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Guided bone regeneration in implant dentistry: a systematic review

Maria Eduarda Tamura Esteves[1], Ruana Molina Garcia Bianchini[1], João Pedro Pereira Gonzatti[1], Andreia Borges Scriboni[1,2*]

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

*Corresponding author: Dra. Andreia Borges Scriboni.
Unorte/Unipos – Graduate and Postgraduate education,
Dentistry department, São José do Rio Preto, São Paulo, Brazil.
Email: abscriboni@hotmail.com

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Abstract

Introduction: The rehabilitation of the dental arch with osseointegrated implants makes it possible to improve the quality of life of patients. Guided bone regeneration (GBR) has been applied to replace lost bone to allow the implant to be fully integrated and maintained during functional loading. GBR is considered one of the most commonly applied methods to reconstruct alveolar bone and to treat peri-implant bone deficiencies. **Objective:** It was to develop a systematic review to highlight the main approaches of guided surgery to promote bone regeneration in implant dentistry. **Methods:** The systematic review rules of the PRISMA Platform were followed. The search was carried out from March to May 2023 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases, using articles from 1977 (Golden pattern - Bra°nemark et al.) to 2023. **Results and Conclusion:** A total of 117 articles were found, 38 articles were evaluated and 28 were included and developed in this systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 22 studies with a high risk of bias and 15 studies that did not meet GRADE. It was concluded that the application of a membrane to prevent nonosteogenic tissues from interfering with bone regeneration is a fundamental principle. Membrane properties and biological outcomes drive bone regeneration in membrane-covered defects. Barrier membranes play the role of preventing the invasion of soft tissue by exiting the mucosa and creating an underlying space to support bone growth. Collagen membranes have excellent biological properties and bone regeneration results. While collagen membranes do not provide sufficient mechanical protection of the covered bone defect, titanium-reinforced membranes, and non-resorbable membranes need to be removed in a second surgery.

Keywords: Bone regeneration. Guided bone regeneration. Implant dentistry. Biomaterials. Membranes.

Introduction

The rehabilitation of the dental arch with osseointegrated implants makes it possible to improve the quality of life of patients. To achieve a good long-term prognosis for osseointegrated implants, there must be sufficient bone volume at the implant sites. In this regard, guided bone regeneration (GBR) has been applied to replace lost bone to allow the implant to be fully integrated and maintained during functional loading. Therefore, GBR is considered one of the most commonly applied methods to reconstruct alveolar bone and to treat peri-implant bone deficiencies [1,2].

In this sense, GBR is successful when osteoprogenitor cells are exclusively allowed to repopulate the site of the bone defect, preventing the entry of non-osteogenic tissues. In this scenario, about 40% of osseointegrated implants require GBR as part of the patient's rehabilitation, with a survival rate of up to 100% [1]. Thus, maxillary atrophy is an increasingly frequent clinical condition and the causes that lead to focal or generalized atrophy are multiple factors [3-5]. Bone density influences the operative protocol and the choice of implant type used to replace missing teeth [6].

In this context, the optimization of faster and more accurate techniques by dentists and postoperative surgeons with better results and quality of life, stimulated the development of numerous software and hardware to perform computer-guided surgeries, the so-called Virtual Surgeries (VS). [7]. In this sense, it is essential to perform Computed Tomography (CT) on the patient [8].

Thus, these programs allow the placement of implants in the program, as well as the manufacture of a high-precision surgical guide, leading to the possibility of performing flapless surgeries, for the placement of implants and prostheses in immediate loading in patients [9]. However, the accuracy of Guided Surgery systems for placing dental implants depends on a series of cumulative and interactive factors, which can lead to errors [10], such as the image acquisition process, the registration process, the navigation of the software, surgical guide production and human error [11-14].

In this way, reconstruction technologies have expanded to include the use of virtual surgical planning (VSP) and computer-aided design and manufacturing (CAD-CAM), and threedimensional printing. The advantages of VSP over traditional techniques may be related to late reconstruction, maxillary reconstruction, placement of dental implants, and precision-guided oncology [15]. Yet, the use of CT and software developments for virtual planning are orienting oral surgery precisely towards a specific target [16].

In this sense, computer-based guided surgery (GS) refers to the use of a tissue-supported surgical model. This reproduces the virtual position of the implant directly from the CT scan data and this information can be converted into guide templates to be used during surgery [17]. Dynamic-guided surgery reproduces the virtual position of the implant directly from CT data and uses motion-tracking technology to guide implant osteotomy preparation [18]. Several protocols for GS are available in the literature and are differentiated by different guide production techniques, support methods, and drilling/placement protocols [19]. In this way, it became possible to plan the position of the optical implant virtually the ideal implant position, taking into account the adjacent vital anatomical structures and future prosthetic requirements [20].

Therefore, the present study developed a systematic review to highlight the main approaches of guided surgery to promote bone regeneration in implant dentistry.

Methods

Study Design

This was followed by a systematic literature review model, according to PRISMA rules. Available at: http://prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed on: 05/10/2023.

Data sources, Study Quality and Risk of Bias

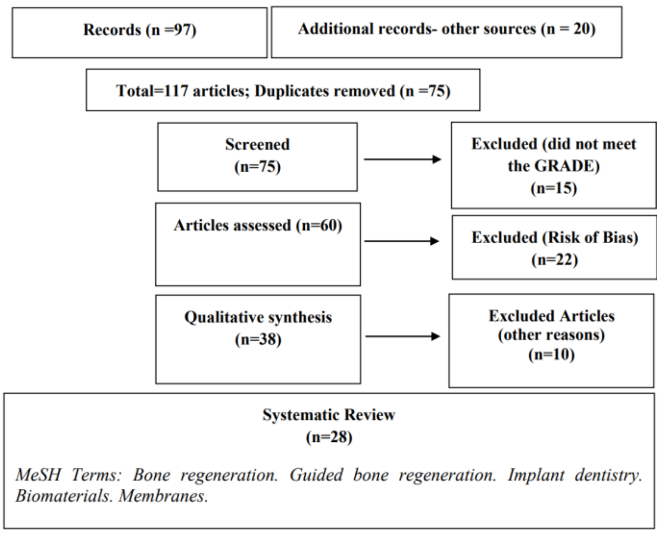
The literary search process was carried out from March to May 2023 and was developed based on Scopus, PubMed, Science Direct, Scielo, and Google Scholar, using articles from 1977 (Golden pattern - Bra°nemark et al.) to 2023, using the descriptors (MeSH Terms): *"Bone regeneration. Guided bone regeneration. Dental implant. Biomaterials. Membranes",* and using the Booleans "and" between the descriptors (MeSH Terms) and "or" between the historical findings. The quality of the studies was based on the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument.

Results

Summary of Literary Findings

A total of 117 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 75 articles. A total of 38 articles were evaluated and 28 were included and developed in this systematic review study (**Figure 1**). Considering the Cochrane tool for risk of bias, the overall assessment resulted in 22 studies with a high risk of bias and 15 studies that did not meet GRADE.

Figure 1. Selection of studies.



Major Approaches

In the GBR scenario, the application of a membrane to prevent non-osteogenic tissues from interfering with bone regeneration is a fundamental principle. Membrane materials have some properties that are amenable to modification. Membrane properties and biological outcomes drive bone regeneration in membrane-covered defects. Experimental data suggest that different modifications in the physical-chemical and mechanical properties of the membranes can promote bone regeneration. Optimization of membrane materials systematically addressing both barrier and bioactive properties is required [21].

In this regard, a meta-analysis study accumulated information regarding the network of effects of various membranes on vertical bone regeneration and clinical complications in GBR or guided tissue regeneration (GTR). The effects of high-density polyethylene (d-PTFE), expanded polytetrafluoroethylene (e-PTFE), cross-linked collagen membrane (MCC), non-crosslinked collagen membrane (CM), titanium mesh (TM), titanium plus uncrosslinked (TM + CM), titanium mesh plus crosslinked (TM + CCM), titanium-reinforced d-PTFE, titanium-reinforced e-PTFE, polylactic acid (PLA), polyethylene glycol (PEG) and polylactic acid 910 (PLA910). A total of 19 articles were included in a meta-analysis. Titanium-reinforced d-PTFE exhibited the greatest vertical bone increment effect. Soft tissue injury and membrane exposure were the most common complications [22].

In addition, barrier membranes play a role in preventing soft tissue invasion from the mucosa and creating an underlying space to support bone growth. Different membrane types provide different biological mechanisms due to their different origins, preparation methods, and structures. In highlight, collagen membranes show excellent biological properties and bone regeneration results for non-absorbable membranes even without a second surgery for removal [23]. Thus, barrier membranes represent a GBR surgical technique and are usually made of resorbable collagen or non-resorbable materials. While collagen membranes do not provide sufficient mechanical protection of the covered bone defect, titanium-reinforced membranes, and non-resorbable membranes need to be removed in a second surgery.

A study by Rider et al. (2021) used a biodegradable membrane of pure magnesium (99.95%) and proved to have all the requirements for an ideal regenerative result. After implantation, the magnesium membrane separates the regenerating bone from the more rapidly proliferating, overlying soft tissue. During the initial healing period, the membrane maintained a barrier and space provision function, maintaining the positioning of the bone graft material within the defect space. As the magnesium metal corroded, it formed a layer of salt corrosion and local gas cavities, which extended the functional life of the membrane's barrier capabilities. During the resorption of metallic magnesium and magnesium salts, the membrane was observed to be surrounded and then replaced by new bone. After the membrane was completely resorbed, only the healthy tissue remained [24].

A recent experimental study developed by Jung et al. (2023) analyzed whether recombinant human bone morphogenetic protein-2 (rhBMP-2) would optimize GRB with the collagen membrane. Four critical cranial bone defects were created and treated in 30 New Zealand white rabbits, including a control group, critical defect only; group 1, only collagen membrane; group 2, only biphasic calcium phosphate (BCP); group 3, collagen membrane + BCP; group 4, collagen membrane with rhBMP-2 (1.0 mg/mL); group 5, collagen membrane with rhBMP-2 (0.5 mg/mL); group 6, collagen membrane with rhBMP-2 (1.0 mg/mL) + BCP; and group 7, collagen membrane with rhBMP-2 (0.5 mg/mL) + BCP. Combining collagen membranes with rhBMP-2 and BCP produced significantly higher bone formation rates compared to the other groups. A healing period of 2 weeks produced significantly less bone formation than 4 and 8 weeks [25].

In this scenario, GRB is considered accurate and reliable compared to free implant surgery. However, a deviation between virtual implant planning and actual implant position can occur due to the surgical learning curve and accumulated errors that can occur over the various steps of the digital workflow. The learning curve is fundamental to dealing with any complication [18].

One study compared the virtual planning accuracy of new model-based computer-assisted implant placement techniques using stereolithographic CAD/CAM surgical models with or without metallic sleeves. Patients were randomized according to a parallel group design into two groups: surgical cast with or without metallic sleeves. Three deviation parameters (angular, horizontal, vertical) were defined to assess the discrepancy between the planned and placed positions of the implants. No implants failed and there were no complications. Forty-one implants were placed using surgical templates with metal sleeves, while 49 implants were placed using a surgical template without metal sleeves. Of these, 16 implants were placed through open sleeves and 33 through closed sleeves. There was a statistically significant difference in the angle and the vertical plane, with lower values for implants placed with a surgical mold without metallic sleeves. In the test group, closed sleeves were more accurate compared to open sleeves in the angle and horizontal plane. Therefore, the surgical models without metallic sleeves were more accurate in the vertical plane and the angle compared to the conventional model. Open sleeves should be used with caution in the molar region only in case of reduced space between the squares [20].

In addition, a study evaluated the effects of preoperative virtual planning and mandibular reconstruction guided by dental implant rehabilitation on denture rehabilitation after mandibular reconstruction. A total of 29 patients were included in the study, with 16 patients in the nonavigation group and 13 in the navigation group. A total of 101 implants were inserted, and the implant success rate was 98.02%. All patients received prosthetic treatment. Of the 13 patients in the navigation group, 9 received implant-supported fixed prostheses, while the other 4 received removable prostheses. Of the 16 patients in the non-navigation group, 9 eventually received implanted fixed prostheses and 7 received removable prostheses. There were no significant intergroup differences in terms of prosthesis type (p=0.702). However, the proportion of implantsupported fixed prostheses in the navigation group was higher compared to the non-navigation group. Therefore, preoperative virtual planning and dental implant-guided mandible reconstruction through preoperative designs may provide a good opportunity to achieve high implant success rates and dental rehabilitation. This method can also benefit prosthetic restorations supported by fixed implants. Furthermore, the use of navigation after virtual planning does not affect the type of prosthetic reconstruction [26].

Based on the literary findings presented above, it is possible to develop a preoperative planning method, associated with the area of implant dentistry, using digital images. In this group of digital images, all the potentialities of the great diversity of CAD programs and threedimensional image editing are included. The great utility of imaging diagnostic methods such as CT is highlighted, being essential to develop all methods [27].

Still, concerning the conventional surgical guide, it presented some advantages such as being cheaper, simple, and easy to perform, however, it leads to a greater operative risk for the patient. However, the precision of the place to be implanted is not the best and there is a greater probability of this guide becoming worn, due to the contact of the drills with it. In general, the manufacture of a surgical guide ensures that during surgery the implants are positioned and inclined according to the pre-established location, considering the amount of bone, positioning, inclination, and three-dimensional relationships of the implants [28].

Conclusion

It was concluded that the application of a membrane to prevent non-osteogenic tissues from interfering with bone regeneration is a fundamental principle. Membrane properties and biological outcomes drive bone regeneration in membrane-covered defects. Barrier membranes play the role of preventing the invasion of soft tissue by exiting the mucosa and creating an underlying space to support bone growth. Collagen membranes have excellent biological properties and bone regeneration results. While collagen membranes do not provide sufficient mechanical protection of the covered bone defect, titanium-reinforced membranes, and non-resorbable membranes need to be removed in a second surgery.

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Ethical Approval

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Informed consent

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Data sharing statement

No additional data are available.

Conflict of interest

The authors declare no conflict of interest.

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References

1. Girón J, Kerstner E, Medeiros T, Oliveira L, Machado GM, Malfatti CF, Pranke P. Biomaterials for bone regeneration: an orthopedic and dentistry overview. Braz J Med Biol Res. 2021 Jun 14;54(9):e11055. doi: 10.1590/1414-431X2021e11055.
2. Gugliandolo A, Fonticoli L, Trubiani O, Rajan TS, Marconi GD, Bramanti P, Mazzon E, Pizzicannella J, Diomede F. Oral Bone Tissue Regeneration:

Mesenchymal Stem Cells, Secretome, and Biomaterials. Int J Mol Sci. 2021 May 15;22(10): 5236. doi: 10.3390/ijms22105236.
3. You JS, Kim SG, Oh JS, Kim JS. Effects of Platelet-Derived Material (Platelet-Rich Fibrin) on Bone Regeneration. Implant Dent. 2019 Mar 8. doi: 10.1097/ID.0000000000000877].
4. Pye AD, Lockhart DEA, Dawson MP, Murray CA, Smith AJ. A review of dental implants and infection. J Hosp Infect ; 2009, 72:104–110.
5. Bra°nemark PI, Hansson BO, Adell R, Breine U, Lindstrom J, Hallen O et al. Osseointegrated implants in the treatment of edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg Suppl. 1977, 16:1–192.
6. Bugarin Júnior JG, GarrafaII V. Bioethics and biosafety: the use of biomaterials in dental practice. Rev Saúde Pública. 2007, 41(2):223-8.
7. Mazaro JVQ, Godoy Pai, Junior JFS, Mello CC, Pellizzer EP, Zavanelli AC; Regeneração óssea guiada em implantodontia: relato de caso ; RFO, Passo Fundo. 2014, v. 19, n. 1, p. 121-128.
8. Tahmaseb A, WU V, Wismeijer D, et al. The accuracy of static computer-aided implant surgery: a systematic review and meta-analysis. Clin Oral Implants Res. 2018, 29(Suppl 16):416–35.
9. Tahmaseb A, Wismeijer D, Coucke W, et al. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants; 2014, 29(Suppl):25– 42.
10. Jung RE, Schneider D, Ganeles J, et al. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants; 2009, 24(Suppl):92– 109.
11. D'Haese J, Van De Velde T, Komiyama A, et al. Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature. Clin Implant Dent Relat Res;2012, 14:321–35.
12. Oh JH, An X, Jeong SM, et al. Digital workflow for computer-guided implant surgery in edentulous patients: a case report. J Oral Maxillofac Surg. 2017, 75: 2541–9.
13. El Kholy K, Janner SFM, Schimmel M, et al. The influence of guided sleeve height, drilling distance, and drilling key length on the accuracy of static computerassisted implant surgery. Clin Implant Dent Relat Res. 2019, 21(1):101–7.
14. Zhou W, Liu Z, Song L, et al. Clinical factors affecting the accuracy of guided implant surgery-a systematic review and meta-analysis. J Evid Based Dent Pract;18:28–40, 2018.
15. Cassetta M, Bellardini M. How much does experience in guided implant surgery play a role in accuracy? A randomized controlled pilot study. Int J Oral Maxillofac Surg; 2017, 46:922–30.
16. Rungcharassaeng K, Caruso JM, Kan JY, et al. Accuracy of computer-guided surgery: a comparison of operator experience. J Prosthet Dent; 2015, 114:407–13.
17. D'Haese J, Ackhurst J, Wismeijer D, DE Bruyn H, Tahmaseb A. current state of the art of computer-guided implant surgery. Periodontol 2000. 2017 Feb;73(1):121-133. doi: 10.1111/prd.12175.
18. Pommer B, Busenlechner D, Fürhauser R, Watzek G, Mailath-Pokorny G, Haas R. Trends in techniques to avoid bone augmentation surgery: Application of short implants, narrowdiameter implants and guided surgery. J Craniomaxillofac Surg. 2016 Oct;44(10):16301634. doi: 10.1016/j.jcms.2016.08.012.
19. Oliveira G, Mattos W, Albaricci M, Marcantonio É, Queiroz T, Margonar R. Original Research: Analysis of linear and angular deviations of implants installed with a tomographic guided surgery technique. A prospective cohort-study. J Oral Implantol. 2019 Jun 17. doi: 10.1563/aaid-joi-D-18-00265.
20. AL YAFI F, CAMENISCH B, AL-SABBAGH M. Is Digital Guided Implant Surgery Accurate and Reliable? Dent Clin North Am. 2019 Jul;63(3):381-397. doi: 10.1016/j.cden.2019.02.006.
21. Elgali I, Omar O, Dahlin C, Thomsen P. Guided bone regeneration: materials and biological mechanisms revisited. Eur J Oral Sci. 2017 Oct;125(5):315-337. doi: 10.1111/eos.12364.
22. Zhang M, Zhou Z, Yun J, Liu R, Li J, Chen Y, Cai H, Jiang HB, Lee ES, Han J, Sun Y. Effect of Different Membranes on Vertical Bone Regeneration: A Systematic Review and Network Meta-Analysis. Biomed Res Int. 2022 Jul 14;2022:7742687. doi: 10.1155/2022/7742687.
23. Ren Y, Fan L, Alkildani S, Liu L, Emmert S, Najman S, Rimashevskiy D, Schnettler R, Jung O, Xiong X, Barbeck M. Barrier Membranes for Guided Bone Regeneration (GBR): A Focus on Recent Advances in Collagen Membranes. Int J Mol Sci. 2022 Nov 29;23(23):14987. doi: 10.3390/ijms232314987.
24. Rider P, Kačarević ŽP, Elad A, Tadic D, Rothamel D, Sauer G, Bornert F, Windisch P, Hangyási DB, Molnar B, Bortel E, Hesse B, Witte F.

Biodegradable magnesium barrier membrane used for guided bone regeneration in dental surgery. Bioact Mater. 2021 Nov 29;14:152-168. doi: 10.1016/j.bioactmat.2021.11.018.

25. Jung N, Park J, Park SH, Oh S, Kim S, Cho SW, Kim JE, Moon HS, Park YB. Improving Bone Formation by Guided Bone Regeneration Using a Collagen Membrane with rhBMP-2: A Novel Concept. J Funct Biomater. 2023 Mar 22;14(3):170. doi: 10.3390/jfb14030170.
26. Albiero AM, Benato R, Momic S, Degidi M. Guided-welded approach planning using a computer-aided designed prosthetic shell for immediately loaded complete-arch rehabilitations supported by conometric abutments. J Prosthet Dent. 2019 May 8. pii: S0022-3913(18)30742-X. doi: 10.1016/j.prosdent.2018.12.002.
27. Tallarico M, Martinolli M, Kim Y, Cocchi F, Meloni SM, Alushi A, Xhanari E. Accuracy of Computer-Assisted Template-Based Implant Placement Using Two Different SurgicalTemplates Designed with or without Metallic Sleeves: A Randomized Controlled Trial. Dent J (Basel). 2019 Apr 2;7(2). pii: E41. doi: 10.3390/dj7020041.
28. Zhu H, Zhang L, Cai Z, Shan X. Dental Implant Rehabilitation After Jaw Reconstruction Assisted by Virtual Surgical Planning. Int J Oral Maxillofac Implants. 2019 Feb 19. doi: 10.11607/jomi.7278.