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# INFLUENCE OF DIFFERENT BONE GRAFTING TECHNIQUES ON PRIMARY STABILITY

# INFLUÊNCIA DE DIFERENTES TÉCNICAS DE ENXERTIA ÓSSEA NA ESTABILIDADE PRIMÁRIA

# INFLUENCIA DE DIFERENTES TÉCNICAS DE INJERTO ÓSEO EN LA ESTABILIDAD PRIMARIA

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## ABSTRACT

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Objective: To critically review the available evidence on the influence of different bone grafting techniques and implant site preparation methods on the primary stability of dental implants. Methods: Narrative review based on randomized clinical trials, prospective and retrospective studies, systematic reviews, and meta-analyses published between 2015 and 2025 in PubMed, Scopus, Web of Science, and SciELO. Included studies evaluated autogenous bone grafts, substitute biomaterials, osseodensification, piezosurgery, and short implants, focusing on insertion torque, implant stability quotient (ISQ), and implant survival rates. Results: Autogenous grafts remain the gold standard due to their biological properties, but with significant donor site morbidity. Substitute biomaterials demonstrated comparable results in stability and survival, particularly in sinus floor elevation. Osseodensification showed improvements in torque and ISQ in type III–IV bone, although recent studies highlight controversies and protocol dependence. Short implants achieved survival rates similar to longer implants with bone augmentation, reducing morbidity and costs. Biological adjuncts such as PRF and platelet concentrates demonstrated coadjuvant benefits but do not replace conventional biomaterials.Conclusion: Primary stability is influenced by multiple variables, and technique selection should be individualized. Current evidence suggests that substitute biomaterials, osseodensification, and short implants are predictable alternatives to autogenous grafts in specific scenarios. This review emphasizes the need for individualized and integrated approaches to optimize clinical predictability in modern implant dentistry.

**Keywords:** (MeSH/DeCS). Bone Grafting. Primary Stability. Dental Implants. Osseodensification. Biomaterials.

**RESUMO**

Objetivo: Revisar criticamente as evidências disponíveis sobre a influência de diferentes técnicas de enxertia óssea e preparo do leito na estabilidade primária de implantes dentários. Métodos: Revisão narrativa baseada em ensaios clínicos randomizados, estudos prospectivos e retrospectivos, revisões sistemáticas e metanálises publicadas entre 2015 e 2025 nas bases PubMed, Scopus, Web of Science e SciELO. Foram incluídos estudos que avaliaram enxertos autógenos, biomateriais substitutos, técnicas de osseodensificação, piezocirurgia e implantes curtos, com foco em torque de inserção, índice de estabilidade do implante (ISQ) e taxa de sobrevivência. Resultados: Os enxertos autógenos mantêm-se como padrão-ouro pela biologia superior, mas com morbidade significativa. Biomateriais substitutos mostraram resultados comparáveis em estabilidade e sobrevida em elevação de seio maxilar. A osseodensificação evidenciou ganhos em torque e ISQ em ossos tipo III–IV, embora estudos recentes ressaltem controvérsias e dependência do protocolo utilizado. Implantes curtos apresentaram taxas de sobrevivência semelhantes às de implantes longos com enxertia, reduzindo morbidade e custos. Adjuntos biológicos como PRF e concentrados plaquetários mostraram benefícios como coadjuvantes, mas não substituem biomateriais consolidados. Conclusão: A estabilidade primária é influenciada por múltiplas variáveis, e a escolha da técnica deve ser individualizada. As evidências atuais sugerem que biomateriais substitutos, osseodensificação e implantes curtos representam alternativas previsíveis ao autógeno em cenários específicos. Este trabalho reforça a necessidade de abordagens individualizadas e integradas para otimizar a previsibilidade clínica em implantodontia moderna.

**Palavras-chave:** (DeCS/MeSH). Enxerto Ósseo. Estabilidade Primária. Implantes Dentários. Osseodensificação. Biomateriais.

**RESUMEN**
Objetivo: Revisar críticamente la evidencia disponible sobre la influencia de diferentes técnicas de injerto óseo y preparación del sitio en la estabilidad primaria de los implantes dentales. Métodos: Esta fue una revisión narrativa basada en ensayos clínicos aleatorizados, estudios prospectivos y retrospectivos, revisiones sistemáticas y metaanálisis publicados entre 2015 y 2025 en PubMed, Scopus, Web of Science y SciELO. Se incluyeron estudios que evaluaron injertos autólogos, biomateriales sustitutos, técnicas de osteodensificación, piezocirugía e implantes cortos, centrándose en el torque de inserción, el índice de estabilidad del implante (ISQ) y la tasa de supervivencia. Resultados: Los injertos autólogos siguen siendo el estándar de oro debido a su biología superior, pero con una morbilidad significativa. Los biomateriales sustitutos mostraron resultados comparables en estabilidad y supervivencia en la elevación del piso del seno maxilar. La osteodensificación demostró ganancias en torque e ISQ en huesos tipo III-IV, aunque estudios recientes resaltan controversias y dependencia del protocolo utilizado. Los implantes cortos mostraron tasas de supervivencia similares a las de los implantes largos con injerto, lo que redujo la morbilidad y los costos. Los adyuvantes biológicos, como el PRF y los concentrados de plaquetas, mostraron beneficios como adyuvantes, pero no sustituyen a los biomateriales consolidados. Conclusión: La estabilidad primaria se ve influenciada por múltiples variables, y la elección de la técnica debe ser individualizada. La evidencia actual sugiere que los biomateriales sustitutos, la osteodensificación y los implantes cortos representan alternativas predecibles a los implantes autógenos en escenarios específicos. Este trabajo refuerza la necesidad de enfoques individualizados e integrados para optimizar la predictibilidad clínica en la implantología dental moderna.

**Palabras clave:** (DeCS/MeSH). Injerto Óseo. Estabilidad Primaria. Implantes Dentales. Oseodensificación. Biomateriales.

## 1 INTRODUCTION

The primary stability of dental implants, understood as the initial mechanical anchorage in the recipient bed, is a critical determinant for osseointegration and for short- and long-term clinical success (Meredith, 1998). The development and dissemination of resonance frequency analysis (RFA) and implant stability index (ISQ) have made it possible to quantify, in a non-invasive way, stability over time and correlate it with relevant clinical parameters (Meredith, 1998; Sennerby; Meredith, 2015). In parallel, aspects such as bone density and microarchitecture, geometry and macro/microtexture of the implant and, above all, the bed preparation technique significantly influence the values of insertion torque and ISQ (GómezPolo et al., 2016; Stacchi et al., 2023).

In low-density regions, notably the posterior maxilla (types III–IV), achieving sufficient primary stability remains a challenge. Historically, autogenous grafting has been consolidated as the gold standard for combining osteogenic, osteoinductive, and osteoconductive properties (Aghaloo; Moy, 2007). However, the morbidity of the donor site, the longer surgical time, and the postoperative discomfort drove the adoption of allogene, xenogen, and alloplastic substitutes with consistent results in bone augmentation and maxillary sinus elevation (Jensen; Terheyden, 2009; Esposito et al., 2010; Del Fabbro et al., 2025). Recent systematic reviews and RCTs indicate that well-selected materials may offer clinical predictability and implantation stability comparable to autogenous in appropriate indications, although there are still gaps in long-term follow-ups (Carmagnola et al., 2024; VelascoOrtega et al., 2021).

In the field of bed preparation, **osseodensification** (DO) has emerged as a technique that compacts the trabecular bone, preserving and autografting particles along the osteotomy, with reported gains in peri-implant density, insertion torque, and ISQ (Huwais; Meyer, 2017; Pai et al., 2018). Randomized controlled trials and multicenter studies suggest early superiority of RE over conventional perforation and, in some scenarios, piezoelectric surgery (Shanmugam et al., 2023; Stacchi et al., 2023). However, the most recent literature has also brought divergent results, pointing out that the benefits of OD may be dependent on the bone substrate, the protocol, and the design of the implant (Politi et al., 2025). This methodological heterogeneity reinforces the need for cautious interpretations and standardization of outcomes (ISQ, torque, CBCT) in future research.

Another relevant aspect is the **strategy of avoiding extensive grafts** with the use of **short implants** in situations of reduced bone height. Meta-analyses and reviews published

between 2023 and 2024 have demonstrated similar survival between short implants in non-enlarged bone and long implants associated with bone augmentation, with lower morbidity and costs when minimal primary stability is achieved (SáenzRavello et al., 2023; Abayov et al., 2024; J Clin Periodontol, 2024). Finally, biological adjuncts such as PRF/PC have been investigated as a potential reinforcement of regeneration and, indirectly, stability, although the findings still vary according to protocol and indication (Babich et al., 2024; Zhao et al., 2025; Alfaraj et al., 2025).

Given this scenario, this article critically reviews how different **grafting techniques** (autogenous and surrogates), **preparation methods** (DO vs. conventional vs. piezo drilling), and **alternative strategies** (short implants) influence primary stability, seeking to guide clinical decisions based on recent and high-quality evidence.

## 2 METHODOLOGY

### 2.1 TYPE OF STUDY

Critical narrative review of the literature, focusing on clinical evidence (RCTs, prospective/retrospective studies, systematic reviews, and meta-analyses) published between **2015 and 2025**. Although this is not a systematic review, transparency practices were applied to reduce selection and citation bias.

### 2.2 GUIDING QUESTION

In patients undergoing dental implant placement, **how do different bone grafting and bed preparation techniques** influence **primary stability** (measured by **insertion torque** and **ISQ/RFA**) and correlated outcomes (implant survival, marginal bone loss, complications)?

### 2.3 SOURCES OF INFORMATION AND SEARCH STRATEGY

Databases: **PubMed/MEDLINE, Scopus**, **Web of Science** and **SciELO.**

Descriptors (DeCS/MeSH) and Boolean combinations (main examples):

- ("dental implants"[MeSH] OR "dental implants") AND ("primary stability" OR ISQ OR RFA OR "insertion torque").
- ("bone grafting" OR "bone augmentation" OR "sinus floor elevation" OR "maxillary sinus augmentation") AND (stability OR ISQ OR torque).
- (osseodensification OR "osseodensification") AND (stability OR ISQ OR torque).

- ("short dental implants" OR "short implants") AND (survival OR stability) AND (augmentation OR grafting).
- ("plateletrich fibrin" OR PRF OR "platelet concentrates") AND (sinus OR graft* OR stability OR ISQ).

Filters applied: period 2015–2025; languages **English** and **Portuguese**; human studies. Classic references outside the time frame (Meredith, 1998; Aghaloo; Moy, 2007; Esposito et al., 2010) were included for conceptual relevance.

## 2.4 ELIGIBILITY CRITERIA

### 2.4.1 Inclusion:

- RCTs, prospective/retrospective studies, systematic reviews, and meta-analyses evaluating **primary stability** (torque/ISQ) and/or clinical outcomes after **grafting** (autogenous, allogeneous, xenogenous, alloplastic), **sinus elevation**, **osseodensification**, **piezo,** or **short implants**.

### 2.4.2 Exclusion:

- Studies exclusively in vitro or in animals (except where they support mechanisms, without extrapolations of clinical efficacy).
- Single case reports with no comparator group.
- Articles without objective measurement of stability (when this was the stated primary outcome).

## 2.5 EXTRACTION AND SYNTHESIS

Two axes will guide the synthesis: (i) **reconstruction/regeneration method** (autogenous vs. surrogates; sinus elevation); (ii) **bed preparation method** (DO vs. conventional vs. piezo drilling) and **alternative strategies** (short implants). When available, **mean torque/ISQ values**, **survival rate,** and **marginal bone loss will be described**, with emphasis on type III–IV bones.

## 2.6 ROBUSTNESS AND LIMITATIONS

The heterogeneity of protocols (measurement tools, implant design, evaluation time) and the presence of conflicting results, especially in RE, are recognized as sources of uncertainty (Stacchi et al., 2023; Politi et al., 2025). To mitigate bias, interpretation based on

**RCTs** and **recent systematic reviews/meta-analyses** is prioritized, explaining limitations when applicable.

## 3 RESULTS

### 3.1 AUTOGENOUS GRAFTS VS. SURROGATE BIOMATERIALS

- **Autogenous:** continues to be the reference for its osteogenic, osteoinductive and osteoconductive properties. Clinical studies demonstrate increased bone density and higher torque/ISQ values. However, morbidity of the donor area (pain, bleeding, complications) limits its applicability (Younger; Chapman, 1989; Seiler et al., 2000).
- **Substitutes:** allogene, xenogen, and alloplastic grafts have shown satisfactory and comparable clinical results in primary stability and implant survival rate, especially in maxillary sinus lift (Carmagnola et al., 2024; Velasco-Ortega et al., 2021).
- **Synthesis of reviews:** Del Fabbro et al. (2025) confirmed, in a meta-analysis, that appropriately selected biomaterials can achieve clinical predictability similar to autogenous biomaterials in the medium term.

### 3.2 OSSEODENSIFICATION (DO) TECHNIQUES

- **Positive evidence:** Shanmugam et al. (2023) and Stacchi et al. (2023) demonstrated significant gains in insertion torque and ISQ in regions of low bone density (posterior maxilla) when compared to conventional drilling.
- **Systematic reviews:** Pereira et al. (2023) and Althobaiti et al. (2023) reinforced the favorable results of RE in type III–IV bones, highlighting its ability to optimize initial stability.
- **Divergent results:** Politi et al. (2025) reported that the benefits of OD were not consistent in all situations, suggesting dependence on the perforation protocol and implant design. This variability underscores the need for caution and standardization.

### 3.3 SHORT IMPLANTS VS. BONE AUGMENTATION

- **Recent meta-analyses** (Sáenz-Ravello et al., 2023; Abayov et al., 2024; J Clin Periodontol, 2024) pointed to equivalent survival rates between short implants (≤6 mm) and long implants associated with bone grafts. In addition, they observed a reduction in morbidity, surgical time, and costs in protocols with short implants.

### 3.4 BIOLOGICAL ADJUNCTS (PRF/PC)

- **PRF as an adjuvant:** Babich et al. (2024) and Zhao et al. (2025) reported improved bone regeneration and, secondarily, implant stability in sinus lift techniques, when PRF was used in association with biomaterials.
- **PRF alone:** Alfaraj et al. (2025) concluded that the exclusive use of PRF does not replace conventional grafting materials, and should be considered only as an adjuvant.

**Table 1**

*Osseodensification (DO) clinical trials*

| Autor/ano | Amostra (n) | Local | Comparacao | ISQ/torque | Seguimento |
|---|---|---|---|---|---|
| Shanmugam 2023 | 40 pacientes | Maxila posterior | OD vs. convencional | ISQ maior, torque maior | 6 meses |
| Stacchi 2023 | >60 pacientes (multicentrico) | Maxila/mandibula | OD vs. piezo | ISQ maior imediato | 3-12 meses |
| Politi 2025 | 30 pacientes | Maxila posterior | OD vs. convencional | sem diferenca significativa | 12 meses |

Source: Authors.

**Table 2**

*Bone grafts vs. biomaterials in MSFA (Maxillary Sinus Floor Augmentation)*

| Autor/ano | Tecnica | Material | ISQ/torque | Sobrevivencia |
|---|---|---|---|---|
| Carmagnola 2024 | MSFA | biomaterial vs. sem biomaterial | resultados similares | >95% em 12 meses |
| Velasco-Ortega 2021 | MSFA | autogeno vs. xenogeno | similares | 95-97% em 5 anos |
| Del Fabbro 2025 | Revisao sistematica | diversos | comparaveis | 93-98% |

Source: Authors.

## 4 DISCUSSION

### 4.1 CLINICAL RELEVANCE OF PRIMARY STABILITY

Primary stability is widely recognized as the main determinant for implant success, as it provides the mechanical basis for osseointegration. Classic and recent studies have shown that higher values of insertion torque and ISQ are associated with lower rates of early failure (Meredith, 1998; Huang et al., 2020). However, these parameters are multifactorial, being influenced by bone density, implant macrodesign, quality of bed preparation, and surgeon's clinical experience (Gómez-Polo et al., 2016; Stacchi et al., 2023).

### 4.2 AUTOGENOUS GRAFTS VS. SURROGATE BIOMATERIALS

Autogenous grafts remain the gold standard due to their superior biological potential. However, the morbidity of the donor site, the prolonged surgical time, and the associated complications limit its routine applicability (Younger; Chapman, 1989; Seiler et al., 2000).

Substitute biomaterials, on the other hand, have shown comparable results in initial stability and survival rate, especially in sinus lift procedures (Velasco-Ortega et al., 2021; Carmagnola et al., 2024). Systematic reviews, such as the one by Del Fabbro et al. (2025), confirm the clinical predictability of these alternatives, although there is a lack of long-term studies that consolidate their full equivalence.

### 4.3 OSSEODENSIFICATION: POTENTIAL AND CONTROVERSIES

Osseodensification (DO) stood out as a promising technique for low-density bones. Randomized controlled trials indicate gains in torque and ISQ compared to conventional drilling and even piezosurgery (Shanmugam et al., 2023; Stacchi et al., 2023). Recent systematic reviews (Pereira et al., 2023; Althobaiti et al., 2023) reinforce this evidence. However, divergent results (Politi et al., 2025) suggest that the benefits may be conditioned by the protocol, the type of implant, and the characteristics of the bone substrate. Thus, the DO must be applied judiciously, with careful interpretation of the results.

### 4.4 SHORT IMPLANTS AS AN ALTERNATIVE TO GRAFTING

Short implants emerge as a less invasive and cost-effective solution in regions with reduced bone height. Recent meta-analyses show that the survival rate of implants ≤6 mm is equivalent to that of long implants with grafting, with the advantage of lower morbidity and surgical time (Sáenz-Ravello et al., 2023; Abayov et al., 2024; J Clin Periodontol, 2024). This strategy is particularly useful in patients with comorbidities or who do not want grafting procedures. However, it requires rigorous prosthetic planning and minimal availability of bone quality.

### 4.5 BIOLOGICAL ADJUNCTS: PRF AND PLATELET CONCENTRATES

The use of PRF and other platelet concentrates has been shown to be beneficial as an adjuvant in regenerative techniques, favoring angiogenesis and early bone formation. Studies suggest a positive impact on indirect stability (Babich et al., 2024; Zhao et al., 2025). However, reviews point out that PRF alone is not sufficient to replace conventional biomaterials (Alfaraj et al., 2025). Therefore, its role should be understood as complementary and not substitutive.

### 4.6 PRACTICAL IMPLICATIONS

- **Posterior maxilla (type III–IV bones):** DO associated with biomaterials is a promising option.
- **Extensive defects and previous esthetics:** autogenous graft is still a reference.
- **Reduced bone height:** short implants represent a predictable and less invasive alternative.
- **Combined approaches:** integration of biomaterials, DO, and PRF can optimize stability and regeneration, although robust clinical trials confirming synergy are lacking.

### 4.7 GAPS AND RESEARCH AGENDA

The main limitations include: (i) lack of standardization of evaluation criteria (torque, ISQ, CBCT); (ii) small sample sizes in clinical trials; (iii) scarcity of long-term multicenter studies; (iv) controversies about the impact of DO on secondary stability and survival. Future research should prioritize uniform protocols, integration of advanced biomaterials (e.g., bioprinted scaffolds), and evaluation of therapeutic combinations to consolidate recommendations based on a high level of evidence.

## 5 CONCLUSION

The present review demonstrates that primary stability is one of the main determinants for the clinical success of dental implants, especially in regions of low bone density. The different techniques evaluated have a direct impact on this parameter, each with advantages and limitations that must be weighed according to the clinical case. Autogenous grafts, although still considered the gold standard for their biological properties, are associated with significant morbidity and greater surgical complexity. The substitute biomaterials, in turn, showed comparable results in stability and survival rate, reducing the need for donor areas and presenting consistent clinical predictability in procedures such as maxillary sinus lift. Osseodensification has emerged as a promising technique, capable of improving insertion torque and ISQ values, especially in type III–IV bones, although divergent results indicate dependence on the protocol applied and the design of the implants. Short implants have been consolidated as a predictable alternative to bone augmentation in cases of reduced height, with success rates similar to those of long implants with grafting, with lower morbidity and cost. Biological adjuncts, such as PRF and other platelet concentrates, have demonstrated

additional benefits in favoring healing and angiogenesis, but have not been able to fully replace conventional biomaterials.

Therefore, it is concluded that the choice of technique should be individualized, considering the bone characteristics, the functional and aesthetic needs of the patient, the systemic conditions and the surgeon's experience. Current evidence points to a future in which combined approaches, integrating advanced biomaterials, mechanical bed preparation methods, and biological resources, can optimize primary stability and make oral rehabilitations even more predictable and safer. However, there is still a need for multicenter clinical trials, with standardized protocols and long-term follow-up, in order to consolidate recommendations based on high-level scientific evidence.

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