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Immediate Dentoalveolar Regeneration: Integrating Evidence and Current Concepts

Regeneración Dentoalveolar Inmediata: Integración de la Evidencia y los Conceptos Actuales

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ABSTRACT: Immediate Dentoalveolar Regeneration (IDR) is a therapeutic approach aimed at the immediate preservation or restoration of the alveolar ridge following tooth extractions. This strategy seeks to enable faster, more predictable, and aesthetically satisfactory prosthetic rehabilitation. Given the high global prevalence of dental extractions, IDR has emerged as an essential tool in contemporary regenerative dentistry. To critically analyze the current scientific evidence regarding the clinical application of IDR, including its biological foundations, materials employed, surgical protocols, and the main factors influencing treatment outcomes. A scoping review was conducted using the databases PubMed, Scopus, ScienceDirect, Web of Science, SciELO, and LILACS, covering the period from 2020 to 2025. Original research articles, systematic reviews, meta-analyses, and clinical guidelines were included. Study selection was based on thematic relevance, methodological rigor, and full-text availability. Tools such as Rayyan, Zotero, and the SANRA checklist were employed for data organization and quality assessment. The literature indicates that, when properly indicated, IDR allows for effective control of bone resorption and preservation of soft tissues. The use of biomaterials, such as xenogeneic grafts, and bioactive agents, such as PRF, enhances osteogenesis and accelerates the healing process. However, factors such as the integrity of the buccal bone plate, gingival biotype, and absence of local infection are critical determinants of clinical success. IDR is a promising technique in regenerative dentistry, though it still requires robust clinical trials to standardize protocols and confirm its long-term effectiveness. The integration of emerging technologies and advanced biomaterials is expected to further optimize future clinical outcomes.

KEY WORDS: Dental Rehabilitation; Dental Implants; Restorative Dentistry.

INTRODUCTION

Epidemiological data indicate that more than 500 million tooth extractions are performed annually worldwide, with a significant proportion of these cases requiring subsequent prosthetic or implant-supported rehabilitation (Pjetursson *et al*., 2014). This scenario underscores the relevance of therapeutic strategies such as Immediate Dentoalveolar Regeneration (IDR). According to the medicine-based evidence hierarchy, randomized clinical trials (RCTs) are considered the highest level of methodological evidence. However, due to the scarcity of robust RCTs on IDR and the heterogeneity of clinical contexts, a narrative review was chosen. This approach allows for greater flexibility and clinical applicability by integrating multiple sources of observational and experimental evidence (Murad *et al*., 2016).

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IDR consists of a set of therapeutic procedures performed immediately after tooth extraction, aiming to preserve or restore the alveolar ridge architecture, thereby facilitating the placement of dental implants and promoting the patient's functional and esthetic rehabilitation. This approach seeks to minimize post-extraction physiological bone resorption, which can significantly compromise esthetics and hinder subsequent implant placement (Chen & Buser, 2014). Studies have shown that alveolar bone loss begins within the first 24 hours following extraction and can reach up to a 60% reduction in ridge width and height within the first six months (Van der Weijden *et al*., 2009). This phenomenon has led to the development of techniques such as socket filling with biomaterials, use of barrier membranes, and immediate implant placement—strategies that combine the principles of guided tissue regeneration (GTR) and alveolar preservation, yielding clinically predictable outcomes (Araújo & Lindhe, 2005).

IDR differs from conventional bone regeneration by taking place in a highly active biological environment, rich in inflammatory cells, growth factors, and remodeling extracellular matrix. This environment is conducive to osteogenesis, provided that surgical trauma is adequately controlled and clot stability is maintained (Hämmerle *et al*., 2012). The technique also requires careful selection of biomaterials, which must be biocompatible, osteoconductive, and ideally osteoinductive, to promote true bone regeneration.

Among the most used biomaterials in IDR are autogenous, allogenic, xenogeneic, and synthetic bone grafts, with or without the addition of bioactive factors or stem cells. Bone substitutes such as bovine hydroxyapatite and beta-tricalcium phosphate have demonstrated favorable clinical and radiographic outcomes (Jensen *et al*., 2006). Furthermore, the use of resorbable collagen membranes aids in clot stabilization and selective exclusion of epithelial cells, thereby supporting guided tissue regeneration.

Primary implant stability and the integrity of the buccal bone plate are critical factors for the success of IDR. The absence of the buccal wall compromises esthetics and reduces the predictability of treatment, making the use of particulate grafts combined with membranes or bone blocks recommended in such cases (Urban *et al*., 2013). Therefore, three-dimensional planning using cone-beam computed tomography and customized surgical guides is essential to minimize failures and optimize clinical outcomes.

IDR thus represents a promising strategy for patients seeking fast, minimally invasive, and esthetically pleasing rehabilitative treatments. However, its indication must consider local and systemic factors, the clinician's experience, and the strength of the available scientific evidence. Current literature reinforces the importance of individualized treatment planning and long-term follow-up to ensure the predictability and clinical success of the technique (Avila-Ortiz *et al*., 2019).

For the screening of articles included in this review, the Rayyan software was used, and Zotero was employed as the reference management tool. The methodological quality of this narrative review was assessed using the SANRA (Scale for the Assessment of Narrative Review Articles) checklist, following the criteria of justification, literature coverage, critical analysis, referencing, and logical structuring.

MATERIAL AND METHOD

This study consists of a scoping review, with an exploratory and qualitative nature, aimed at gathering and critically analyzing current scientific evidence on Immediate Dentoalveolar Regeneration (IDR). The analysis encompasses clinical, biological, technical, and therapeutic aspects related to the applicability of this approach in contemporary dentistry.

The literature search was conducted between January 2020 and May 2025, using the following databases: PubMed/MEDLINE, Scopus, ScienceDirect, Web of Science, SciELO, and LILACS. These platforms were selected for their broad coverage of indexed scientific journals and international recognition in the health sciences field. To increase the sensitivity of the search, both controlled descriptors and free-text keywords were used, combined with Boolean operators, according to the following strategy: (“ridge preservation” OR “socket preservation” OR “alveolar ridge regeneration”) AND (“immediate dental implant” OR “bone grafting” OR “dentoalveolar regeneration”).

Included in this review were original research articles, systematic reviews, meta-analyses, and clinical guidelines, published in English, Portuguese, or Spanish, provided they were available in full text, had a clear methodology, and demonstrated direct relevance to the topic of IDR. The initial selection was based on titles and abstracts, followed by full-text reading of potentially eligible studies. Additionally,

relevant cross-references found within the included studies were also considered to minimize the loss of pertinent data, as recommended by Warriner (2018). Studies were excluded if they exhibited weak methodological designs (such as isolated case reports lacking expanded discussion), duplicate publications across different databases, articles with declared conflicts of interest without peer review, or studies not directly focused on post-extraction alveolar regeneration, even if related to implant dentistry.

Data extraction was performed independently by two reviewers, with disagreements resolved by consensus or by a third reviewer, ensuring the reproducibility and reliability of the process. Extracted information included: author, year, country of origin, study type, number of patients or specimens, techniques applied, biomaterials used, main clinical and radiographic outcomes, and the assigned level of evidence for each study.

The data analysis was descriptive and categorical, with findings organized into four main thematic axes:1) Biological characteristics of alveolar regeneration; 2) Biomaterials used in IDR; 3) Clinical protocols adopted; 4) Key factors influencing the success of the technique.

The methodological framework followed the principles of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), adapted for narrative reviews, to ensure transparency, rigor, and quality in the synthesis of available evidence (Page *et al*., 2021).

Scoping Review

IDR is a surgical technique aimed at restoring the anatomy of the alveolar ridge immediately after tooth extraction, minimizing the effects of physiological bone resorption and preserving both aesthetics and function in edentulous areas. This approach has gained prominence in modern implant dentistry, particularly in esthetically demanding regions, due to its ability to maintain bone volume and soft tissue architecture (Chen & Buser, 2014; Avila-Ortiz *et al*., 2019).

Following extraction, an intense process of bone remodeling begins within the first 24 hours, with a significant reduction in alveolar volume especially in the buccal bone plate, which consists of bundle bone, a structure highly dependent on the integrity of the periodontal ligament (Araújo & Lindhe, 2005). Histological and radiographic studies have shown that horizontal bone loss can reach up to 50% of the original width within three to six months, with more pronounced resorption in the anterior maxillary region (Van der Weijden *et al*., 2008).

IDR integrates guided bone regeneration (GBR) and/or guided tissue regeneration (GTR) techniques, often combined with immediate implant placement or alveolar socket preservation using biomaterials. Commonly used materials include autogenous, allogenic, xenogenic (e.g., Bio-Oss), and synthetic bone grafts (e.g., b-TCP), in addition to resorbable collagen membranes (Jensen *et al*., 2006; Urban *et al*., 2013). The selection of biomaterials should consider the extent of bone loss, the integrity of the buccal plate, and the restorative objectives.

Immediate implant placement, when properly indicated, reduces the number of surgical interventions and the overall treatment time, showing success rates comparable to delayed placement provided that primary stability and buccal plate preservation are achieved (Kuchler *et al*., 2016). However, in cases where the buccal bone is compromised, the use of particulate grafts and membranes is recommended to reconstruct the socket and prevent esthetic collapse (Botticelli *et al*., 2004).

Several studies have demonstrated the high regenerative potential of IDR, particularly when associated with growth factors such as platelet-rich fibrin (PRF), which promote angiogenesis, cell migration, and osteoblastic differentiation (Del Corso *et al*., 2012). Recent advancements also include the use of mesenchymal stem cells and bioactive scaffolds, ushering in a new era of personalized tissue engineering in regenerative dentistry (Kaigler *et al*., 2013).

From a clinical standpoint, the predictability of IDR is directly linked to proper case selection. Factors such as a thin gingival biotype, active infection, smoking, and uncontrolled systemic conditions may jeopardize osseointegration and graft success (Kan *et al*., 2018). Therefore, three-dimensional imaging and digital planning are indispensable tools in modern surgical protocols.

The literature also emphasizes the importance of achieving primary closure or employing open healing techniques, in which collagen membranes are intentionally left exposed without compromising bone

regeneration especially when using advanced-generation collagen membranes (Barone *et al*., 2008; Buser *et al*., 2004). Moreover, the use of appropriate prosthetic platforms and harmonious emergence profiles significantly contributes to the maintenance of peri-implant tissues and the long-term success of the rehabilitation.

Although IDR provides several advantages such as shorter treatment time and improved esthetic outcomes clinicians must be adequately trained to manage potential complications, including membrane exposure, recipient site infection, or failure of osseointegration. Thus, clinical indication should be cautious and based on robust scientific evidence (Ten Heggeler *et al*., 2011). In conclusion, Immediate Dentoalveolar Regeneration represents a promising approach in contemporary implant dentistry. However, its widespread adoption still requires long-term randomized clinical trials to standardize protocols and enhance predictability. The integration of novel biomaterials, advanced cell-based therapies, and digital planning technologies signals a future in which immediate alveolar regeneration will align closely with the frontiers of regenerative biotechnology (Naung *et al*., 2019).

DISCUSSION

Immediate Dentoalveolar Regeneration represents a strategic approach to managing post-extraction sockets, particularly in esthetic and functional areas where preserving bone and gingival architecture is essential for successful rehabilitation. The literature consistently demonstrates that tooth extraction triggers a cascade of biological events leading to significant bone resorption, particularly in the buccal plate, which is predominantly composed of bundle bone and whose maintenance depends on functional stimulation by the periodontal ligament (Araújo & Lindhe, 2005; Van der Weijden *et al*., 2008).

In this context, IDR emerges as an alternative to spontaneous healing, mitigating the effects of alveolar resorption through the immediate placement of osteoconductive biomaterials, barrier membranes, and/or dental implants. Evidence suggests that, when properly indicated, IDR enhances dimensional stability of the alveolar ridge and supports the preservation of soft tissue volume, thereby reducing the risk of gingival collapse particularly in patients with a thin periodontal biotype (Chen & Buser, 2014; Urban *et al*., 2013).

However, its application must be carefully individualized, considering anatomical, systemic, and clinical variables. The integrity of the buccal plate is widely recognized as one of the most critical factors for the technique's success. In cases where this structure is compromised, the rate of bone resorption increases significantly even when grafts are used thus warranting the implementation of guided bone regeneration (GBR) techniques using particulate biomaterials in conjunction with resorbable membranes to achieve proper three-dimensional alveolar reconstruction (Barone *et al*., 2008).

Another widely discussed aspect in the literature is biomaterial selection. Xenografts such as Bio-Oss® offer excellent long-term volumetric stability but limited remodeling capacity. Conversely, autogenous grafts exhibit superior osteogenic potential but are associated with increased donor-site morbidity. The combination of biomaterials with bioactive agents such as platelet-rich fibrin (PRF) has shown promising results, enhancing angiogenesis, cellular differentiation, and reducing healing time and infection risk (Del Corso *et al*., 2012; Kaigler *et al*., 2013).

The protocol for immediate implant placement in association with IDR requires meticulous planning. Achieving primary stability, ensuring the absence of active infection, and preserving bony structures are essential conditions for long-term success. Controlled clinical trials report success rates exceeding 95% for implants placed immediately into ideal extraction sockets, underscoring the technique’s predictability (Botticelli *et al*., 2003).

From a prosthetic standpoint, IDR enables immediate provisionalization, which contributes to the shaping of peri-implant tissues and enhances the final esthetic outcome of the rehabilitation. However, immediate loading must be carefully indicated and is recommended only in cases with a minimum insertion torque of 35 Ncm and absence of micromovements, as improper loading may compromise osseointegration and result in implant failure (Kan *et al*., 2018).

Despite technological and scientific advances, literature still reveals significant gaps. The lack of randomized clinical trials comparing different biomaterials such as PRF versus synthetic grafts limits the standardization of clinical protocols. Additionally, few studies assess long-term clinical and radiographic outcomes in large patient cohorts, thereby weakening the robustness of current clinical guidelines.

Future research should focus on direct comparisons between biomaterials, the application of cell-based therapies, and the validation of emerging technologies such as 3D printing of customized scaffolds, with emphasis on safety, efficacy, and cost-effectiveness.

In summary, while the current literature supports consistent benefits of IDR, there remains a clear need for additional randomized clinical trials with extended follow-up to enable protocol standardization and enhance clinical predictability. The integration of advanced digital technologies such as virtual planning, 3D-priscaffolds have ides, and bioactive scaffolds holds the potential to establish IDR as the gold standard in complex oral rehabilitations.

CONCLUSION

Immediate Dentoalveolar Regeneration is an essential strategy in regenerative dentistry aimed at preserving and reconstructing the alveolar ridge immediately following tooth extraction, thereby promoting more predictable functional and esthetic prosthetic rehabilitations. Its success depends on appropriate case selection, bone integrity, implant stability, and the choice of biomaterials, in addition to requiring technical expertise and three-dimensional treatment planning. The combined use of biomaterials, resorbable membranes, and growth factors accelerate healing, while digital technologies enhance predictability and reduce surgical morbidity. Despite the need for further long-term studies, IDR is recognized as a safe, effective, and multidisciplinary approach with an increasingly important role in contemporary clinical dental practice.

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Data Availability. All data analyzed during this study are available from the corresponding author upon reasonable request.

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RESUMEN: La Regeneración Dentoalveolar Inmediata (RDI) es un enfoque terapéutico que busca la preservación o restauración inmediata del reborde alveolar tras extracciones dentales. Esta estrategia busca permitir una rehabilitación protésicas más rápida, predecible y estéticamente satisfactoria. Dada la alta prevalencia mundial de extracciones dentales, la RDI se ha convertido en una herramienta esencial en la odontología regenerativa contemporánea. El objetivo es analizar críticamente la evidencia científica actual sobre la aplicación clínica de la RDI, incluyendo sus fundamentos biológicos, los materiales empleados, los protocolos quirúrgicos y los principales factores que influyen en los resultados del tratamiento. Se realizó una revisión scopiew en las bases de datos PubMed, Scopus, ScienceDirect, Web of Science, SciELO y LILACS, durante el período 2020-2025. Se incluyeron artículos de investigación originales, revisiones sistemáticas, metaanálisis y guías clínicas. La selección de los estudios se basó en la relevancia temática, el rigor metodológico y la disponibilidad del texto completo. Se emplearon herramientas como Rayyan, Zotero y la lista de verificación SANRA para la organización de los datos y la evaluación de la calidad. La literatura indica que, cuando está correctamente indicada, la IDR permite un control eficaz de la reabsorción ósea y la preservación de los tejidos blandos. El uso de biomateriales, como injertos xenogénicos, y agentes bioactivos, como el PRF, mejora la osteogénesis y acelera el proceso de cicatrización. Sin embargo, factores como la integridad de la placa ósea vestibular, el biotipo gingival y la ausencia de infección local son determinantes críticos para el éxito clínico. La IDR es una técnica prometedora en odontología regenerativa, aunque aún requiere ensayos clínicos sólidos para estandarizar los protocolos y confirmar su eficacia a largo plazo. Se espera que la integración de tecnologías emergentes y biomateriales avanzados optimice aún más los resultados clínicos futuros.

PALABRAS CLAVE: Rehabilitación dental, implantes dentales, odontología restauradora.

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