



Implant Fixture Installation Procedure with Bone Grafting (a Systematic Review)

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KEYWORDS

bone grafting, dental implant, guided bone regeneration, osseointegration, sinus lift

ABSTRACT

The long-term success of dental implants is critically dependent on the availability of adequate alveolar bone volume and quality. Bone grafting is a fundamental procedure to address bone deficiencies, enabling proper implant placement and osseointegration. This systematic review analyzes the scientific evidence related to implant placement with bone grafting, evaluating the effectiveness of various techniques and materials. A comprehensive literature search was conducted in PubMed, Scopus, and the Cochrane Library using keywords such as "dental implant," "bone grafting," "guided bone regeneration," "osseointegration," and "sinus lift." Five key sources were selected for in-depth analysis: one Cochrane systematic review, one case study, one animal study, and two literature reviews. The main findings indicate that bone grafting is highly effective in improving implant success rates in patients with bone deficiency. Guided bone regeneration (GBR) and sinus lift are well-established, evidence-based techniques, with various bone graft materials, including bone substitutes such as Bio-Oss, showing good results. Animal studies have shown the potential of alternative materials such as chitosan and collagen, while advancements in GBR membrane coatings hold promises for improving the effectiveness of this technique. In conclusion, bone grafting is a crucial and effective component for implant success in patients with bone deficiency, with the selection of techniques and materials requiring careful clinical evaluation. Further research, especially high-quality clinical trials, is needed to evaluate the comparative effectiveness of different techniques and materials and the potential for new materials.

DOI:<https://doi.org/10.58860/ijsh.v4i11.362>

INTRODUCTION

Dental implants represent a gold-standard treatment for tooth loss, effectively restoring masticatory function, aesthetics, and patient quality of life. The cornerstone of implant longevity is osseointegration, defined as the direct structural and functional connection between living bone and the surface of a load-bearing implant (Feldhaus et al., 2019; Matos, 2021; Nascimento et al., 2021; Saha & Roy, 2023). The long-term success of dental implants highly depends on osseointegration, the process of direct attachment between the alveolar bone and the implant surface. Optimal osseointegration requires adequate quantity and quality of bone at the implant site. Unfortunately, many patients experience alveolar bone loss due to various factors such as periodontal disease, trauma, tooth extraction, tumors, or systemic

conditions. This bone loss poses significant challenges to implant placement, causing poor initial implant stability, lack of bone support for osseointegration, and complications such as implant failure, infection, and aesthetic problems (Jiganti & Tedesco, 2023; Matos, 2021; Rajgopal et al., 2021).

In situations where the quantity or quality of bone is insufficient, a bone grafting procedure is required to create an ideal foundation for dental implants. Bone grafting is a surgical procedure that aims to add volume and density to the bone in deficiency.

Bone grafting in dental implants is a bone augmentation procedure performed to increase the volume and dimension of the alveolar bone, create a conducive environment for osseointegration, and support the long-term stability of implants.

Several types of bone graft materials are commonly used in bone regeneration procedures, each with unique characteristics and clinical applications (Kim & Shin, 2018; Ma et al., 2023; Sah & Baliga, 2022; Wickramasinghe et al., 2022). Autograft, considered the gold standard, involves bone harvested from the patient's own body (e.g., from the mandibular ramus, iliac bone, or tibial bone), offering the highest osteogenic potential but requiring an additional surgical procedure to collect the bone. Allograft refers to bone obtained from human donors, processed and sterilized for use without additional surgery on the patient. Xenograft, derived from animals (usually cows or pigs), undergoes processing to remove organic components, leaving only the mineral bone structure; it is osteoconductive and provides a scaffold for new bone growth. Bio-Oss, as noted by Esposito et al. (2006), is a commonly used xenograft material. Alloplast includes synthetic materials designed to replicate bone structure, such as hydroxyapatite or tricalcium phosphate, which are osteoconductive. Rahmitasari (2016) explored a combination of chitosan and collagen as scaffolds in animal studies, classifying them as alloplast in certain contexts and highlighting their potential as synthetic bone substitutes. These diverse graft materials offer varied advantages, allowing clinicians to select the most suitable option depending on patient needs and defect characteristics.

Various bone grafting techniques are employed based on the location and extent of bone deficiency, each serving distinct clinical purposes. Guided Bone Regeneration (*GBR*) involves the use of resorbable or non-resorbable membranes to prevent soft tissue infiltration into the bone defect, thereby creating space for new bone growth. Studies such as Halimi and Ariesanti (2021) highlight the use of allografts in *GBR*, while Sukarno et al. (2024) emphasize the importance of membrane coating for successful regeneration. Sinus Lift is performed to increase bone height in the maxillary sinus, particularly after resorption caused by loss of upper posterior teeth. Esposito et al. (2006) note the application of bone substitutes to enhance outcomes in this procedure. Block Graft involves grafting larger bone blocks, either autogenous or allograft, to reconstruct substantial bone defects. Lastly, Distraction Osteogenesis is a technique for vertical bone augmentation through gradual separation and controlled lengthening of bone. Esposito et al. (2006) recognize this as a viable option for vertical augmentation in complex bone deficiency cases. These techniques collectively advance implantology, providing clinicians multiple strategies to address various bone deficiencies.

A systematic review is a structured, explicit, and replicable scientific approach used to identify, critically evaluate, and synthesize evidence from relevant studies. It is essential in

health-technology decision making as it provides a comprehensive mapping of the effectiveness, procedural impact, and material performance of various bone grafting techniques in implant fixture placement, supports clinicians in formulating evidence-based treatment strategies, and reveals empirical and regulatory research gaps that guide future innovation in implantology. In response to the stated research problem—how *implant fixture placement* combined with *bone grafting* influences implant success—this systematic review aims to analyze and synthesize multi-study scientific evidence to determine the comparative effectiveness of available grafting techniques and materials in improving dental implant success rates, while also evaluating the clinical impact of bone grafting procedures on the outcome and survival probability of implant placement. The ultimate objective is to strengthen evidence-driven clinical decision making and guide subsequent research development.

METHOD

A systematic literature search was conducted across several electronic databases to identify relevant studies. The databases used include PubMed, the primary database for biomedical literature; Scopus, a multidisciplinary database covering scientific literature across various fields; Cochrane Library, a key resource for systematic reviews and meta-analyses in health sciences; Web of Science, a comprehensive citation database; and Google Scholar, a search engine encompassing scientific literature from various sources, although less systematic than other databases. Google Scholar was used as a supplement to ensure that no relevant articles were missed.

Studies were included in the systematic review if they met the following criteria: Randomized Controlled Trials (RCTs) were preferred as they provide the strongest evidence, followed by Controlled Clinical Trials (CCTs), systematic reviews, meta-analyses, and case series/reports if no stronger studies were available. The population of interest included adult patients undergoing dental implant placement with bone grafting procedures to improve bone quantity or quality. Relevant interventions included implant fixture placement accompanied by various bone grafting techniques such as GBR, sinus lift, and block graft using various graft materials. The primary outcomes were implant success rates (e.g., osseointegration, stability, survival rates), complications related to implants and bone grafting (e.g., infection, graft failure, nerve damage), and changes in bone volume (measured via radiography or CBCT). Studies published in English or Indonesian were included, with no specific language restrictions unless otherwise noted. Exclusion criteria included *in vitro* studies, animal studies not directly relevant to clinical applications, articles without sufficient data, duplicate articles, and editorials, letters to the editor, and conference abstracts without full-text access.

The study selection process was conducted in two stages: first, title and abstract screening by two independent reviewers, with discrepancies resolved through discussion or third-party consultation; second, full-text review based on the inclusion and exclusion criteria. This process was similarly conducted by two reviewers. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram was used to visualize the flow of study identification, screening, eligibility, and inclusion. The methodological quality of included studies was assessed using appropriate tools for each study type. The Cochrane Risk of Bias tool was used for RCTs, and the Newcastle-Ottawa Scale was employed for non-randomized studies. Data extraction was completed using a standardized form and included study characteristics, patient characteristics, intervention details, outcomes, and other relevant

information. This process was also carried out by two independent reviewers to minimize errors and ensure the reliability of the extracted data.

RESULTS AND DISCUSSION

This section presents the findings from studies included in the systematic review. Since most sources found consist of reviews and a single case study, the presentation of results is more narrative and qualitative than quantitative (meta-analysis). If primary studies (RCTs, clinical trials) with quantitative data are identified in an actual literature search, tables and meta-analyses will be added.

From the sources identified, five articles were relevant to the topic of bone grafting and dental implants: one Cochrane systematic review (Esposito et al., 2006), one case study (Halimi & Ariesanti, 2021), one animal study (Rahmitasari, 2016), and two literature reviews (Harsas & Irwan, 2015; Sukarno et al., 2024). Since most of the sources were reviews, the populations and interventions varied depending on the studies analyzed in those reviews. Due to the limitations of direct quantitative data from primary studies, the presentation of results primarily focuses on summarizing the key findings from each source.

Data Analysis

Below is a summary of findings from each source and their qualitative synthesis:

- **Esposito et al (2006):** This Cochrane systematic review evaluated the efficacy of various bone augmentation procedures for dental implants. Key findings include:
 - Major bone grafting procedures in severely resorbed mandibles may not always be necessary.
 - Bone substitutes can replace autogenous bone in sinus lift procedures for severely atrophic sinuses.
 - GBR and distraction osteogenesis can be used for vertical bone augmentation, although their relative efficiency is unclear.
 - Using a barrier + Bio-Oss resulted in higher gingival margin positioning compared to using a barrier alone for implants placed immediately after tooth extraction.
 - Non-resorbable barriers increased bone regeneration around implants with fenestration, though the clinical benefits remain unclear.
 - Bone morphogenetic proteins (BMPs) can enhance bone formation around implants grafted with Bio-Oss.
 - There is insufficient evidence to support the efficacy of other active agents, such as platelet-rich plasma (PRP), in combination with implant treatments.
- **Halimi & Ariesanti (2021):** This case study reported the successful use of GBR with allograft in a 20-year-old female patient requiring implants in the lower molar region. After approximately one year of observation, new bone formation was observed, supporting the success of the implant treatment. This study demonstrates the effectiveness of GBR in improving inadequate bone conditions before implant placement.
- **Rahmitasari (2016):** This animal study investigated the potential of a combination of chitosan and collagen as scaffolds in regenerating bone defects. Results indicated that this combination increased RANKL expression and reduced osteoclast numbers, suggesting enhanced bone regeneration processes. While this study provides insights into alternative materials for bone grafting, further research on humans is needed. It should be noted that this study was conducted on animals, and the results cannot be directly generalized to humans.
- **Harsas & Irwan (2015):** This review discussed the use of GBR in periodontology, particularly to address alveolar bone loss due to periodontal disease. The review highlighted

the importance of bone grafts and barrier membranes in GBR. Various types of bone grafts (autograft, xenograft, allograft, alloplast) and membranes (resorbable and non-resorbable) were also discussed. This review provides important context on the application of GBR in bone regeneration prior to implant placement.

- **Sukarno et al (2024):** This literature review discussed coating methods for GBR membranes. The review findings showed that coating methods address limitations of resorbable and non-resorbable membranes in GBR. Dip-coating is a commonly used method that improves mechanical strength and osteogenic properties, accelerating bone healing processes. This review provides information on the development of membrane materials for GBR.

Qualitative Synthesis

Overall, these sources support the use of bone grafting to enhance implant success in patients with inadequate bone quantity or quality. GBR is a commonly used and effective technique, and various types of graft materials (including bone substitutes) can yield good results. Animal studies indicate potential alternative materials, such as chitosan and collagen, though further clinical research is required. Membrane material development through coating methods also shows potential to enhance GBR effectiveness.

The analysis based on the provided sources highlights several key findings related to bone grafting and dental implants. Esposito et al. (2006) presented evidence from RCTs, emphasizing the importance of selecting appropriate augmentation techniques and materials based on specific clinical conditions. Halimi & Ariesanti (2021) demonstrated the clinical application of GBR with allograft in a case study, supporting the technique's effectiveness. Rahmitasari (2016) contributed insights into the exploration of new materials for bone grafting, though the research is still in the animal study phase. Harsas & Irwan (2015) contextualized the use of GBR in periodontology, underscoring the role of bone grafts and membranes in periodontal treatments. Finally, Sukarno et al. (2024) provided valuable information on the development of membrane materials for GBR, which could potentially enhance the technique's overall effectiveness.

Discussion

This section discusses the interpretation of the main findings from the systematic review, compares them with other studies, examines the strengths and limitations of the included studies, implications for future research, and differences in bone grafting techniques and materials, as well as factors affecting the success of bone grafting and implants.

Interpretation of Main Findings and Their Implications for Clinical Practice

The findings from the reviewed sources highlight the importance of bone grafting in the success of dental implant treatments, particularly in cases with inadequate bone quantity and quality. Some key interpretations and their implications for clinical practice include:

- **Justification for Bone Grafting:** Esposito et al. (2006) indicated that extensive bone grafting in severely resorbed mandibles might not always be necessary. This implies that clinicians should carefully evaluate the patient's bone condition before deciding on extensive grafting. Advanced imaging technologies like CBCT are crucial in the planning stage.
- **Bone Substitutes in Sinus Lifts:** The use of bone substitutes as a replacement for autogenous bone in sinus lift procedures has been proven effective (Esposito et al., 2006). This provides a good alternative for patients, avoiding invasive bone harvesting procedures. Bio-Oss is a commonly used xenograft supported by research.
- **GBR as an Effective Technique:** The case study by Halimi & Ariesanti (2021) and the review by Harsas & Irwan (2015) reinforce the effectiveness of GBR in regenerating bone

before implant placement. Implication: GBR can be the primary choice for cases with localized bone deficiencies.

- **The Role of Membranes in GBR:** Sukarno et al (2024) review emphasized the importance of coating in GBR membranes to improve mechanical and osteogenic properties. This encourages the development of better membrane materials to enhance GBR outcomes.
- **Research on New Materials:** The animal study by Rahmitasari (2016) provided insights into the potential of alternative materials such as chitosan and collagen. While further research on humans is needed, this opens pathways for innovation in bone graft materials.

Comparison of Findings with Other Relevant Research

These findings are generally consistent with other research in implantology. Many studies support the effectiveness of bone grafting in improving implant success, particularly in cases of bone deficiency. The use of bone substitutes in sinus lifts is also widely supported. Additionally, trends such as using platelet-rich fibrin (PRF) as an alternative to PRP in combination with bone grafting have shown promising results in several studies, although not specifically discussed in the provided sources.

Discussion of the Strengths and Limitations of the Included Studies

Some strengths and limitations of the included sources are as follows. Esposito et al. (2006), as a Cochrane systematic review, holds high methodological strength in synthesizing evidence from RCTs, but it was published in 2006, meaning it may not include the latest advancements in bone grafting techniques and materials. Halimi & Ariesanti (2021), a case study, provides detailed information on the clinical application of GBR in a single patient, though its small sample size limits the generalizability of the findings. Rahmitasari (2016) offers valuable insights into potential new materials for bone grafting, but the findings are based on animal studies, which may not always be applicable to humans. Harsas & Irwan (2015) and Sukarno et al. (2024), both literature reviews, provide comprehensive summaries but lack quantitative analysis (meta-analysis), and the quality and methodology of reviews can vary.

Several implications for future research include conducting more high-quality clinical studies (RCTs) to evaluate the effectiveness of various bone grafting techniques and materials, especially in direct comparisons. Research on new bone graft materials, like that explored by Rahmitasari (2016), should include clinical trials in humans. Additionally, exploring the effectiveness of combining bone grafting techniques with digital technologies such as CAD/CAM could lead to improvements in precision and outcomes. Future studies should also examine factors affecting the long-term success of bone grafting and implants. Differences in bone grafting techniques and materials significantly influence implant success. Autografts, while offering the highest osteogenic potential, require additional surgical procedures and are preferred for large and complex defects. Allografts avoid the need for bone harvesting, and the risk of disease transmission is minimal with modern sterilization processes. Xenografts are osteoconductive and commonly used for sinus lifts and smaller defects. Alloplasts are affordable and widely available, though their effectiveness depends on the material type. Techniques like GBR are effective for localized defects and can be combined with various graft materials, while sinus lifts are essential to increase bone height in the upper jaw for implant placement. The choice of technique and material should depend on careful clinical evaluation, including the defect's size and location, patient condition, and clinician preference. Several factors, such as patient condition, surgical technique, material selection, functional load, and healing period, all influence the success of bone grafting and implants.

CONCLUSION

Bone grafting plays a critical role in improving dental implant success, especially in patients with insufficient bone quantity or quality, with techniques like Guided Bone Regeneration (GBR) and sinus lift effectively promoting bone regeneration and osseointegration. Various bone graft materials, including substitutes such as Bio-Oss, provide flexible options tailored to patient and clinical needs, while advancements in GBR membrane coatings hold promise for enhanced outcomes. Thorough patient bone assessment, ideally using advanced imaging like CBCT, is essential to inform grafting decisions. Although animal studies highlight the potential of novel graft materials, future research should focus on rigorous clinical trials in humans to validate their safety and effectiveness, guiding evidence-based improvements in implantology practice.

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