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Current clinical considerations of the use of guided bone regeneration for dental implants through the use of CAD-CAM systems: a systematic review

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Abstract

Introduction: It is estimated that up to 40% of osseointegrated implants require guided bone regeneration (GBR) as part of the patient's rehabilitation. Bone loss or insufficiency presents a major challenge for osseointegration. In this sense, the use of CAD-CAM systems (Computer-Aided Design/Computer-Aided Manufacturing) is highlighted in this process. **Objective:** It elucidated the current clinical considerations of the use of guided bone regeneration for dental implants through the use of CAD-CAM systems. **Methods:** The PRISMA Platform systematic review rules were followed. The search was carried out from February to April 2024 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** 118 articles were found, 30 articles were evaluated in full and 12 were included and developed in the present systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 20 studies with a high risk of bias and 31 studies that did not meet GRADE and AMSTAR-2. Most studies did not show homogeneity in their results, with X^2=79.5%>50%. Guided bone regeneration is well documented and constitutes a predictable and successful approach to lateral and vertical bone augmentation of atrophic ridges. Thus, guided bone regeneration is considered one of the most commonly applied methods to reconstruct alveolar bone and to treat peri-implant bone deficiencies, as well as to replace lost bone and allow the implant to be fully integrated and maintained during functional loading. The use of digital tools for the automated fabrication of implant parts (CAD-CAM) is an optimizing reality in Dentistry. CAD-CAM enables highquality, standardized, accurate, and detail-perfect prosthetic restorations. The use of metallic implants in the morse cone system in association with zirconia abutments guarantees a final product with mechanical resistance, biocompatibility, and aesthetics. Also, immunomodulatory guided bone regeneration membranes are developed mainly by improving macrophage recruitment and aggregation as well as regulating macrophage polarization.

Keywords: Bone regeneration. Guided bone regeneration. Dental Implant. CAD-CAM.

Introduction

It is estimated that up to 40% of osseointegrated implants require guided bone regeneration (GBR) as part of the patient's rehabilitation. Bone loss or insufficiency presents a major challenge for osseointegration. To achieve a good long-term prognosis for osseointegrated implants, there must be a sufficient volume of bone at the implantation sites. Different strategies, such as bone grafting, alveolar distraction, and GBR techniques, have been applied to replace lost bone and allow the implant to be fully integrated and maintained during functional loading. Guided bone regeneration is considered one of the most commonly applied methods to reconstruct alveolar bone and to treat peri-implant bone deficiencies [1,2].

In this context, GBR can be achieved when osteoprogenitor cells are exclusively allowed to repopulate the site of the bone defect, preventing the entry of non-osteogenic tissues. Several reports have indicated that survival rates for implants placed in GBR-augmented sites are similar to those reported for implants placed in original sites. The membrane used for GBR is an essential component of the treatment [3-5].

In the scenario of dental implant procedures, the intraoral scanner and a milling unit are used to manufacture a computer-aided design and a computer-aided surgical and radiographic guide [6]. In this sense, the use of CAD-CAM systems (Computer-Aided Design/Computer-Aided Manufacturing) is highlighted in the processes of prostheses and dental implants [7,8].

In this context, the CAD-CAM system was introduced in dentistry to promote the fabrication of prostheses based on a state-of-the-art three-dimensional system [9]. Where the search for aesthetic solutions has been increasingly challenging, given the patient's demand and the growing number of techniques and materials available for protective rehabilitation [10]. Aims that the material's resistance is the primary factor to determine the indication of the technique, as well as the preservation of the rehabilitation over time and the need for movements that lead to the possibility of carrying out rehabilitation of greater extensions [9,10].

In this sense, the CAD-CAM system performs an intraoral scanner, while the CAM is the milling machine [11-13]. Ceramics are the main alternative restorative material for tooth structure due to their favorable properties [13,14]. In addition, a fixed complete dental prosthesis supported by a metal-acrylic resin implant is an important restorative option. However, maintenance and repair increase time, but CAD-CAM assistance can improve efficiency and reduce complications. Thus, CAD-CAM can fabricate a fixed complete dental prosthesis supported by a metal-acrylic resin implant metal-acrylic resin that minimizes individual tooth fracture and facilitates efficient resurfacing of worn surfaces [15]. Thus, one of the main CAD-CAM objectives is the simplification and optimization in the production of prosthetic structures with high quality and aesthetics [14-16].

Based on this entire scope, the present systematic review study elucidated the current clinical considerations of the use of guided bone regeneration for dental implants through the use of CAD-CAM systems.

Methods

Study Design

The present study followed the international systematic review model, following the rules of PRISMA (preferred reporting items for systematic reviews and meta-analysis). Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed on: 02/22/2024. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: https://amstar.ca/. Accessed on: 02/22/2024.

Data Sources and Research Strategy

The literary search process was carried out from February to April 2024 and was developed based on Scopus, PubMed, Web of Science, Lilacs, Ebsco, Scielo, and Google Scholar, covering scientific articles from various to the present. The descriptors (MeSH Terms) were used: *"Bone regeneration. Guided bone regeneration. Dental Implant. CAD-CAM."* and using the Boolean "and" between the MeSH terms and "or" between historical discoveries.

Study Quality and Risk of Bias

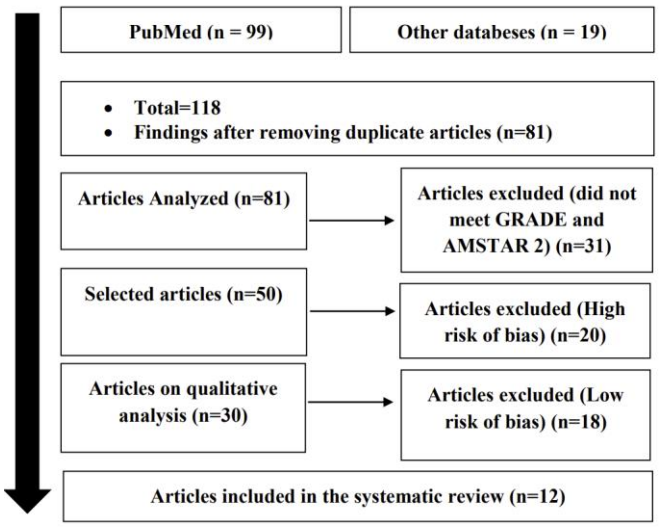
Quality was classified as high, moderate, low, or very low in terms of risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. The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

Results and Discussion

Summary of Findings

A total of 118 articles were found that were subjected to eligibility analysis, with 12 final studies being selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. The biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies showed homogeneity in their results, with X^2=79.5%>50%. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 20 studies with a high risk of bias and 31 studies that did not meet GRADE and AMSTAR-2.

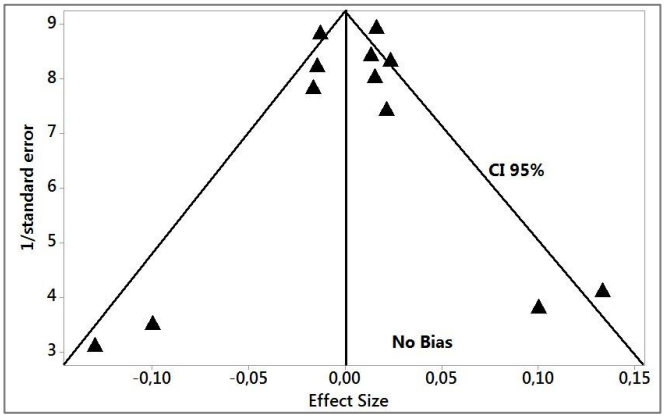
Figure 1. The article selection process by the level of methodological and publication quality.



Source: Own authorship.

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

Figure 2. The symmetric funnel plot suggests no risk of bias among the small sample size studies that are shown at the bottom of the graph. High confidence and high recommendation studies are shown above the graph (n=12 studies).



Source: Own authorship.

Main Clinical Results

In sites with insufficient bone, guided bone regeneration (GBR) is performed before or in conjunction with implant placement to achieve a three-dimensional implant position driven by the prosthesis. To date, GBR is well documented and constitutes a predictable and successful approach for lateral and vertical bone augmentation of atrophic ridges. Evidence suggests that the use of barrier membranes maintains the main biological principles of GBR. Since the material used to construct barrier membranes ultimately dictates their characteristics and their ability to maintain the biological principles of the GBR, various materials have been used over time [17].

In this sense, the implantation of GBR membranes triggers an immune response, which can lead to inflammation and failure of bone augmentation. Macrophages play crucial roles in immune responses and participate in the entire process of repairing bone injuries. The significant diversity and high plasticity of macrophages complicate the understanding of the immunomodulatory mechanisms underlying GBR. Macrophages can promote osteogenesis or the formation of fibrous tissue in bone defects and the degradation or fibrous encapsulation of membranes. Furthermore, GBR membranes can influence macrophage recruitment and polarization. Therefore, immunomodulatory GBR membranes are mainly developed by improving macrophage recruitment and aggregation as well as regulating macrophage polarization [18].

The CAD-CAM system has advanced the dental restoration process to include implantsupported crowns. Thus, a study compared the fracture strength after mechanical loading and thermocycling of various combinations of screw-retained and cemented ceramic materials and polymethylmethacrylate using the TiBase abutment compared to implanted crowns. Screw-retained implant restorations demonstrated higher fracture loads than their cemented counterparts. Lithium disilicate hybrid abutment/crown implant-supported restoration using the TiBase abutment may be an ideal clinical choice due to its simplicity [19-23].

In addition, one study described a technique to fabricate a custom anatomical healing abutment for delayed loading implants using CAD-CAM from a polymethylmethacrylate (PMMA) blank. The dimensions of the custom healing abutment are measured from a conventional dental radiograph and diagnostic models. The healing abutment is used in the second surgical phase to guide soft tissue healing [24].

Also, the CAD-CAM technique is particularly beneficial for a long scan span and large edentulous space with multiple scan bodies, and a verification device can be used to confirm the accuracy of a definitive implant impression [25]. Another study presented eight patients who underwent three-dimensional reconstruction of the fibula flap with iliac crest graft and dental implants using CAD/CAM virtual planning. The increase in the vertical crest and the

horizontal dimensions of the fibula, the peri-implant bone resorption of the iliac crest graft, the implant success rate, and the functional and esthetic results were evaluated. Vertical reconstruction ranged from 13.4 mm to 10.1 mm, with a mean of 12.22 mm. A total of 38 implants were placed in the new mandible, with an average of 4.75 ± 0.4 implants per patient and an osseointegration success rate of 94.7%. All patients were rehabilitated with fixed implant prostheses with good aesthetic and functional results [26].

Besides, a retrospective study of 25 patients analyzed the differences, in terms of mechanical and biological complications, in multi-unit zirconia fixed dental prostheses (FPDs) in posterior implants produced through a digital workflow. Occlusal and interproximal corrections were not clinically significant. In the study sample, the survival rate and success rate of FPDs after 3 years were 100% and 96%, respectively. Monolithic zirconia FPDs and partial veneer FPDs showed a 100% survival rate, presenting an interesting alternative to metalceramic restorations. Partial veneer FPDs had a higher technical complication rate than monolithic FPDs but without statistical significance [27].

Also, a review article analyzed that high-performance bioactive polymer (BioHPP) and CAD/CAM computer-aided composite resin materials are a relatively new class of dental biomaterials. To avoid many disadvantages of metals and their alloys in dental practice, such as inadequate color, high density, thermal conductivity, and possible allergic reactions, polymer-based materials (BioHPP) and CAD/CAM composite resins are being developed. They are biocompatible materials that are light, strong, durable, and feature high resistance to bending and compression. However, most of its characteristics have been demonstrated through laboratory tests, while clinical studies are relatively scarce [28].

Conclusion

It was concluded that guided bone regeneration is well documented and constitutes a predictable and successful approach for lateral and vertical bone augmentation of atrophic ridges. Thus, guided bone regeneration is considered one of the most commonly applied methods to reconstruct alveolar bone and to treat peri-implant bone deficiencies, as well as to replace lost bone and allow the implant to be fully integrated and maintained during functional loading. The use of digital tools for the automated fabrication of implant parts (CAD-CAM) is an optimizing reality in Dentistry. CAD-CAM enables high-quality, standardized, accurate, and detail-perfect prosthetic restorations. The use of metallic implants in the morse cone system in association with zirconia abutments guarantees a final product with mechanical resistance, biocompatibility, and aesthetics. Also, immunomodulatory guided bone regeneration membranes are mainly developed by improving macrophage recruitment and aggregation as well as regulating macrophage polarization.

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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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It was performed.

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