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THE EFFECT OF MACROGEOMETRY ON DENTAL IMPLANTS: A LITERATURE REVIEW

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Review Article

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Abstract. To ensure that no failures occur in a dental implant system, it is essential to understand the influence of geometric parameters on mechanical strength. Oral rehabilitation through implants plays an important role in restoring masticatory function, aesthetics, and quality of life for patients who experience tooth loss. This study investigates elements such as design, diameters, shapes, depth, and angle of the threads, seeking to understand the impacts on the stability of osseointegrated dental implants. Osseointegration, the stable and functional union between the implant and the bone tissue, is essential for durability and stability and is influenced by macrogeometry. In this study, the objective is to examine how macrogeometry affects the stability and osseointegration of dental implants, focusing on assessing the potential for implant stability and its direct impact on the effectiveness of oral rehabilitation. This is a literature review of 15 specific articles published in the last 10 years in the PubMed and Scielo databases and specific descriptors. The results converge on the importance of examining in detail the characteristics of macrogeometry, including shape, thread, and implant dimensions to improve results in clinical practice. These conclusions emphasize the relevance of these factors in the effectiveness of oral rehabilitation and in improving patients' quality of life. Therefore, the primary stability of implants is directly linked to their shape, highlighting the effectiveness of conical and hybrid shapes.

Keywords — Dental Implant; Macrogeometry; Osseointegration.

1 Introduction

The use of implants in oral rehabilitation plays an essential role in restoring masticatory function, aesthetics, and quality of life in patients who have lost teeth. There are many techniques for installing dental implants, depending on the advanced materials used in this process, and knowledge of bone biology continues to evolve and leverage the number of innovations [1].

Dental implants are not only an alternative, but also have a significant influence on the treatment of edentulism, admirably increasing the survival rate of the implant through osseointegration, which depends on the interaction between the bone and the properties of the implant surface [2].

However, different factors influence the success of the implant, which is osseointegration, a process that ensures the stability and longevity of the implant by directly contacting the bone and implant surfaces, resulting in a stable and functional union [3].

Osseointegration is affected by several factors, including the macrogeometry of the implant, which encompasses elements such as thread design, shape, length, and diameter. These elements contribute to supporting chewing forces, replacing lost teeth in the dental arch [2].

The design of the implant structure is also a matter of debate among professionals, as it can interfere with the distribution of stresses throughout the bone tissue [4]. In this sense, different implant designs have emerged over the years, with the aim of establishing a geometry that would benefit the primary stability process, as well as the maintenance of the surrounding bone tissue throughout its function [5].

The generic geometric parameters of the implant, which include thread design, shape, size, and diameter, have been well established in the scientific literature due to their influence on bone interactions [1].

The macrogeometry configuration not only establishes load distribution and biomechanical stability, but also significantly influences the stability of the bone implant. According to the analysis, a good thread design, especially in terms of number and depth, facilitates osseointegration, resulting in more effective fixation. In this sense, the appropriate selection of the diameter and length of the implant affects the mechanical load transmitted to the bone, which directly affects the biological response and, therefore, becomes fundamental to the prognosis of the treatment [6].

Studies indicate that macroscopic geometry not only influences osseointegration in isolation, but also acts in conjunction with other elements, such as bone mass, occlusion, and load. Therefore, it is necessary to understand the macrogeometry of the implant from a perspective aimed at maximizing osseointegration and ensuring the longevity of implant rehabilitation. By modifying the macroscopic geometry of the implant through its design, the area of contact with bone tissue can be significantly increased [7].

As analyzed by Chowdhary et al. (2015), macroscopic geometry suggests more efficient and rapid reactions during the osseointegration phase. Furthermore, this improvement allows the development of different designs, thus expanding the possibilities for the application of dental implants. Thus, the diversity of macrogeometry makes stable installation possible in areas where osseo s difficult, such as areas of alveolar bone with lower bone quality [8].

The present study aims to analyze how macrogeometry affects the primary stability and osseointegration of dental implants, with an emphasis on collar design, shape, implant length, implant diameter, and thread design.

2 Materials and Methods

The study was conducted through a systematic review of the literature using a classification approach. The review covered studies published in the last 15 years, both in English and Portuguese, and was restricted to the PubMed and Scielo databases. The search strategy used descriptors with the terms "Dental implant," "Macrogeometry," and "Osseointegration." Different types of articles were included in the analysis, with a comprehensive approach to the topic, except for case reports, dissertations, and theses. The selection was made based on specific criteria, considering the relevance and quality of the research, based on the impact factor and citations of the articles. After careful selection, a total of 35 articles were identified as significant contributions. The inclusion criteria favored studies published in scientific journals and studies focusing on the general geometry of dental implants. The incorporation of additional material from reliable sources, together with the literature review, increases reliability, validates the content addressed, and ensures the legitimacy of the data used.

Initially, cylindrical implants had no threads in their geometric shape and were widely used, especially when associated with surface treatment, which had high success rates for the time [9]. The great advantage of this type of implant was that it was easier to install, reducing stress on the cortical bone. However, these cylindrical implants have some disadvantages, such as higher rates of bone resorption, lower primary stability, and greater stress dissipated throughout the trabecular bone tissue [10].

Over time, these types of implants were associated with greater bone loss in the region adjacent to the implant, and there was a need to promote bone/implant union in cylindrical implants through surface treatment with a bioactive coating that benefits the osseointegration process for this type of implant [11].

The study [12] explores various macrogeometries of dental implants, where changes in external design significantly affected surface roughness patterns. Currently, there are different thread formats available on the market, including V-shaped, trapezoidal, inverted trapezoidal, square, and spiral.

Modifications in the thread shape can alter the basic contact area between bone and implant, causing changes in the osseointegration of dental implants. Therefore, it is essential to emphasize the importance of considering not only the overall geometric measurement of the implant, but also the peculiar h y characteristics of the contours, which play an essential role in bone-implant interaction [13].

According to an in vitro experimental study conducted to evaluate the biomechanical effects of a new large-geometry dental implant design, two implants were compared: a conventional one and an innovative one with a circular interstriated clot chamber. The implants were

4.00 mm in diameter and 10.00 mm in length and were assembled according to the general geometry and surface treatment. The stability quotient (ISQ) was measured with Osstell equipment after installation. Even though the new design reduced the insertion torque compared to conventional implants, the ISQ values were not affected, and no correlation was found between insertion torque and ISQ [14].

A new total geometry measurement compared to traditional macrometric implants was revealed on the market. By dividing 86 conical implants into control (conventional) and experimental (with healing chambers between threads) groups, analysis, insertion, and biomechanical evaluation in rabbit tibias showed significant improvements in osseointegration in the experimental group. Biomechanical evaluation demonstrated that the test group obtained higher values in the different analysis periods with statistically significant differences, in addition to greater bone formation and implant-bone contact [15].

The hybrid approach has emerged and shown promising results in the area of biomechanics and structure, highlighting its potential for successful clinical application. Considering that the conical portion provides greater initial stability, reaching values between 65 and 100 nm. In fact, the average percentage of bone-implant contact was 56.34%, demonstrating effective integration with the surrounding tissue [16].

Renowned authors highlight osseointegration as an effective pillar in implant dentistry [17, 18], distinguishing it as the stable and functional union between the implant and the bone, evidencing the essential importance of this phenomenon for the success of implants.

The studies highlight the influence of implant collar design on bone maintenance [19, 20], creating a relevant perspective for understanding the implications involved in this context. They clarify that implants with smooth collars were developed to reduce bacterial plaque retention, but when placed under the bone crest, they create greater shear forces, leading to marginal bone loss and periapical pocket formation. In order to reduce this effect, implants with microthreads in the cervical region were developed, which increase the implant-bone contact area, decrease stress concentration, and improve marginal bone preservation. When investigating the relationship between various implant configurations, the relevance of length and diameter in osseointegration has been described, while an innovative strategy with short implants in immediate loading has been suggested [7, 21, 22].

An analysis related to threads illustrates the importance of the specific characteristics of this component in the search for stability [18], ensuring that square and V-shaped threads can decrease stress on the bone, while square and cross threads can reduce compression. In addition, self-tapping threads may be a suitable alternative to improve primary stability, especially in low-density bones. Thus, osseointegration emerges as a central element, and the above-mentioned studies provide valuable guidelines for building solid foundations in implant dentistry.

When comparing the primary stability of hybrid, conical, and cylindrical implants, it is important to note that the effectiveness of these different designs directly influences the long-term success of the procedures. Recent research has extensively investigated this topic, highlighting the fundamental implications for osseointegration and implant biomechanics [23].

Studies have shown that the hybrid design offers greater primary stability compared to conical and cylindrical implants, highlighting the potential advantage of this specific configuration, which is very significant for immediate loading treatments [17]. Based on further research, hybrid implants can be considered an option for regions with substantial bone loss [23], hybrid implants can be considered an option for regions with substantial bone loss, and the selection of the implant design should depend on specific clinical characteristics. The complexity of estimating primary stability in the literature is highlighted, since numerous interactive variables, including bone support, surgical technique, and specific patient characteristics, affect this parameter.

Adding to the studies described, it has been demonstrated that conical implants offer superior primary stability results when compared to cylindrical implants, indicating the relevance of macrogeometry in optimizing this vital parameter [18].

3 Results

The studies included in the analysis under different aspects of dental implant macro design resulted in the relationship between the parameters evaluated. As described in previous studies, cylindrical implants without threads in their geometric shape had high success rates for the time [9]. It has been demonstrated that the hybrid design offers greater primary stability compared to conical and cylindrical implants [17]. Implants play an essential role in oral rehabilitation, restoring masticatory function, aesthetics, and quality of life [1], implants play an essential role in oral rehabilitation, restoring masticatory function, aesthetics, and quality of life, highlighting that there are many advanced techniques and materials used in this process. The ease of installation has been highlighted as an advantage, with disadvantages including higher rates of bone resorption, lower primary stability, and greater stress dissipation throughout the trabecular bone tissue [10]. It has been clarified that, because these types of implants are associated with greater bone tissue loss, it was necessary to favor bone/implant union with cylindrical implants by performing surface treatment with a bioactive coating [11]. Research has explored various macrogeometries of dental implants, where changes in external design significantly affected surface roughness patterns [12]. The importance of considering not only the overall geometric measurements of the implant but also the specific characteristics of its contours has also been highlighted [13]. Regarding the hybrid approach, promising results have been presented in the area of biomechanics and structure, highlighting its potential for successful clinical application [16]. It has also been indicated that the use of a 0.5 mm non-threaded microtextured layout above the implant collar with 1.8 mm microtextured microgrooves is more effective in maintaining marginal bone [20]. Implants with microthreads in the cervical region increase the implant–bone contact area, decrease stress concentration, and improve marginal bone preservation [24]. When investigating the relationship between different implant configurations, the relevance of length and diameter in osseointegration has been described, while an innovative strategy with short implants under immediate loading has also been suggested [15, 21] in immediate loading comparable to standard length implants. Pabst et al. (2022) contribute that hybrid implants can be considered an option for regions with substantial bone loss, and that the selection of the implant design should depend on specific clinical characteristics. An analysis related to threads by Heimes et al. (2023) illustrates the importance of the specific characteristics of this component in the search for stability. Self-tapping threads may be a suitable alternative to improve primary stability, osseointegration emerges as a central element, and the above-mentioned studies provide valuable guidelines for building solid foundations in implant dentistry. The conical shape and rounded chambers contribute to a more uniform load distribution and better adaptation to the bone contours, resulting in greater initial implant stability. The macrogeometry of the implant plays a key role in primary stability, directly influencing the interaction of the implant with the surrounding bone, which is essential for successful osseointegration of the implant. Conical implants offer superior primary stability results when compared to cylindrical implants, indicating the relevance of macrogeometry in optimizing this vital parameter.

4 Discussion

Regarding the relevance of the microtextured layout in maintaining marginal bone, there is still debate as to whether this feature can influence implant collars [20]. However, studies have shown that machined collars exhibit lower performance compared to smooth and rough surfaces, although further investigation is needed since the observed effectiveness may be related to the methodology used [19]. During a 90-day evaluation, it was observed that implant macrogeometry had no significant influence on primary stability [21]. This finding is consistent with several previously published studies demonstrating that variables such as thread shape and diameter, bone compression techniques, and the surgeon's skill in assessing bone density for final drill selection are key factors. When these variables are optimized, high stability can be achieved, although elevated torque levels may complicate implant installation. Studies have shown that short implants (6 mm) present satisfactory outcomes for single-tooth restorations in the posterior maxilla, and their viability under immediate loading conditions has been reinforced [22, 25]. The macrogeometry of dental implants plays a crucial role in achieving primary stability, with larger diameters and hybrid or conical configurations demonstrating superior performance. The linear relationship between implant length and stability appears to be valid up to approximately 12 mm, while the collar and thread design also have significant influence on biomechanical behavior.

5 Conclusion

This study concluded that the stability of dental implants is directly linked to their design, with conical and hybrid implants being the most suitable. Increasing the length has a positive impact up to 12 mm, with conical and hybrid implants being ideal for immediate placement and in the anterior region. Short implants, with torque control and adequate bone preparation, are effective in atrophic jaws. The combination of short and long implants is appropriate in areas with low bone density, noting that larger diameter and threads, especially square and V-shaped, influence stability, but there are limitations in the review due to heterogeneity and lack of prospective clinical studies. The implant alternative should be performed specifically for each case, evaluating the patient's local and systemic factors, the surgeon's skill, and the technical possibilities. The surgeon's experience and competence with the specific implant design are also relevant, noting that an implant design that is ideal for the case is of no benefit if the practitioner does not know how to handle it on a daily basis.

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