

JNT FACIT BUSINESS AND TECHNOLOGY JOURNAL

ISSN: 2526-4281 - ANO 2026 - MÊS DE MARÇO

Ed. 72. Vol. 1 - Págs. 134-146

DOI: 10.5281/zenodo.19019466



QUALIS
A2



STATE OF THE ART OF BARRIER MEMBRANE DERIVED FROM XENOGENEIC CORTICAL BONE: A NARRATIVE REVIEW¹

ESTADO DA ARTE DE MEMBRANA DE BARREIRA DERIVADA DE OSSO CORTICAL XENÓGENO: UMA REVISÃO NARRATIVA

Expedito Victor Dlano Carvalho FREIRE
Universidade Federal do Ceará (UFC)
E-mail: victordlanocf1@gmail.com
ORCID: <http://orcid.org/0009-0001-0736-9682>

Alysson Guimarães Parente LOPES
Universidade Federal do Ceará (UFC)
E-mail: alyssongplopes@gmail.com
ORCID: <http://orcid.org/0009-0000-0712-9251>

Luiza Frota XIMENES
Centro Universitário INTA (UNINTA)
E-mail: luizaximenesfrota@gmail.com
ORCID: <http://orcid.org/0009-0008-3326-8800>

Igor Iuco CASTRO-SILVA
Universidade Federal do Ceará (UFC)
E-mail: igor.iuco@sobral.ufc.br
ORCID: <http://orcid.org/0000-0003-4815-6357>

ABSTRACT

Barrier membranes are fundamental in guided bone regeneration (GBR) because they prevent soft tissue invasion and promote new bone formation. Although conventional collagen membranes are widely used, they present limitations regarding mechanical strength and degradation rate. In recent years, membranes derived from xenogeneic cortical bone have emerged as a promising alternative. The aim of this narrative review was to analyze evidence on cortical membranes applied to GBR. Original articles published between 2015 and 2025 were retrieved from the PubMed database and stratified by origin, country, processing, and performance. Of the nine studies, porcine membranes predominated over bovine and equine membranes, with studies concentrated in the Global North and there was methodological heterogeneity regarding partial or enzymatic demineralizing processing for collagen preservation or exposure. They were reported favorable biological properties, including

¹ COMO CITAR: (ABNT): FREIRE, E. V. D. C.; LOPES, A. G. P.; XIMENES, L. F.; CASTRO-SILVA, I. I. State Of The Art Of Barrier Membrane Derived From Xenogeneic Cortical Bone: A Narrative Review. **JNT Facit Business and Technology Journal**. Qualis A2. ISSN: 2526-4281, Mês de Março de 2026 - Ed. 72. VOL. 01. Págs. 134-146. Disponível: <http://revistas.faculadefacit.edu.br>. Acesso em: __/__/__.

biocompatibility, good clinical handling, mechanical strength, cell adhesion, and in vitro osteogenic differentiation, as well as evidence of in vivo osteopromotion. Partial preservation of laminar architecture and the benefits of collagen were highlighted as relevant factors for tissue integration and maintenance of regenerative space. However, important limitations persist, such as the small number of studies and lack of methodological standardization. It is concluded that xenogeneic cortical bone membranes, especially porcine ones, represent a sustainable alternative with osteopromotive potential for use in dentistry, although more robust clinical trials are needed.

Keywords: Guided tissue regeneration. Heterografts. Cortical bone.

RESUMO

As membranas de barreira são fundamentais na regeneração óssea guiada (ROG), pois evitam a invasão de tecido mole e favorecem a neoformação óssea. Embora as membranas colágenas convencionais sejam amplamente utilizadas, apresentam limitações quanto à resistência mecânica e velocidade de degradação. Nos últimos anos, membranas derivadas de osso cortical xenógeno surgiram como alternativa promissora. O objetivo desta revisão narrativa foi analisar evidências sobre membranas corticais aplicadas à ROG. A partir da base PubMed, foram recuperados artigos originais entre 2015 e 2025 e estratificados por origem, país, processamento e desempenho. Dos nove estudos, houve predomínio das membranas porcinas sobre bovinas e equinas, concentradas no Norte Global e heterogeneidade metodológica quanto ao processamento desmineralizador parcial ou enzimático para preservação ou exposição colágena. Foram relatadas propriedades biológicas favoráveis, incluindo biocompatibilidade, boa manipulação clínica, resistência mecânica, adesão e diferenciação osteogênica in vitro, além de evidências de osteopromoção in vivo. A preservação parcial da arquitetura laminar e os benefícios do colágeno foram destacados como fatores relevantes para a integração tecidual e manutenção do espaço regenerativo. Contudo, limitações importantes persistem, como o baixo número de estudos e ausência de padronização metodológica. Conclui-se que as membranas de osso cortical xenógeno, especialmente as suínas, representam uma alternativa sustentável e com potencial osteopromotor para uso em Odontologia, embora ensaios clínicos mais robustos sejam necessários.

Palavras-chave: Regeneração tecidual guiada. Xenoenxertos. Osso cortical.

INTRODUCTION

Guided bone regeneration (GBR) is a set of therapeutic approaches used in the reconstruction of craniofacial bone defects, with the aim of restoring the form and function of lost bone structures (Elgali *et al*, 2017). Barrier membranes are fundamental in GBR, protecting blood clots from soft tissue invasion to promote osteogenesis and the beneficial effects can be enhanced when combined with mineral bone grafts, whether in small periodontal defects or large bone losses in the alveolar process (Araújo *et al*, 2023; Choi *et al*, 2023; Elgali *et al*, 2017). Ideally, these membranes should be biocompatible, easy to handle, moldable to the defect, exhibit cell occlusion, maintain regenerative space, and have a degradation rate compatible with bone neoformation (Araújo *et al*, 2023; Choi *et al*, 2023).

Regenerative membranes generally have a natural xenogeneic or synthetic origin, a more heterogeneous composition within the classes of metallic, ceramic, polymeric, or composite biomaterials, and, depending on their interaction with biological tissue, can be bioinert, bioabsorbable, or bioactive (Araújo *et al*, 2020). The consumer market still offers a wide range of membranes according to their intrinsic characteristics (Sanz *et al*, 2019), such as non-resorbable PTFE membranes for small bone defects (Turri *et al*, 2021) and titanium meshes for large-size bone reconstructions (Roca-Millan *et al*, 2020). However, most GBR techniques involve collagen membranes due to their favorable biological properties, although they still face limitations such as functional fragility, variable immunogenicity, and rapid degradation, which drives improvements in their structure and processing (Almazrooa; Noonan; Woo, 2014; Toledano *et al*, 2021; Toledano-Osorio *et al*, 2021).

In recent years, cortical bone sheets, manufactured from collagenized porcine bone, have gained prominence as an option in vertical and horizontal bone reconstructions, offering good handling and clinical performance for dental applications (Debortoli *et al*, 2024). However, there is a lack of state-of-the-art literature on the subject, focusing on its development, effectiveness for GBR, and efficiency compared to other membranes. The aim of this narrative review was to identify and describe the types of barrier membranes derived from xenogeneic cortical bone available in literature, their processing characteristics, biological properties, and osteopromotive potential.

METHODOLOGY

Study Design

A quantitative, descriptive, and cross-sectional study of a bibliometric-documentary nature was conducted, using online document analysis in the form of a narrative literature review (Celestino; Lima; Ribeiro, 2024).

For the construction of the search strategies, an adaptation of the strategy PICO (P: Population, I: Intervention, C: Comparison and O: Outcome) was used, to guide the formulation of the exploratory research question and the bibliographic search and allows the researcher to accurately locate the best available information (Menezes *et al*, 2015).

PVO is an acronym proposed by two Brazilian researchers that constitutes an alternative for reviews that move away from the clinical nature of PICO, where: "P" is the description of the problem (population, context or disease), "V" is the definition of limits or variables and "O" is the definition of outcomes, whether desired or not (Menezes; Novaes, 2019). Considering this framework, the literature search adopted the following criteria: "P" for the context of xenogeneic cortical bone membranes for GBR; "V" for the categorical variables of study design such as *in vitro*, *in vivo*, or clinical ones, time limit of the last ten years, spatial or country origin, animal origin such as porcine, bovine or equine, anatomical removal site, such as femur, iliac, rib, jawbone or unknown, biomaterial composition considering collagen or collagen and apatite; and "O" for whether the results were satisfactory or not for use as a barrier membrane alone or associated with bone grafts.

This research was conducted in accordance with the bioethical principles in force in Brazil for research considering the use of publicly accessible secondary data, in compliance with Resolution No. 510/2016 of the National Health Council.

Guiding Question

The guiding question for the following study was: "What scientific evidence has existed in the last decade, regarding the effectiveness of xenogeneic cortical membranes as barriers in GBR?".

Eligibility Criteria

The methodology adopted followed the principles of the PRISMA 2020 guideline for non-systematic reviews and sought to ensure scientific rigor in the selection and analysis of sources.

The data collection process accessed the PubMed database (<https://pubmed.ncbi.nlm.nih.gov/>). The search strategy used the descriptors "cortical membrane" and "guided bone regeneration," combined using the Boolean operator AND. Inclusion criteria included articles published between 2015 and 2025, in English, with full text available, and that were original studies. Exclusion criteria included duplicate articles, systematic reviews, meta-analyses, and those that did not directly address cortical bone membranes or were off-topic content.

The titles and abstracts of all articles were analyzed by two independent reviewers, with internal calibration by the research team. All studies that met the inclusion criteria were selected for full-text reading and included for data extraction, while the reasons for exclusion were recorded.

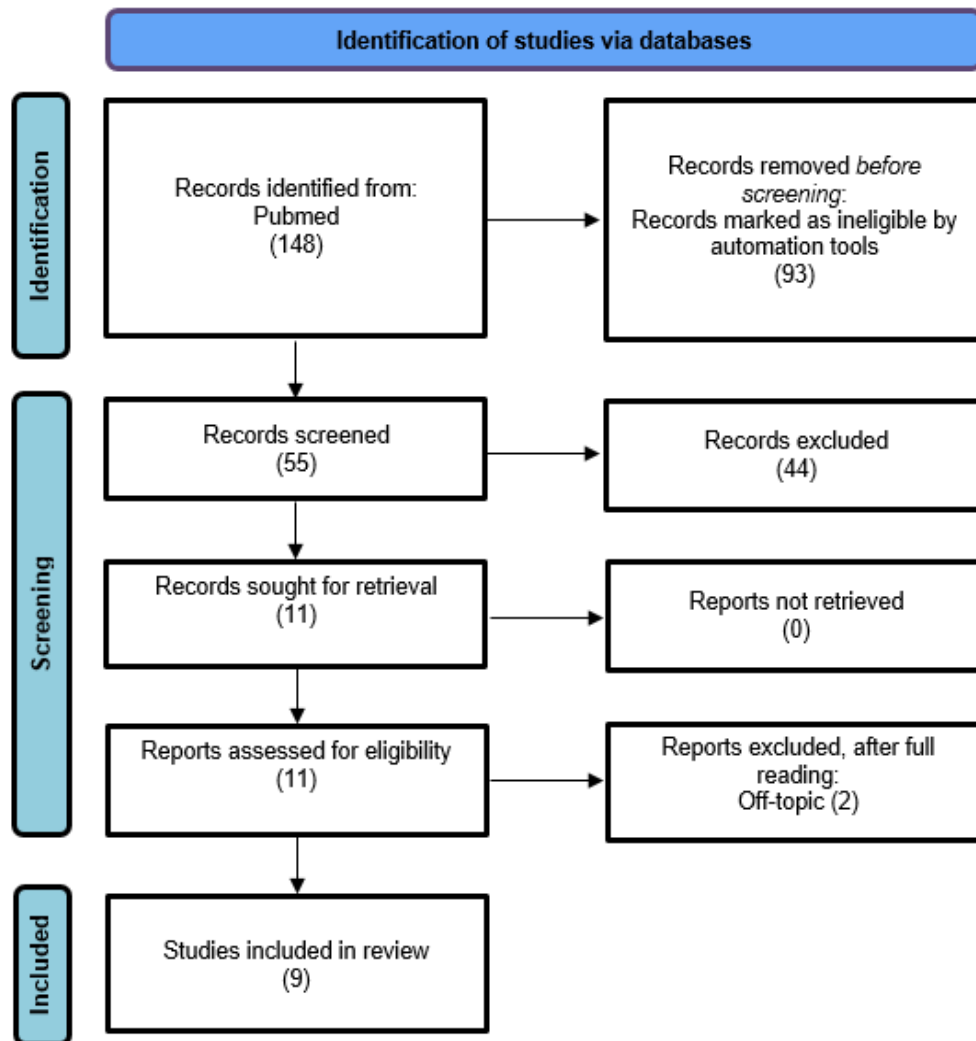
Data Collection and Analysis

The data from the selected articles were extracted and organized descriptively to allow for a comparative synthesis of the information. The analysis was conducted considering the elements defined in the PVO strategy, to evaluate the application context, the variables studied, and the outcomes related to the effectiveness of xenogeneic cortical membranes in guided bone regeneration. The level of scientific evidence of the included articles was categorized to identify frequencies and the most typical profile for the research object under analysis (Zhang *et al*, 2022).

RESULTS

One hundred and forty-eight records were found in the PubMed database, of which 55 articles remained after initial screening by title and abstract. After applying the eligibility criteria, 11 articles were selected for full reading and final analysis, two were excluded for deviating from the study's objective, resulting in nine studies included in this narrative review. (Figure 1).

Figure 1: Flowchart for study eligibility for narrative review.



Source: Research data.

Based on the selected literature, a growing trend of publications on the use of cortical membranes applied to GBR was observed. In 2017, only two relevant studies were identified. (Di Stefano; Garagiola; Bassi, 2017; Kamadjaja *et al*, 2017). From 2020 onwards, the number of publications increased substantially, with the last five years accounting for 77.8% of the evidence, although the absolute number of articles is still small (Danieletto-Zanna *et al*, 2020; Debortoli *et al*, 2024; Di Stefano *et al*, 2020; Güney; Jaballah; Coulibaly, 2024; Nehal *et al*, 2024; Pierfelice *et al*, 2023; Rossi; Ghezzi; Tomecek, 2020).

The analysis of the geographical origin of the studies demonstrated a clear predominance of 66.7% of the analyzed articles developed by institutions located in the so-called Global North, including Italy (Di Stefano *et al*, 2020; Di Stefano; Garagiola; Bassi, 2017; Pierfelice *et al*, 2023; Rossi; Ghezzi; Tomecek, 2020) and France (Debortoli *et al*, 2024; Güney; Jaballah; Coulibaly, 2024), equivalent to double that developed in the remaining 33.3% of countries belonging to the Global South,

including Indonesia (Kamadjaja *et al*, 2017), Brazil (Danieletto-Zanna *et al*, 2020) and India (Nehal *et al*, 2024).

Regarding the biological origin of the membranes, the data showed that the majority or 56% of natural biomaterials were of porcine origin (Debortoli *et al.*, 2024; Güney; Jaballah; Coulibaly, 2024; Nehal *et al*, 2024; Pierfelice *et al*, 2023; Rossi; Ghezzi; Tomecek, 2020), followed by bovine (Danieletto-Zanna *et al*, 2020; Kamadjaja *et al*, 2017) and equine (Di Stefano *et al*, 2020; Di Stefano; Garagiola; Bassi, 2017), both with 22% of the sample. When evaluating the anatomical location used to obtain the cortical bone membranes, none of the nine included studies explicitly provided this information, making it impossible to correlate the intraoral or extraoral origin of the bone segment or the morphotype of long, short, or flat bone (Danieletto-Zanna *et al.*, 2020; Debortoli *et al.*, 2024; Di Stefano *et al.*, 2020; Di Stefano; Garagiola; Bassi, 2017; Güney; Jaballah; Coulibaly, 2024; Kamadjaja *et al*, 2017; Nehal *et al*, 2024; Pierfelice *et al*, 2023; Rossi; Ghezzi; Tomecek, 2020).

There was heterogeneity in the manufacturing processes of the xenogeneic cortical bone membranes, with all protocols employing conservative physicochemical treatments, and no report of complete demineralization (Danieletto-Zanna *et al*, 2020; Debortoli *et al*, 2024; Di Stefano *et al*, 2020; Di Stefano; Garagiola; Bassi, 2017; Güney; Jaballah; Coulibaly, 2024; Kamadjaja *et al*, 2017; Nehal *et al*, 2024; Pierfelice *et al*, 2023; Rossi; Ghezzi; Tomecek, 2020).

In most cases, the membranes underwent controlled cleaning and deproteinization steps, emphasizing the hard inorganic matrix portion due to its richness in hydroxyapatite over the slightly demineralized organic part. There are mentions of mild and controlled enzymatic treatment, although the authors did not specify the type of enzyme, concentration, or exposure time, concluding with sterilization for immediate use or storage (Danieletto-Zanna *et al*, 2020; Debortoli *et al.*, 2024; Kamadjaja *et al*, 2017; Rossi; Ghezzi; Tomecek, 2020). The photodynamic protocol with light-emitting diode cited in one study could have a beneficial antibacterial effect on the use of porcine cortical laminae, without compromising the osteoconductive action for osteoblasts (Pierfelice *et al*, 2023).

The demineralization protocols, when present, were superficial or partial, sufficient to expose the collagen and increase bioactivity without compromising mechanical strength, thus ensuring good stability, barrier function, and osteopromotive behavior, as reported in clinical and experimental studies (Debortoli *et al*, 2024; Di Stefano *et al*, 2020; Güney; Jaballah; Coulibaly, 2024).

In equine membranes, a simplified protocol was employed for the OsteoBiol® cortical plate, aimed at removing immunogenic proteins and preserving the structural integrity and collagen of the matrix (Di Stefano *et al*, 2020; Di Stefano; Garagiola; Bassi, 2017). In porcine bone sheets, collagenization and lyophilization have been reported to dually preserve the mineral phase and the organic matrix (Debortoli *et al*, 2024; Rossi; Ghezzi; Tomecek, 2020). In bovine sheets, the use of partially demineralized cortical bone was observed, achieved through the action of a strong acid at low concentration, with slight exposure of the organic matrix. This could be justified by the content of proteins and growth factors that promote osteoinduction, followed by a lyophilization process to preserve the functional architecture (Danieletto-Zanna *et al*, 2020; Kamadjaja *et al*, 2017).

The frequency of clinical studies (Danieletto-Zanna *et al*, 2020; Debortoli *et al*, 2024; Rossi; Ghezzi; Tomecek, 2020; Güney; Jaballah; Coulibaly, 2024) it was equivalent to in vitro studies (Di Stefano; Garagiola; Bassi, 2017; Kamadjaja *et al*, 2017; Nehal *et al*, 2024; Pierfelice *et al*, 2023) and both outperformed in vivo studies (Di Stefano *et al*, 2020; Di Stefano; Garagiola; Bassi, 2017; Kamadjaja *et al*, 2017). Among the main findings regarding the performance of the cortical laminae, good clinical handling and mechanical resistance stand out (Debortoli *et al*, 2024; Rossi; Ghezzi; Tomecek, 2020; Güney; Jaballah; Coulibaly, 2024), partial preservation of the laminar architecture after conservative chemical processing (Kamadjaja *et al*, 2017), as well as the natural benefits of collagen present in the bone matrix, which contribute to the bioactivity and tissue integration of grafts (Nehal *et al*, 2024).

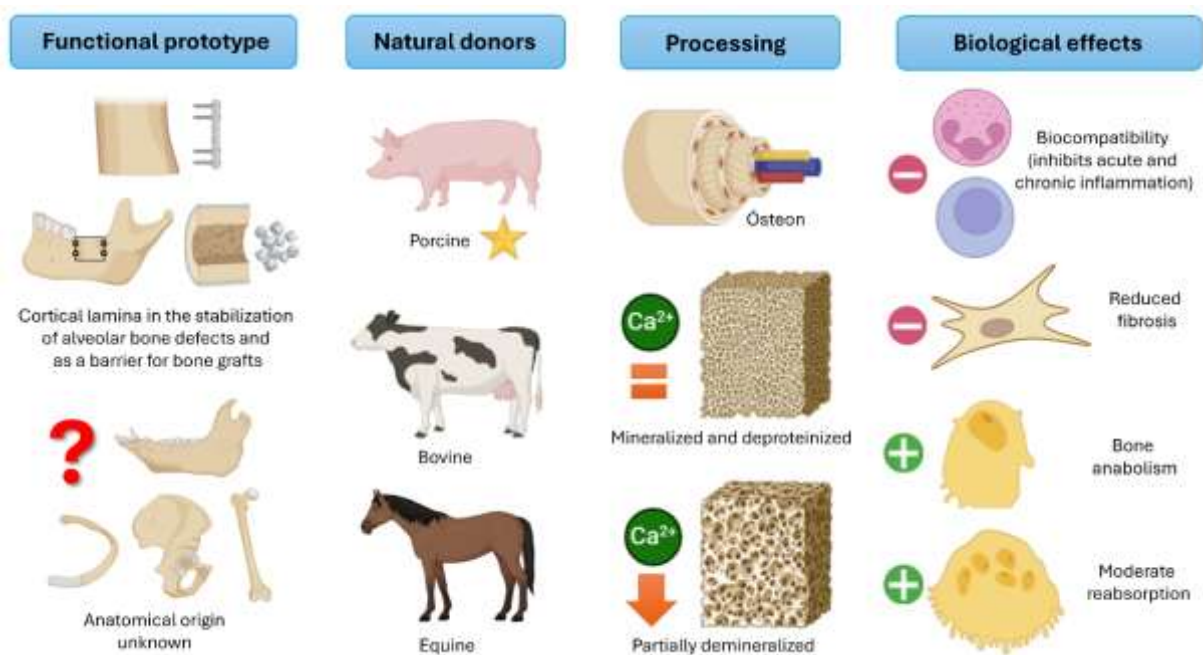
Regarding performance in different biological systems, cortical laminae demonstrated maintenance of laminar architecture after conservative processing, showing favorable properties of cell adhesion and proliferation, mechanical resistance, and support for in vitro osteogenic differentiation (Di Stefano; Garagiola; Bassi, 2017; Pierfelice *et al*, 2023; Rossi; Ghezzi; Tomecek, 2020).

In animal models, satisfactory biocompatibility and tissue integration were demonstrated, without tissue irritation or persistent acute or chronic inflammation, in addition to osteopromotive potential of bovine and porcine membranes favoring the anabolism of osteogenic cells and decreasing fibroplasia and fibrous tissue in the bone defect (Danieletto-Zanna *et al*, 2020; Rossi; Ghezzi; Tomecek, 2020). Evidence of in vivo osteopromotion was also observed, with effective isolation of soft tissue and stimulation of bone neoformation in critical defects (Di Stefano *et al*, 2020; Di Stefano; Garagiola; Bassi, 2017).

In the clinical field, case reports have confirmed the applicability of membranes in GBR procedures, with consistent results in preserving bone volume, closing complex defects, and stabilizing implants (Di Stefano *et al*, 2020; Di Stefano; Garagiola; Bassi, 2017; Güney; Jaballah; Coulibaly, 2024; Kamadjaja *et al*, 2017). In different protocols, moderate resorption with gradual turnover associated with clinical bone gains has been reported (Debortoli *et al*, 2024; Di Stefano *et al*, 2020; Rossi; Ghezzi; Tomecek, 2020).

A summary of the scientific evidence and frontiers of knowledge regarding the scope of xenogeneic cortical lamina barrier membrane for GBR is found in Figure 2.

Figure 2: State of the art on xenogeneic cortical lamina barrier membrane for GBR.



Source: Research data.

DISCUSSION

This narrative review gathered and analyzed the scientific evidence available in the last decade on the use of barrier membranes derived from xenogeneic cortical bone. Although the topic is expanding, the research field on membranes derived from cortical laminae is still underexplored and presents ample potential for development. It can be inferred that, given the *in vitro*, *in vivo*, and clinical results, the evidence on cortical laminae is at the level of translational knowledge frontier research, between basic and applied research aimed at solving real-world problems (Zhang *et al*, 2022).

The predominance of studies using membranes of porcine origin could be related to the wide availability of raw materials, economic viability, and the low immunogenicity of porcine bone (Araújo *et al*, 2023; Souza *et al*, 2022; Lopes *et al*,

2024). The lack of anatomical detail limits the comparative analysis regarding the influence of this variable on the biological and clinical performance of the biomaterial, since the anatomical site influences critical bone characteristics, such as cortical thickness, mineral density, and collagen content, which are implicated in mechanical resistance and the rate of resorption (Lopes *et al*, 2024). The diversity of approaches and the consequent lack of standardization in the description of cortical lamina processing also limit the reproducibility of studies (Araújo *et al*, 2023; Nehal *et al*, 2024; Souza *et al*, 2022).

In biological terms, cortical bone membranes have demonstrated relevant osteopromotive characteristics, such as the ability to effectively isolate soft tissue, provide support for new bone formation, and integrate appropriately into the recipient bed (Debortoli *et al*, 2024; Di Stefano *et al*, 2020; Di Stefano; Garagiola; Bassi, 2017; Güney; Jaballah; Coulibaly, 2024; Rossi; Ghezzi; Tomecek, 2020). These properties were reinforced by histological, morphometric, and immunohistochemical analyses in animal models, which confirmed biocompatibility and the induction of an osteogenic response (Danieletto-Zanna *et al*, 2020; Kamadjaja *et al*, 2017). Evidence suggests that these membranes can promote ossification through both osteopromotion, by stimulating cellular activity and osteoblastic differentiation, and osteoconduction, by maintaining space and acting as a physical barrier that guides bone tissue growth. This is favored by the Haversian system, with osteons that are more compactly packed than in the trabecular pattern (Nehal *et al*, 2024; Pierfelice *et al*, 2023).

Cortical laminae could be a clinical alternative to conventional collagen barrier membranes, offering advantages such as easier manipulation, resistance to early resorption, and maintenance of space for bone neoformation (Debortoli *et al*, 2024; Güney; Jaballah; Coulibaly, 2024). These evidences support the promising role of xenogeneic cortical bone membranes in GBR, both in experimental and medium- to long-term clinical settings.

The predominance of scientific production by institutions in the Global North reveals a significant gap in national literature. In Brazil, the only study retrieved focused on the performance analysis of membranes derived from bovine and porcine bone, with an emphasis on biocompatibility, osteopromotive potential, and structural characterization (Danieletto-Zanna *et al*, 2020). This scenario points to the need to expand national scientific production in clinical investigations with greater methodological robustness, to consolidate the translational application of these biomaterials and reduce dependence on foreign biotechnological research (Castro-

Silva *et al*, 2021; Lopes *et al*, 2024). This scenario encourages innovation in GBR for dentistry, through accessible, safe, and effective materials (Castro-Silva *et al*, 2021).

CONCLUSION

Xenogeneic cortical bone membranes show promising performance in GBR, with good tissue integration and osteopromotive potential. Despite these results, the heterogeneity of methods and the scarcity of robust clinical trials still limit definitive conclusions. Future studies with methodological standardization, larger sample sizes, and strengthened national production are essential to consolidate the clinical evidence for these biomaterials.

144

REFERENCES

ALMAZROOA, S. A.; NOONAN, V.; WOO, S. B. Resorbable collagen membranes: histopathologic features. **Oral Surgery, Oral Medicine, Oral Pathology, and Oral Radiology**, [s.l.], v. 118, n. 2, p. 236-240, 2014. <https://doi.org/10.1016/j.oooo.2014.04.006>. Acesso em: 23-mar-2026.

ARAÚJO, L. K. *et al*. Brazilian dentists' perceptions of using bone grafts: an inland survey. **Acta Odontologica Latinoamericana**, Buenos Aires, v. 33, n. 3, p. 165-173, 2020. <https://doi.org/10.54589/aol.33/3/165>. Acesso em: 23-mar-2026.

ARAÚJO, L. K. *et al*. Efficiency analysis of commercial polymeric membranes for bone regeneration in rat cranial defects. **Acta Cirúrgica Brasileira**, Rio de Janeiro, v. 38, p. e380623, 2023. <https://doi.org/10.1590/acb380623>.

CASTRO-SILVA, I. I. *et al*. Pesquisa odontológica brasileira em regeneração óssea guiada: um estudo bibliométrico de quatro décadas. **Research, Society and Development**, Itabira, v. 10, n. 2, p. e25510212504, 2021. <https://doi.org/10.33448/rsd-v10i2.12504>. Acesso em: 23-mar-2026.

CELESTINO, L.; LIMA, A. A.; RIBEIRO, T. L. S. Theoretical analysis of digital transformation in applied social sciences: a bibliometric review of the literature. **Revista Ibero-Americana de Estratégia**, São Paulo, v. 23, n. 3, p. e25923, 2024. <https://doi.org/10.1007/s10668-022-02874-7>. Acesso em: 23-mar-2026.

CHOI, W. *et al*. Occlusive membranes for guided regeneration of inflamed tissue defects. **Nature Communications**, [s.l.], v. 14, n. 1, p. e7687, 2023. <https://doi.org/10.1038/s41467-023-43428-3>. Acesso em: 23-mar-2026.

DANIELETTO-ZANNA, C. F. *et al*. Osteopromotion capacity of bovine cortical membranes in critical defects of rat calvaria: histological and immunohistochemical analysis. **International Journal of Biomaterials**, [s.l.], v. 2020, n. 1, p. e6426702, 2020. <https://doi.org/10.1155/2020/6426702>. Acesso em: 23-mar-2026.

DEBORTOLI, C. *et al*. Utilization of a cortical xenogeneic membrane for guided bone regeneration: a retrospective case series. **Journal of Clinical Medicine**, Basel, v. 13,

n. 15, p. e4575, 2024. <https://doi.org/10.3390/jcm13154575>. Acesso em: 23-mar-2026.

DI STEFANO, D. A.; GARAGIOLA, U.; BASSI, M. A. Preserving the bone profile in anterior maxilla using an equine cortical bone membrane and an equine enzyme-treated bone graft: a case report with 5-year follow-up. **The Journal of Contemporary Dental Practice**, Cincinnati, v. 18, n. 7, p. 614-621, 2017. <https://doi.org/10.5005/jp-journals-10024-2094>. Acesso em: 23-mar-2026.

DI STEFANO, D. *et al.* Implant and prosthetic success following peri-implant guided bone regeneration in the esthetic zone using an equine cortical bone membrane and an equine enzyme-treated bone graft: a retrospective study with 9-year follow-up. **International Journal of Oral & Maxillofacial Implants**, Berlim, v. 35, n. 4, p. 824-832, 2020. <https://doi.org/10.11607/jomi.7906>. Acesso em: 23-mar-2026.

ELGALI, I. *et al.* Guided bone regeneration: materials and biological mechanisms revisited. **European Journal of Oral Sciences**, Gotemburgo, v. 125, n. 5, p. 315-337, 2017. <https://doi.org/10.1111/eos.12364>. Acesso em: 23-mar-2026.

GÜNEY, S.; JABALLAH, N.; COULIBALY, C. K. Management of extensive buccosinus and bucconasal communications after maxillary giant cell tumor resection using the cortical bone lamina technique: a case report. **Cureus**, São Francisco, v. 16, n. 4, p. e59180, 2024. <https://doi.org/10.7759/cureus.59180>. Acesso em: 23-mar-2026.

KAMADJAJA, D. B. *et al.* Demineralized freeze-dried bovine cortical bone: its potential for guided bone regeneration membrane. **International Journal of Dentistry**, Nova York, v. 2017, p. e5149675, 2017. <https://doi.org/10.1155/2017/5149675>. Acesso em: 23-mar-2026.

LOPES, M. S. *et al.* Influence of hydrogen peroxide on composition, thermostability, porosity and swelling of collagen matrices of demineralized porcine cortical bone. **Brazilian Archives of Biology and Technology**, Curitiba, v. 67, p. e24230742, 2024. <https://doi.org/10.1590/1678-4324-2024230742>. Acesso em: 23-mar-2026.

MENEZES, K. R.; NOVAES, M. R. C. G. Formação pedagógica de professores de graduação em enfermagem: revisão integrativa da literatura. **Comunicação em Ciências da Saúde**, Brasília, v. 29, n. 4, p. 243-254, 2019. <https://doi.org/10.51723/ccs.v29i04.336>. Acesso em: 23-mar-2026.

MENEZES, S. S. C. *et al.* Raciocínio clínico no ensino de graduação em enfermagem: revisão de escopo. **Revista da Escola de Enfermagem da USP**, São Paulo, v. 49, n. 6, p. 1037-1044, 2015. <https://doi.org/10.1590/S0080-623420150000600021>. Acesso em: 23-mar-2026.

NEHAL, R. *et al.* Cortical laminar bone membrane: transforming regenerative approaches in dentistry. **Cureus**, São Francisco, v. 16, n. 12, p. e75138, 2024. <https://doi.org/10.7759/cureus.75138>. Acesso em: 23-mar-2026.

PIERFELICE, T. V. *et al.* Functionalization of a cortical membrane with a photodynamic protocol. **Journal of Functional Biomaterials**, Basel, v. 14, n. 3, p. e133, 2023. <https://doi.org/10.3390/jfb14030133>. Acesso em: 23-mar-2026.

ROCA-MILLAN, E. *et al.* Evaluation of bone gain and complication rates after guided bone regeneration with titanium foils: a systematic review. **Materials**, Basel, v. 13, n. 23, p. e5346, 2020. <https://doi.org/10.3390/ma13235346>. Acesso em: 23-mar-2026.

ROSSI, R.; GHEZZI, C.; TOMECEK, M. Cortical lamina: a new device for the treatment of moderate and severe tridimensional bone and soft tissue defects. **International Journal of Esthetic Dentistry**, Nova Odessa, v. 15, n. 4, p. 454-473, 2020. <https://www.quintessence-publishing.com/deu/en/article/852415>. Acesso em: 23-mar-2026.

SANZ, M. *et al.* Biomaterials and regenerative technologies used in bone regeneration in the craniomaxillofacial region: consensus report of group 2 of the 15th European Workshop on Periodontology on Bone Regeneration. **Journal of Clinical Periodontology**, Nova York, v. 46, n. Suppl 21, p. 82-91, 2019. <https://doi.org/10.1111/jcpe.13123>. Acesso em: 23-mar-2026.

SOUZA, F. F. P. D. *et al.* Development and characterization of poultry collagen-based hybrid hydrogels for bone regeneration. **Acta Cirúrgica Brasileira**, Rio de Janeiro, v. 37, n. 3, p. e370302, 2022. <https://doi.org/10.1590/acb370302>. Acesso em: 23-mar-2026.

TOLEDANO, M. *et al.* Zn-containing membranes for guided bone regeneration in dentistry. **Polymers**, Basel, v. 13, n. 11, p. e1797, 2021. <https://doi.org/10.3390/polym13111797>. Acesso em: 23-mar-2026.

TOLEDANO-OSORIO, M. *et al.* Testing active membranes for bone regeneration: a review. **Journal of Dentistry**, [s.l.], v. 105, p. e103580, 2021. <https://doi.org/10.1016/j.jdent.2021.103580>. Acesso em: 23-mar-2026.

TURRI, A. *et al.* Early plaque formation on PTFE membranes with expanded or dense surface structures applied in the oral cavity of human volunteers. **Clinical and Experimental Dental Research**, [s.l.], v. 7, n. 2, p. 137-146, 2021. <https://doi.org/10.1002/cre2.344>. Acesso em: 23-mar-2026.

ZHANG, K. *et al.* Evidence-based biomaterials research. **Bioactive Materials**, Pequim, v. 15, p. 495-503, 2022. <https://doi.org/10.1016/j.bioactmat.2022.04.014>. Acesso em: 23-mar-2026.