology scenario through a systematic review of the literature. **Methods:** The present study followed a systematic review model, following the rules of systematic review – PRISMA. The search strategy was performed in the PubMed, Cochrane Library, Web of Science and Scopus, 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:** The total of 156 articles were found. A total of 74 articles were fully evaluated and 20 were included in this study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 50 studies that were excluded with a high risk of bias (studies with a small sample size). Also, 12 studies were excluded because they did not meet the GRADE. Based on the objective of the present study, it was concluded that bone saucerization around osseointegrated implants represents a fundamental process for dental implant success, and with a controlled immunological process.

Keywords: Implantology. Bone regeneration. Stomatognathic system. Osseointegration. Saucerization.

Introduction

In the context of implantology, bone regeneration is a science that aims to recover bone elevation for dental implants, with its main focus being the stomatognathic system [1]. The various areas of this science act in an orchestrated way, in the sense of transforming this suffering into balance, within biological and technical limits [1-4]. Still, bone regeneration aims to achieve results very close to the natural one, both in aesthetic and functional terms [5].

In this scenario, the treatment of oral rehabilitation with implants obtained a substantial evolution through the concept of osseointegration that was launched by Branemark, emphasizing functional rehabilitation [5]. Thus, implant treatments not only restore masticatory function but also acquire aesthetically pleasing, easy-to-clean, and fixed prostheses [6,7]. However, several processes are required, such as bone-implant integration, long-term implant stability, stable bone maintenance around the implant, and healthy and esthetically acceptable peri-implant tissues [1,2].

In this aspect, a physiological process of peri-implant bone remodeling was observed during numerous investigations related to osseointegration and implantology [6]. This process is characterized macroscopically as loss of bone support around the implant, in the cervical portion, with or without osseointegration [7]. 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]. The presence of saucerization is independent of the macro and micro implant design, the type of surface, the way of connecting the prosthetic abutment and the implant, the trademark, and the local and general conditions of the patient [7,9]. Thus, knowledge of its biological and biomechanical mechanism is important to understand and, if possible, reduce or control this peri-implant cervical bone loss [10].

Also, specific immune cells such as macrophages play a crucial role in the dynamics of osseointegration. Infiltrating macrophages and resident 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. Thus, to 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 [11].

Therefore, the present study aimed to present the main approaches and clinical results on the process of bone regeneration, osseointegration, and saucerization in the implantology scenario through a systematic review of the literature.

Methods

Study Design

The present study followed a systematic review model, following the rules of systematic review - PRISMA (Transparent reporting of systematic review and meta-analysis, access available in: http://www.prisma-statement.org/).

Data Sources

The search strategy was performed in the PubMed, Cochrane Library, Web of Science and Scopus, and Google Scholar databases. The present study was carried out from February to May of 2022.

Descriptors (MeSH Terms) And Search Strategy

The main descriptors (MeSH Terms) used were "*Implantology. Bone regeneration. Stomatognathic system. Osseointegration. Saucerization*". The rules of the word PICOS (Patient; Intervention; Control; Outcomes; Study Design) were followed.

Selection Process, Risk of Bias and Quality of Studies

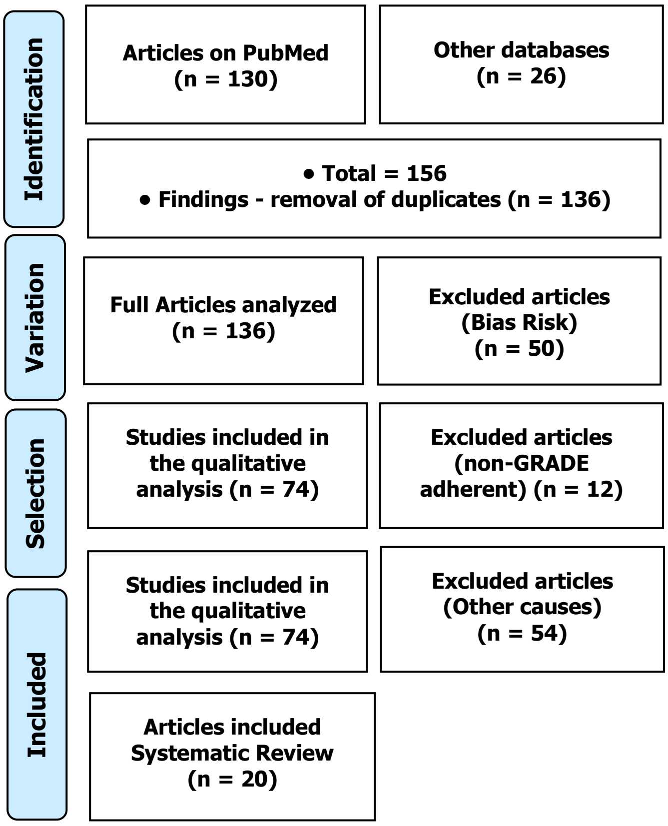
Two independent reviewers performed research and study selection. Data extraction was performed by reviewer 1 and fully reviewed by reviewer 2. A third investigator decided some conflicting points and made the final decision to choose the articles. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument.

Results and Discussion

Article Series and Eligibility

The total of 156 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 74 articles were fully evaluated and 20 were included in this study (**Figure 1**). Considering the Cochrane tool for risk of bias, the overall assessment resulted in 50 studies that were excluded with a high risk of bias (studies with a small sample size). Also, 12 studies were excluded because they did not meet the GRADE.

Figure 1. Flowchart showing the article selection process.



Osseointegration and Dental Implants

Based on the main clinical findings, it was shown that Osseointegrated implants were initially applied in the treatment of totally edentulous patients, to reduce the negative psychological impact of the absence of dental elements [1,2]. Within this context, the purpose of the treatment was to give the patient adequate masticatory function [3]. 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 [12]. 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 [13].

Also, 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 [6]. 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 [7]. This discussion promotes the scientific effort and the 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 regions aesthetic [7].

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 implant and bone around the implant site is critical [5]. 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. 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 with which it is in direct contact [6]. 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 [7].

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 implant installed [9]. 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 [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 [12]. 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 [13].

Moreover, osseointegration is not a process with a specific term or a final phase of the bone regeneration process attached to the implant surface [14]. 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 [14]. 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 [1]. Other factors influence the healing of bone around the implant, such as the extent of surgical trauma and bone deformations related to functional loads [2].

In this context, 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 [7]. Johanson and Albrektsson, in 1987, showed that there is a direct relationship 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 [9].

As major literary findings, 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% [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 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 [13].

Despite the high success rate of osseointegration, the initial failures during the regeneration process can occur, affecting it [13]. 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 peri implant-bone tissue [15-17].

In addition, 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 peri implant-bone tissue [20].

Saucerization and Perimplant Cervical Remodeling

The process of bone resorption, observed on the surface of the osseointegrated bone plane, is termed saucerization [14,20]. 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 [1,2]. 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 peri implant-bone remodeling [5].

In this sense, it has been reported the possibility of observing different reactions of peri implant-bone crest 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 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 [10]. Several theories and explanations have been given for saucerization, however, many of them have difficulty explaining one or the other aspect [12]. 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 scar for many months or even years, and have never entered into occlusion, they also present saucerization [12].

Also, 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 [13]. 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 peri implant-bone [13].

The Epithelial Growth Factor (EGF) of saliva, as well as that of epithelial cells, stimulates peri implant-bone epithelial proliferation, and the formation of the peri implant-bone junctional epithelium begins [5]. The peri implant-bone junctional epithelium gains more layers of cells and assumes a conformation similar to the junctional epithelium of the natural teeth. This new modeling of the peri implant-bone 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 peri implant-bone 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 peri implant-bone junctional epithelium, as occurs in natural teeth [12].

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 [13,20].

Furthermore, some theories try to explain this phenomenon, which even described decades ago is a current topic, contradictory, and extremely important in Oral Implantology [4]. Displacement of the periosteum: In the long bones, 90.0% of the arterial blood supply and 100.0% of the venous return are 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 [7].

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 [12]. 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 peri implant-bone loss, due to the creation of a devitalized zone around the implant [14]. 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].

Besides, the host autoimmune response, this hypothesis is based on the possibility that bacteria are the primary agents causing peri-implant marginal bone loss. Occlusal traumatism would thus constitute a secondary and accelerating factor in this process [4]. However, a good portion of peri-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 peri-implant bone loss can not be substantiated [5].

Regarding 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) [6]. In addition, 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 [6].

This theory does not fully explain the phenomenon of peri-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 [7].

And, about 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 [7,9]. 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 [9,12]. 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 inflammatory reactions perimplanar [12].

Through an in vitro study, they evaluated bacterial infiltration in 13 possible combinations between implants and prosthetic components produced by nine different manufacturers [15,20]. To this end, the authors experimented to observe the penetration capacity of Escherichia coli bacteria through the contact area between the implant and prosthetic abutment. The authors concluded that good adaptation between prosthetic components and implants did not prevent bacterial infiltration.

Conclusion

Based on the objective of the present study, it was concluded that bone saucerization around osseointegrated implants represents a fundamental process for dental implant success, and with a controlled immunological process.

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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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