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Surgical-prosthetic management of root fracture with dental implant and guided bone regeneration

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Abstract
Dental implantology has evolved significantly since Brånemark introduced the concept of osseointegration, becoming one of the most predictable alternatives for the replacement of missing teeth. The success of implants depends on multiple factors, among which the preservation and regeneration of the alveolar ridge are decisive, since tooth loss leads to dimensional changes in hard and soft tissues that compromise prosthetic rehabilitation. To counteract these changes, various techniques and biomaterials are employed, such as autografts, allografts, xenografts, and alloplastic materials. Xenografts, particularly those of bovine origin, have proven effective by acting as a calcified matrix and reducing post-extraction bone resorption. Likewise, the use of acellular dermal matrix has shown favorable outcomes in soft tissue regeneration, as it promotes revascularization and structural integration without eliciting an immunogenic response. We present the case of a 45-year-old male patient who attended consultation due to gingival recession, bleeding, and mobility in tooth 11, previously treated with endodontics and prosthetic restoration. Clinical and radiographic findings confirmed the presence of a vertical root fracture. Surgical extraction was performed, followed by alveolar preservation using a bovine xenograft and coverage with an acellular dermal matrix. Subsequently, after eight months, a Straumann titanium implant with immediate loading was placed, achieving an adequate emergence profile and esthetic restoration with lithium disilicate crowns.

Keywords: Dental implant, dental implant design, bone regeneration, dental prosthesis

Introduction

Since ancient times, humans have sought to replace missing teeth, with records indicating attempts at transplantation by the Egyptians. Modern implantology began in 1965, when Brånemark successfully placed the first clinical dental implant with osseointegration. In 1982, he introduced his titanium implant and the concept of osseointegration, driving the growth of the implant market. By 1988, the American Dental Association and the National Institutes of Health had approved implant systems based on Brånemark's principles, including Astra Tech, Nobel Biocare, Steri-Oss, and Straumann, thereby consolidating implantology worldwide [1, 3].

Dental implants constitute a prosthetic unit designed to replace the natural tooth, consisting of the implant body, abutments, and the prosthetic crown, which may be screw-retained or cemented. These implants, manufactured from ceramic or metallic materials, are placed in submucosal, subperiosteal, or intraosseous tissues, providing support for fixed or removable prostheses. Osseointegration, which determines implant success, depends on bone quality as evaluated by the Lekholm and Zarb classification, which considers the proportion of cortical and trabecular bone: quality 1 being predominantly cortical, and quality 4 predominantly trabecular. Clinical success in implantology is multifactorial and requires thorough assessment of medical history, intraoral examination, study models, and diagnostic wax-up articulated in a semi-adjustable or fully adjustable articulator, along with three-dimensional surgical and prosthetic planning. The use of surgical guides is indispensable in high-esthetic-demand areas, and in certain cases guided bone regeneration may be required to preserve the anterior alveolar ridge [4, 6].

Dental trauma is one of the main causes of tooth loss, generating functional, esthetic, and psychological disharmony that often necessitates prosthetic intervention. Among these injuries, vertical root fractures may be partial or complete, compromising the longitudinal axis of the tooth. Their clinical management aims to preserve function and periodontal health, control microbial invasion, and minimize tissue loss, thereby improving patient comfort, esthetics, and confidence [7, 8].

Tooth loss, however, also produces dimensional changes in both hard and soft tissues, frequently resulting in alveolar ridge defects that complicate prosthetic rehabilitation. For this reason, ridge preservation and augmentation are aimed at maintaining or increasing alveolar volume, thereby optimizing conditions for implant placement and future restorations. To achieve this goal, different biomaterials are employed to prevent post-extraction volumetric reduction and promote osteogenesis, with bone grafts being particularly relevant [9].

Autogenous grafts, considered the "gold standard," provide direct osteogenesis, but their use is limited due to the need for a second surgical site. Allografts, obtained from human donors, offer a biocompatible alternative following processing. Xenografts, such as bovine-derived Bio-Oss, function as a calcified matrix and have demonstrated the ability to reduce bone resorption rates, supporting alveolar crest stability after extraction. Alloplasts, of synthetic origin, mainly act as osteoconductive scaffolds [10, 11].

In addition, acellular dermal matrix (ADM) represents a soft tissue grafting option with significant regenerative properties. This dermal allograft undergoes decellularization and structural preservation processes, maintaining collagen, elastin, and bioactive proteins, thereby ensuring its non-immunogenic character. ADM provides a biological scaffold that allows colonization by fibroblasts and endothelial cells, promotes revascularization, increases tissue thickness, and integrates predictably with periodontal tissues, resembling connective tissue [12].
Surgical techniques available for soft tissue, hard tissue, or combined augmentation benefit from these materials by facilitating controlled regeneration of the alveolar ridge. This comprehensive approach restores both bone and gingival volume while providing a solid foundation for the systematic evaluation of gingival architecture defects, ensuring more predictable functional and esthetic outcomes.
Immediate post-extraction implant placement represents a strategy that reduces healing time, initiating osseointegration at the moment of extraction. In some cases, mucogingival surgery or bone grafting may be required to correct peri-implant defects, ensuring adequate support for the future prosthesis. Prosthetic considerations are fundamental: components must allow for an appropriate emergence profile, preserving the gingival margin and interdental architecture. The selection of impression materials, particularly addition silicones (VPS), guarantees dimensional accuracy and stability of the models, both critical factors for successful prosthetic rehabilitation [9, 13].
As part of the considerations for determining implant success, several classifications have been proposed, including those by Seibert [14], Elian [15], and Amler [16].

Seibert's classification of alveolar defects: Class I: Buccolingual loss with preserved apicocoronal dimension. Class II: Apicocoronal loss with preserved buccolingual dimension. Class III: Combined width and height defect.
Elian *et al*. proposed a classification for extraction sites, considering the presence of soft tissue and buccal bone wall, useful for determining whether alveolar preservation is required or if immediate implant placement is possible:

Table 1: Elian *et al*. classification of soft tissue and buccal bone wall conditions.

Type I	Soft tissue and buccal bone wall are at the cementoenamel junction (CEJ) level before extraction and remain intact post-extraction. These are easy-to-treat cases with predictable outcomes.
Type II	Soft tissue levels are normal before extraction, but partial loss of the buccal bone wall occurs post-extraction. These may resemble Type I, with relatively predictable results.
Type III	Loss of buccal bone wall and soft tissue occurs post-extraction. These are difficult-to-treat cases with less predictable outcomes, where alveolar preservation is recommended.

Amler's five stages of post-extraction socket healing: Stage I: Formation of a clot of white and red cells with hemostasis occurring immediately. Stage II: Granulation tissue replaces the clot by day 4–5. Angiogenesis begins through endothelial cell chains and capillary formation. Stage III: Granulation tissue is gradually replaced by connective tissue in 14–16 days, with complete epithelial coverage. Stage IV: Calcification of osteoid tissue begins at the base and periphery of the socket within 7–10 days. By 6 weeks, trabecular bone nearly fills the socket. Osteoblastic activity is at its peak, with proliferation of connective tissue elements and osteoblasts beneath osteoid tissue around immature bone lacunae. After week 8, osteogenesis appears to decrease. Stage V: By weeks 4–5, complete epithelialization of the socket occurs. Complete bone filling is achieved between weeks 5–10. By 16 weeks, bone fill is complete, with minimal osteogenic activity remaining [17].
Dental implantology requires an understanding of the interaction between implants and hard and soft tissues, as well as the biomechanics of the masticatory system, in order to apply the most suitable treatment according to functional forces. Prosthetic components play a key role in conditioning soft tissues, being designed to match abutment profiles and achieve predictable esthetic results [18].
Accuracy in reproducing dental anatomy depends on high-fidelity impression materials, such as addition silicones (VPS), which offer dimensional stability and minimize distortion. Factors such as temperature, time between impression-taking and pouring, gypsum wettability, and disinfection must be controlled to ensure model accuracy [19].
Prosthetic planning prior to alveolar ridge augmentation procedures is essential. Provisional restorations should ensure an appropriate emergence profile, preserving the gingival margin and interproximal papillae. In esthetic zones, cement-retained prostheses are often the most suitable option. Proper selection and fabrication of provisional restorations allow preservation of the emergence profile and passive fit, both key elements for peri-implant tissue health.

Case Report
A 45-year-old male patient presented to the Centro Mexicano en Estomatología, Morelia Campus, reporting gingival recession accompanied by bleeding and tooth mobility. The patient indicated that tooth 11 had undergone endodontic treatment approximately four years earlier and that, since placement of the prosthetic crown, he had perceived it as oversized. A few months after cementation, the patient experienced pain, tooth loosening, and inflammation.
Intraoral clinical examination revealed inflammation of the free vestibular gingiva in tooth 11, as well as a Kotlow class I upper labial frenum. Radiographic examination showed periodontal ligament thickening, gutta-percha filling in the root canal, root canal enlargement for prosthetic purposes, and radiolucent changes suggestive of a vertical root fracture. Figure 1.

Fig. 1: A) Intraoral panoramic photograph showing gingival recession and localized gingivitis in tooth 11, with a medium gingival biotype. B) Periapical radiograph showing thickening of the periodontal ligament in tooth 11 after removal of the porcelain-fused-to-metal crown.

Based on these findings, a diagnosis of vertical root fracture in the apical third of traumatic occlusal etiology was established. Surgical extraction of tooth 11 was indicated. Laboratory results: hemoglobin 16.1 g/dL, hematocrit 50.1%, platelets 208,000/µL, PT: 11 s, PTT: 33 s, glucose 95 mg/dL. Under local anesthesia with supraperiosteal infiltration of 72 mg lidocaine with epinephrine, extraction was performed, confirming the vertical root fracture. Immediately afterward, alveolar preservation was carried out using bovine bone graft (Bio-Oss) and covered with an acellular dermal matrix, with flap approximation using 6-0 nylon sutures. Figure 2.

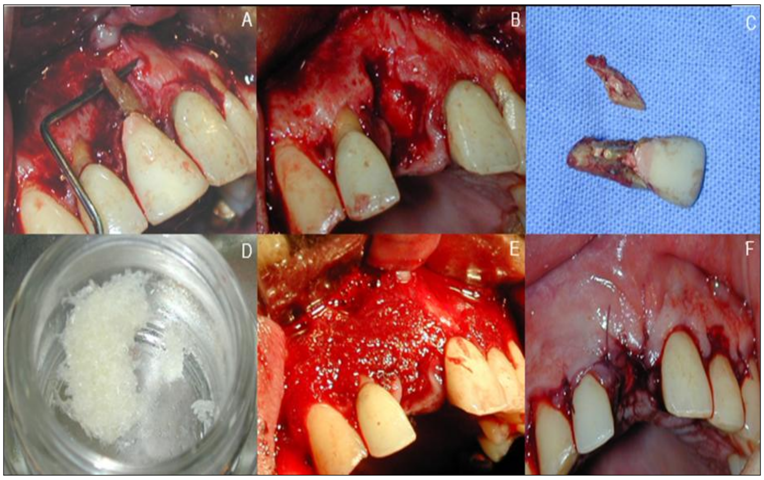

Fig. 2: A) Vertical root fracture of tooth 11. B) Seibert class II alveolus. C) Extracted right maxillary central incisor with vertical root fracture. D) Bio-Oss hydrated with saline. E) Alveolar preservation. F) Flap approximation with 6-0 nylon sutures.

At 8 months, osteotomy was performed for placement of a Straumann tissue-level titanium implant, 3.3 mm in diameter and 12.0 mm in length. Immediate loading was applied to design the emergence profile. Figure 3. At 12 months, prosthetic rehabilitation began with closed-tray impression technique and esthetic rehabilitation using E-max crowns. Figure 4.

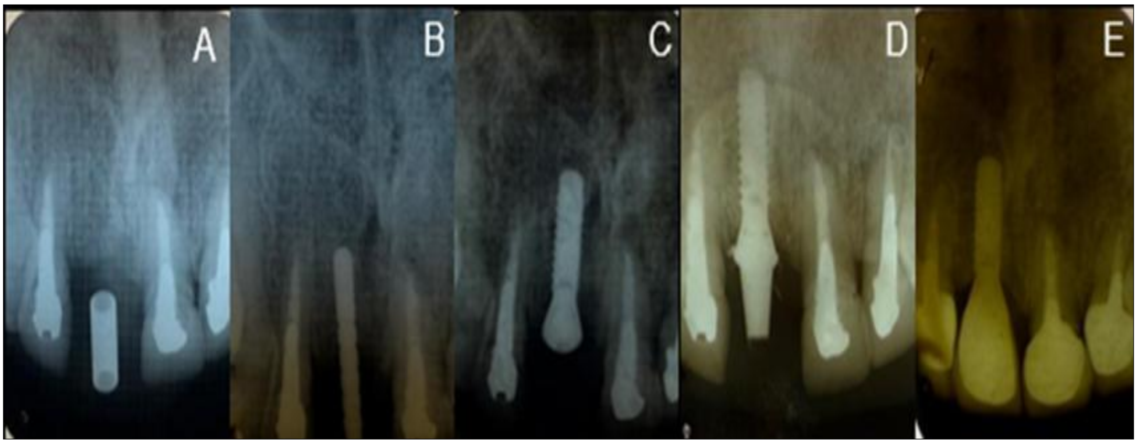

Fig. 3: A) Initial radiograph with self-fabricated surgical guide. B) Initial marking with a parallelism or depth pin. C) Implant placement. D) Radiograph of implant with prosthetic abutment. E) Temporarily restored implant with final crown.

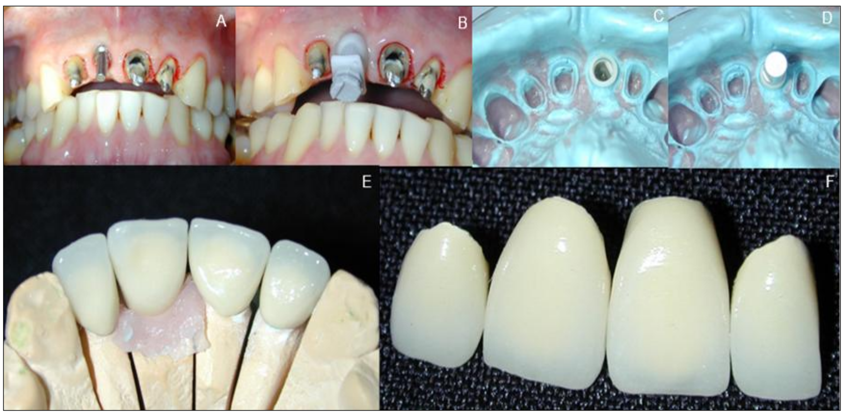

Fig. 4: A) Preparation of teeth 12, 21, and 22 for impression taking. B) Placement of transfer for closed-tray impression technique. C) Analog check in impression. D–F) Lithium disilicate crowns for teeth 12, 11, 21, 22.

For esthetic comparison, results of implant-based anterior esthetic rehabilitation were contrasted with the replacement of porcelain-fused-to-metal crowns in the anterior sector with E-max crowns placed on a post-extraction implant, achieving improved anterior esthetics. Figure 5.

Fig. 5: A) Initial panoramic photograph prior to extraction of fractured tooth 11. B) Post-rehabilitation panoramic photograph showing anterior esthetic restoration with preservation of interdental papillae at tooth 11.

Discussion

A review of the literature shows that different treatment alternatives are available depending on the needs of the patient. Each patient presents unique requirements; therefore, even when the same treatments are considered, they are not applied in the same manner, timing, sequence, or combination of techniques. Individualized treatment planning is thus essential, with the use of appropriate auxiliary tools to ensure the most effective therapeutic approach.

From the planning stage, it is crucial not to overlook any detail in each of the structures involved. Implant therapy is not limited to implant placement alone; it encompasses postoperative care, potential use of regenerative materials, operator skill, surgical techniques, treatment duration, and materials for prosthetic rehabilitation. Successful outcomes therefore depend on an integrated and individualized approach.

Conclusions

When placing implants, several factors must be considered: the bone quality, density, and quantity at the recipient site, as well as the selection of an appropriate graft. This choice depends on the planning of the surgical technique, the type of membrane used, the graft location, the extent of the bone defect, and the need for bone regeneration during dental implant surgery. Autografts are biocompatible and capable of inducing osteogenesis, while allografts and xenografts—although structurally similar to human bone—lack human osteoinductive properties.

The selection of the graft type should be guided by specific clinical factors, such as the location and extent of the bone defect and the need for bone regeneration during implant surgery. It is essential to keep in mind the specific characteristics of each bone graft and the potential for resorption. Therefore, careful attention must be paid to the surgical technique and the selection of an appropriate membrane to optimize graft outcomes and minimize resorption.

The vascularization of bone grafts is a critical factor affecting their long-term success. When selecting the graft type, special consideration should be given to vascularization. In special cases, such as cleft palate coverage, microvascular corticocancellous bone grafts, such as those harvested from the femur, may be considered.

Continuous follow-up and evaluation of patients undergoing bone graft surgery are recommended. This will allow treatment strategies to be adjusted as needed and will improve the long-term predictability of bone graft outcomes.

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