BULLETIN OF STOMATOLOGY AND MAXILLOFACIAL SURGERY
Volume 22, Issue 4

DOI:10.58240/1829006X-2026.22.4-40

CLINICAL CASE SERIES

CLINICAL AND RADIOGRAPHIC OUTCOMES OF INTENTIONAL REIMPLANTATION OF IMPACTED MAXILLARY CANINES: A RETROSPECTIVE CASE SERIES WITH FIVE-YEAR FOLLOW-UP

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Received: Apr 4 2026; **Accepted:** May 23. 2026; **Published:** May 31. 2026

ABSTRACT

Background: Management of impacted maxillary canines remains a significant challenge in oral surgery and orthodontics. Although surgical exposure followed by orthodontic traction is considered the standard treatment, certain cases present with severe displacement, unfavorable angulation, or suspected ankylosis, making orthodontic repositioning difficult or unpredictable. In such situations, intentional reimplantation may offer a biologically based alternative for preserving the natural tooth.

Objective: To evaluate the clinical and radiographic outcomes of intentional reimplantation of impacted maxillary canines using standardized surgical and endodontic protocols.

Materials and Methods: This retrospective case series included 24 patients treated between 2021 and 2025 for impacted maxillary canines with an unfavorable prognosis for orthodontic traction. All patients underwent atraumatic surgical extraction, extraoral endodontic treatment when indicated, immediate reimplantation, and semi-rigid splint stabilization. Clinical and radiographic follow-up assessments were performed from the immediate postoperative period to a maximum of 5 years. Outcome measures included tooth retention, mobility, periodontal health, root resorption, ankylosis, and functional integration.

Results: All reimplanted canines remained functional throughout the available follow-up period, resulting in a 100% tooth retention rate. Clinical success, defined as functional stability without progressive root resorption, ankylosis, periodontal deterioration, or loss of function, was achieved in 22 of 24 cases (91.7%). Mild non-progressive external root resorption was observed in one patient (4.2%), while two patients (8.3%) demonstrated persistent Grade I mobility without functional impairment. No cases of infection, ankylosis, severe mobility, progressive root resorption, or tooth loss were identified. Radiographic evaluation demonstrated preservation of periodontal ligament space and stable alveolar bone support in the majority of cases.

Conclusion: Intentional reimplantation of impacted maxillary canines may represent a viable tooth-preserving treatment option in carefully selected cases where orthodontic repositioning is not feasible or is associated with poor prognosis. Preservation of periodontal ligament vitality, atraumatic surgical handling, minimization of extraoral time, and appropriate postoperative stabilization appear to be critical determinants of favorable outcomes. Further prospective multicenter studies with larger patient cohorts are required to validate long-term predictability and identify prognostic factors influencing treatment success.

Keywords: Impacted canine; reimplantation; periodontal ligament; tooth transplantation; root resorption

INTRODUCTION

Impaction of maxillary canines represents one of the most common disturbances of dental eruption after third molars, with a reported prevalence ranging from 1% to 3% in the general population.[1] The permanent maxillary canine plays a critical role in facial esthetics, dental arch integrity, functional occlusion, and canine-guided disclusion. Failure of eruption may result in several clinical complications, including root resorption of adjacent teeth, cystic changes, periodontal damage,

malocclusion, and long-term esthetic and functional impairment.[2,3] Consequently, early diagnosis and appropriate management of impacted canines are considered essential components of contemporary orthodontic and oral surgical practice[4].

The etiology of maxillary canine impaction is multifactorial and involves a combination of genetic, systemic, and local anatomical factors (table1)[5].

Table 1. Major Etiological Factors Associated with Impacted Maxillary Canines

Etiological Category	Representative Factors
Local	Space deficiency, retained deciduous canines, ankylosis, supernumerary teeth, odontogenic pathology, trauma, eruption disturbances, and adjacent tooth anomalies.
Systemic	Skeletal syndromes, endocrine disorders, metabolic abnormalities, vitamin deficiencies, and radiation exposure.
Genetic	Tooth germ displacement, developmental anomalies, hereditary factors, and craniofacial defects.

Proposed etiological mechanisms include arch length deficiency, ectopic positioning of the tooth germ, abnormal eruption pathway, prolonged retention or ankylosis of the primary canine, and hereditary influences affecting eruption guidance.[6,7]

Because the severity and spatial position of impacted canines may vary considerably, accurate radiographic localization is fundamental for treatment planning and prognosis assessment. Panoramic radiography remains a routine diagnostic tool; however, cone-beam computed tomography (CBCT) has significantly improved three-dimensional evaluation of impacted teeth, adjacent root relationships, angulation, and alveolar bone morphology.[8,9]

Several radiographic classification systems have been proposed to evaluate the position and treatment prognosis of impacted maxillary canines. Among these, the Ericson and Kurol classification is widely used to assess mesiodistal position, angulation, and proximity to adjacent teeth using panoramic radiographs.[10,11] Increased mesial displacement and severe angulation have been associated with greater treatment complexity, prolonged orthodontic treatment duration, and increased risk of adjacent root resorption.

CBCT-based evaluation has further enhanced the ability to determine the severity of impaction and potential feasibility of orthodontic repositioning.

Table 2. Ericson and Kurol Radiographic Classification of Impacted Maxillary Canines and Clinical Implications

Parameter	Classification	Clinical Significance
Sector 1	Distal to the lateral incisor axis	Favorable eruption prognosis
Sector 2	Overlapping distal half of lateral incisor root	Preventive extraction of primary canine often effective
Sector 3	Overlapping mesial half of lateral incisor root	Moderate impaction; close orthodontic monitoring required
Sector 4	Overlapping central incisor axis	Severe impaction; surgical-orthodontic intervention often indicated
Sector 5	Mesial to central incisor axis	Very severe impaction with increased treatment complexity
α-angle <20°	Mild inclination	Favorable prognosis
α-angle 20–30°	Moderate inclination	Interceptive treatment may be successful
α-angle >30°	Severe inclination	Early surgical exposure and orthodontic traction recommended

Various treatment modalities have been described for the management of impacted maxillary canines, including surgical exposure followed by orthodontic traction, extraction with prosthetic rehabilitation, autotransplantation, and intentional reimplantation.[12,13] Orthodontic traction remains the gold standard treatment impacted maxillary canines because it preserves the natural tooth within the dental arch while maintaining periodontal support and functional integration.[14,15]

Nevertheless, successful orthodontic repositioning depends on several factors, including favorable tooth position, sufficient arch space, adequate patient compliance, and absence of ankylosis. In cases involving severe displacement, unfavorable angulation, dilaceration, or suspected ankylosis, orthodontic traction may become unpredictable, excessively prolonged, or clinically contraindicated.[16-18]

Intentional reimplantation is defined as the deliberate extraction of a tooth followed by reinsertion into its original or surgically prepared socket under controlled clinical conditions.[19,20]

Historically, the procedure was considered a treatment of last resort because of concerns regarding ankylosis, root resorption, and long-term periodontal failure. However, advances in microsurgical techniques, modern endodontic protocols, biomaterials, and improved understanding of periodontal ligament biology have renewed clinical interest in intentional reimplantation as a conservative tooth-preserving

procedure.[21]

Intentional tooth replantation (ITR) is currently guided by two major clinical protocols. The first was published by the American Association of Endodontists (AAE) in 2019, and the second by the European Society of Endodontology (ESE) in 2021.[22]

These guidelines provide comprehensive and detailed recommendations regarding case selection, clinical procedures, and postoperative follow-up. Both protocols aim to standardize clinical practice, improve procedural predictability, and enhance long-term tooth survival through evidence-based management strategies.

Despite increasing interest in this technique, standardized surgical protocols and evidence-based follow-up criteria for intentional reimplantation of impacted maxillary canines remain insufficiently established. The currently available literature consists predominantly of isolated case reports, case series, and studies extrapolated from autotransplantation and traumatic tooth avulsion research. Consequently, the predictability and long-term biological behavior of intentionally reimplanted impacted canines remain incompletely understood[23-25].

The biological success of intentional reimplantation depends primarily on preservation of viable periodontal ligament (PDL) cells during extraction, handling, and reinsertion of the tooth. Viable PDL cells are essential for periodontal regeneration, cementum repair, and re-establishment of functional attachment between the root surface and alveolar bone. Damage to the periodontal ligament caused by mechanical trauma, dehydration, bacterial contamination, or prolonged extraoral time may compromise healing and increase the risk of inflammatory root resorption or ankylosis.[26-28]

For this reason, atraumatic extraction, maintenance of root surface hydration, and minimization of extraoral manipulation are considered critical determinants of successful healing.

Autotransplantation and intentional reimplantation share similar biological principles, particularly with respect to preservation of periodontal ligament vitality and promotion of periodontal healing. However, the two procedures differ in clinical indication and surgical approach. In autotransplantation, a donor tooth is transferred to a different recipient site, whereas intentional reimplantation involves reinsertion of the same tooth into its original or modified socket.[28,29]

Both procedures require careful case selection, atraumatic surgical handling, and appropriate stabilization to optimize periodontal healing and long-term survival.

Recent studies have reported survival rates ranging from approximately 70% to 90% for intentional reimplantation and tooth autotransplantation procedures when appropriate biological and surgical principles are respected, particularly with minimized extraoral time and preservation of periodontal ligament integrity.[30,31] Nevertheless, evidence specifically evaluating intentional reimplantation of impacted maxillary canines remains limited, and most available reports involve small retrospective series with heterogeneous methodologies and variable follow-up durations.

Therefore, the aim of the present retrospective case series was to evaluate the clinical and radiographic outcomes of intentional reimplantation of impacted maxillary canines performed under standardized surgical and endodontic protocols and to assess the short-term biological stability, periodontal healing, and functional predictability of this treatment approach.

MATERIALS AND METHODS

2.1 Study Design

This retrospective case series was conducted to evaluate the clinical and radiographic outcomes of intentional reimplantation of impacted maxillary canines. A total of 24 consecutive patients treated between January 2021 and January 2025 were included. All surgical and endodontic procedures were performed according to standardized biological and operative protocols designed to preserve periodontal ligament vitality, minimize surgical trauma, and optimize periodontal healing.

Clinical records, operative reports, panoramic radiographs, cone-beam computed tomography (CBCT) scans, and follow-up examinations were retrospectively reviewed and analyzed.

2.2 Patient Selection

Twenty-four patients underwent intentional reimplantation of impacted maxillary canines during the study period. The cohort consisted of 13 males (54.2%) and 11 females (45.8%), with a mean age of 19.6 ± 4.2 years (range: 14–28 years) (Table3).

Table 3. Baseline Characteristics of the Study Population

Variable	Value
Number of patients	24
Mean age (years)	19.6 ± 4.2
Age range (years)	14–28
Male	13 (54.2%)
Female	11 (45.8%)
Tooth 13	12 (50.0%)
Tooth 23	12 (50.0%)
Palatal impaction	16 (66.7%)
Labial impaction	8 (33.3%)
Follow-up duration	Up to 5 years

All patients received comprehensive clinical and radiographic evaluation before treatment planning. Diagnostic assessment included intraoral examination, panoramic radiography, and CBCT imaging when indicated.

Radiographic analysis focused on canine position, angulation, relationship to adjacent teeth, root morphology, alveolar bone availability, and feasibility of orthodontic repositioning.

Intentional reimplantation was considered only when conventional orthodontic traction was associated with an unfavorable prognosis because of severe displacement, excessive angulation, ectopic eruption pathway, suspected ankylosis, root dilaceration, or anticipated prolonged orthodontic treatment.

Inclusion Criteria

Patients were included in the study when the following criteria were fulfilled:

- Presence of an impacted permanent maxillary canine
- Unfavorable prognosis for orthodontic traction or orthodontic repositioning
- Presence of a retained primary canine or an anatomically suitable recipient socket
- Adequate alveolar bone support for reimplantation
- Absence of systemic contraindications to oral surgical procedures
- Availability of postoperative follow-up records and radiographic evaluation

Exclusion Criteria

Patients were excluded from the study under the following conditions:

- Advanced periodontal disease involving adjacent teeth
- Poor oral hygiene or lack of compliance with postoperative care
- Active oral infection at the surgical site
- Severe systemic disease affecting wound healing or bone metabolism
- Immunocompromised status or uncontrolled systemic conditions
- Incomplete clinical or radiographic follow-up data

2.3 Clinical and Surgical Protocol

All procedures were performed under local anesthesia using a standardized surgical protocol designed to preserve periodontal ligament viability and optimize periodontal healing.

Preoperative Preparation

Before surgery, all patients underwent professional oral hygiene instructions and radiographic evaluation. CBCT imaging was used selectively to assess the exact three-dimensional position of the impacted canine, root angulation, relationship to adjacent teeth, and available recipient bone.

Surgical Extraction

A minimally traumatic surgical approach was used in all cases. Mucoperiosteal flap elevation and conservative osteotomy were performed when necessary to expose the impacted canine. The tooth was carefully luxated and extracted with minimal manipulation in order to reduce mechanical injury to the periodontal ligament and root surface.

Particular attention was given to preservation of cementum integrity and maintenance of viable periodontal ligament cells during extraction and handling.

Extraoral Endodontic Management

Following extraction, extraoral endodontic treatment was performed under sterile conditions in teeth with complete root formation when clinically indicated. Root canal instrumentation, irrigation, and obturation were completed using conventional endodontic techniques

and gutta-percha obturation. Throughout the extraoral phase, the root surface was continuously hydrated using sterile saline solution to prevent periodontal ligament desiccation. All efforts were made to minimize extraoral time, ideally maintaining the interval below 15–20 minutes whenever possible.

Recipient Site Preparation and Reimplantation

The recipient site was prepared conservatively using the socket of the retained primary canine or a surgically modified alveolar socket when necessary. Excessive curettage or compression of the socket walls was avoided to preserve vascular supply and facilitate periodontal ligament healing.

The treated canine was then repositioned into the recipient socket with careful axial alignment and passive adaptation. Excessive insertion force was avoided in order to minimize additional trauma to the root surface and surrounding alveolar bone.

Primary stability was assessed clinically immediately after reimplantation.

Splinting and Postoperative Management

Semi-rigid splinting was applied using composite resin and flexible orthodontic wire in all cases. Splints were maintained for approximately 2 to 4 weeks depending on initial stability and periodontal healing.

Postoperative management included systemic antibiotic therapy, nonsteroidal anti-inflammatory medication when indicated, and chlorhexidine mouth rinse twice daily for 7 to 14 days. Patients were instructed to maintain soft diet precautions and avoid excessive functional loading during the healing period.

2.4 Follow-Up Protocol

All patients underwent standardized postoperative clinical and radiographic follow-up evaluations. Clinical examinations were performed during the immediate postoperative period and subsequently at:

- 10 days
- 1 month
- 3 months
- 6 months
- 1 year
- Up to 3 years when long-term follow-up data were available

Follow-up assessment focused on periodontal healing, tooth mobility, gingival condition, functional integration, and radiographic evidence of root or bone changes.

Periapical radiographs were obtained routinely during follow-up, while CBCT imaging was performed selectively in cases requiring additional evaluation of periodontal ligament space, root resorption, ankylosis, or alveolar bone condition.

2.5 Methodological Considerations

The present study was conducted under standardized surgical and follow-up conditions in order to improve consistency of treatment and outcome assessment. Nevertheless, clinical heterogeneity was present due to differences in patient age, canine position, angulation, depth of impaction, root morphology, and available recipient bone.

Because impacted maxillary canines demonstrate substantial anatomical variation, certain intraoperative modifications were occasionally necessary according to individual surgical requirements. Surgical timing, osteotomy extent, and recipient socket preparation were adapted depending on case complexity and anatomical conditions encountered during treatment.

Healing assessment was based on routine clinical examination and radiographic analysis. Parameters evaluated included tooth mobility, periodontal soft tissue adaptation, probing depth, alveolar bone stability, and radiographic signs of periodontal healing or pathological changes.

Follow-up duration varied among patients because of differences in treatment timing and availability of long-term recall examinations. Continuous monitoring was maintained whenever possible to evaluate periodontal stability and detect late complications such as external root resorption or ankylosis.

2.6 Outcome Measures and Evaluation Criteria

Clinical and radiographic outcomes were assessed using predefined evaluation criteria to improve reproducibility and objectivity of data interpretation.

Clinical Evaluation

Clinical assessment included evaluation of tooth mobility, periodontal condition, gingival health, pain, infection, and functional stability.

Tooth mobility was assessed according to a modified

Miller mobility classification system[31]:

- Grade 0: Physiological mobility (<0.2 mm)
- Grade I: Slight horizontal mobility (0.2–1 mm)
- Grade II: Moderate horizontal mobility (>1 mm)
- Grade III: Severe horizontal and vertical mobility

Periodontal evaluation included assessment of gingival adaptation, probing depth measurements when available, bleeding on probing, and presence of suppuration.

Periodontal health was defined as:

- probing depths ≤3 mm,
- absence of bleeding on probing,
- absence of suppuration,
- and clinically healthy peri-radicular soft tissue adaptation.

Functional success additionally required absence of persistent pain, masticatory discomfort, or occlusal instability.

Radiographic Evaluation

Radiographic evaluation was performed using periapical radiographs and CBCT imaging when clinically indicated.

The following radiographic parameters were assessed:

- Presence and continuity of the periodontal ligament space
- Integrity and continuity of the lamina dura
- Presence or absence of external root resorption
- Presence of ankylosis
- Alveolar bone stability and marginal bone levels
- Periapical radiolucency or inflammatory changes

External root resorption was categorized according to severity:

- Mild: superficial and non-progressive resorption
- Moderate: localized dentinal involvement
- Severe: progressive, circumferential, or extensive resorption

Radiographic ankylosis was defined as partial or complete loss of the visible periodontal ligament space associated with direct continuity between root surface and surrounding alveolar bone.

Definition of Clinical Success

Clinical success was defined as:

- functional tooth retention,
- mobility Grade 0 or Grade I,
- absence of progressive external root resorption,
- absence of ankylosis,
- satisfactory periodontal condition,
- and maintenance of functional and esthetic integration throughout the follow-up period.

Cases demonstrating minor non-progressive complications without loss of function were classified as partial success rather than definitive treatment failure.

2.7 Case Report

Clinical Presentation

A patient presented with delayed eruption of a permanent maxillary canine associated with persistence of the corresponding primary canine. Clinical intraoral examination demonstrated absence of the permanent canine within the dental arch, accompanied by mild vestibular and palatal cortical prominence in the canine region. The retained primary canine exhibited reduced mobility and remained in functional occlusion.

Radiographic evaluation using panoramic imaging and cone-beam computed tomography (CBCT) revealed an ectopically positioned impacted maxillary canine with unfavorable angulation and inadequate eruption trajectory. The impacted tooth demonstrated close proximity to adjacent structures, while available orthodontic space and axial orientation were considered unfavorable for conventional orthodontic traction. No significant cystic lesion or advanced root resorption of adjacent teeth was identified.

Diagnosis

Based on the clinical and radiographic findings, the following diagnosis was established:

- Impacted permanent maxillary canine
- Retained primary canine
- Ectopic eruption pathway with unfavorable angulation
- Limited feasibility and poor prognosis for orthodontic repositioning

Treatment Planning

A multidisciplinary treatment plan involving oral surgery and endodontic management was developed. After evaluation of the anatomical limitations and anticipated orthodontic complexity, intentional reimplantation was selected as the most appropriate tooth-preserving treatment option.

The planned procedure consisted of the following stages:

1. Surgical exposure and atraumatic extraction of the impacted canine
2. Extraoral endodontic treatment under sterile conditions
3. Conservative preparation of the recipient socket
4. Immediate reimplantation of the treated canine
5. Semi-rigid splint stabilization during the healing phase

This treatment approach was selected based on previously reported biological principles and clinical outcomes associated with intentional reimplantation and tooth autotransplantation procedures, particularly in cases where orthodontic repositioning is considered difficult or unpredictable.

Surgical Procedure

Atraumatic Surgical Extraction

The procedure was performed under local anesthesia using a minimally traumatic surgical approach. Following mucoperiosteal flap elevation and conservative bone exposure, the impacted canine was carefully luxated and extracted while minimizing injury to the surrounding alveolar bone and periodontal ligament.

Special attention was directed toward preservation of root surface integrity and maintenance of viable periodontal ligament cells, which are considered essential for periodontal healing and prevention of ankylosis or inflammatory root resorption. Mechanical trauma to the cementum surface was avoided as much as possible throughout the extraction procedure. Immediately after extraction, the tooth was maintained in a moist environment using sterile saline solution in order to prevent desiccation of periodontal ligament tissues.

Extraoral Endodontic Treatment

Extraoral root canal treatment was performed immediately following extraction under sterile operative conditions. Cleaning and shaping of the root canal system were completed using conventional endodontic instrumentation techniques, followed by obturation with gutta-percha in teeth demonstrating complete root formation.

Strict aseptic control was maintained during the entire extraoral phase to minimize the risk of bacterial contamination. Particular emphasis was placed on limiting extraoral manipulation time because prolonged exposure of the periodontal ligament has been associated with reduced cellular viability and increased risk of replacement resorption and ankylosis.

According to existing evidence from reimplantation and autotransplantation literature, preservation of periodontal ligament vitality is strongly correlated with minimized extraoral time. Therefore, all surgical and endodontic procedures were performed in a controlled and time-efficient manner, with continuous hydration of the root surface using sterile saline solution throughout the procedure. Reimplantation was completed as rapidly as clinically feasible to optimize periodontal healing potential.

Recipient Site Preparation

The recipient site was prepared using the socket of the retained primary canine with minimal surgical modification. Conservative osteotomy was performed only when necessary to facilitate appropriate positioning and passive adaptation of the reimplanted tooth. Care was taken to preserve surrounding alveolar bone architecture and vascular integrity while avoiding excessive curettage or compression of the socket walls. Maintenance of an adequate blood supply within the recipient site was considered important for periodontal ligament reattachment and early healing.

Reimplantation Procedure

Following completion of endodontic treatment and recipient site preparation, the impacted canine was carefully repositioned into the prepared socket with correct axial orientation and controlled insertion pressure. The tooth was seated passively to minimize additional trauma to the periodontal ligament and to facilitate adaptation between the root surface and surrounding alveolar bone. Immediate primary stability was achieved clinically without excessive force or additional fixation procedures.

Correct occlusal relationship and axial positioning were verified before stabilization.

Splint Stabilization

Semi-rigid splinting was performed using flexible orthodontic wire and composite resin. The splint was designed to provide adequate stabilization while allowing limited physiological micromovement during the healing phase. Functional semi-rigid stabilization has been reported to support periodontal ligament repair and reduce the likelihood of ankylosis compared with rigid fixation techniques. The splint remained in place for the planned postoperative stabilization period according to clinical mobility and periodontal healing.

Postoperative Management and Follow-Up

Postoperative instructions included maintenance of oral hygiene, soft diet recommendations, chlorhexidine mouth rinse, and antibiotic therapy when indicated. Patients were advised to avoid excessive functional loading during the early healing phase.

Immediate Postoperative Findings

Clinical examination immediately after surgery demonstrated:

- Stable positioning of the reimplanted canine
- Absence of active bleeding or displacement
- Satisfactory primary stability
- Acceptable occlusal relationship

No immediate postoperative complications were observed.

Ten-Day Follow-Up

At the 10-day postoperative review, the following findings were recorded:

- Intact semi-rigid splint
- Favorable gingival healing
- Absence of infection or suppuration
- No abnormal tooth mobility
- Satisfactory soft tissue adaptation

The patient remained asymptomatic during this period.

Three-Month Follow-Up

Clinical and radiographic examination performed after 3 months demonstrated favorable periodontal healing and functional stability of the reimplanted canine.

The following observations were identified:

- Stable periodontal condition
- Absence of clinical signs of ankylosis
- No evidence of inflammatory root resorption
- Healthy gingival adaptation
- Functional integration within the dental arch

Radiographic evaluation demonstrated preservation of the periodontal ligament space and favorable early bone healing without pathological radiolucency. Figures 1–8 illustrate the sequence of the presented clinical case.

Figure1.a,b Preoperative CBCT imaging demonstrating ectopic impaction and unfavorable angulation of the maxillary canine

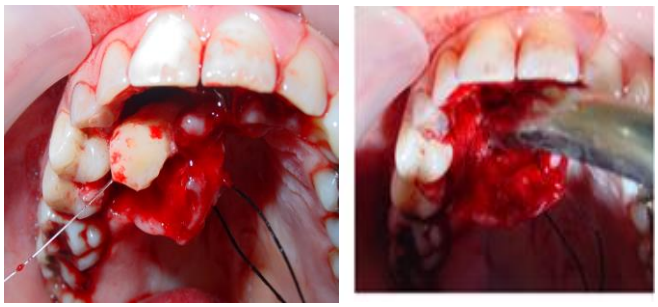

Figure 2.a,b Atraumatic surgical extraction of impacted canine

Figure 3. Extraoral endodontic treatment and immediate reimplantation of the canine into the recipient socket.
Figure 6. Semi-rigid splint stabilization using flexible wire and composite resin

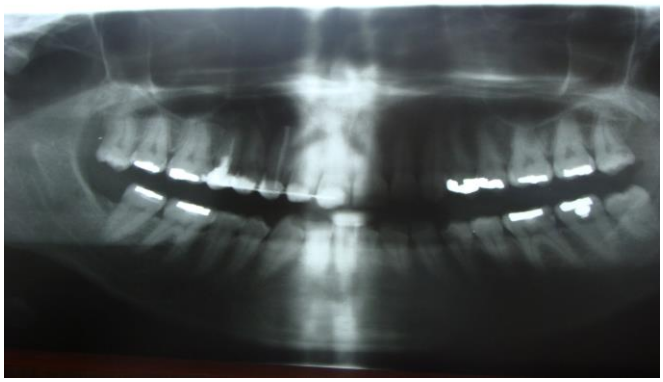

Figure 7. Immediate postoperative radiographic evaluation demonstrating correct positioning of the reimplanted canine.

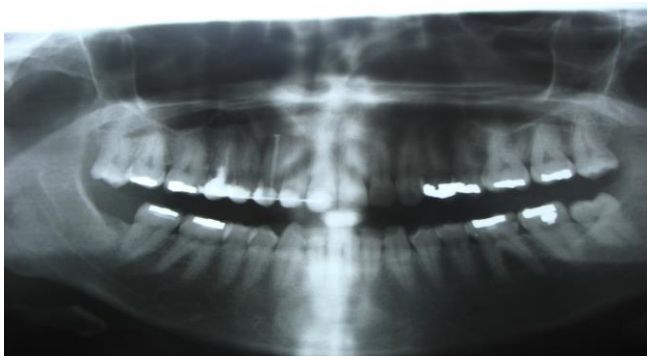

Figure 8. Postoperative radiographic control at 10 days demonstrating satisfactory periodontal adaptation.

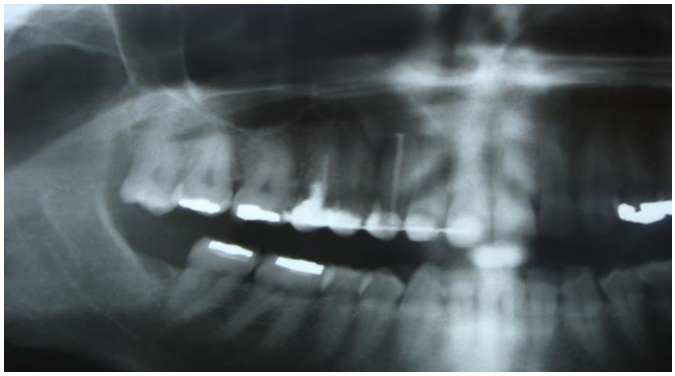

Figure 9. Clinical and radiographic follow-up after 3 years demonstrating functional stability and favorable periodontal healing.

3. RESULTS

A total of 24 patients presenting with impacted maxillary canines underwent surgical extraction followed by intentional reimplantation using a standardized atraumatic surgical and endodontic protocol. All procedures were completed successfully without intraoperative complications, and no surgical interventions required modification or discontinuation. Immediate primary stability was achieved in all cases at the time of reimplantation, allowing satisfactory positioning of the canine within the recipient socket. Clinical examination confirmed acceptable axial alignment, favorable occlusal relationships, and adequate adaptation of surrounding soft tissues immediately after surgery. The postoperative healing period was generally uneventful. All patients attended scheduled clinical and radiographic follow-up visits and were available for outcome assessment. Throughout the observation period, reimplanted teeth demonstrated favorable biological responses with preservation of function and satisfactory integration within the dental arch.

3.1 Survival and Clinical Outcomes

Clinical and radiographic outcomes were assessed according to predefined success criteria established before analysis. Tooth survival was defined as retention of the reimplanted canine within the oral cavity throughout the follow-up period regardless of the presence of minor non-progressive complications. All 24 reimplanted maxillary canines remained present and functional during follow-up, resulting in a survival rate of 100%. No tooth required extraction, replacement, or additional surgical intervention because of treatment failure.

Clinical success was defined according to the following criteria:

- Functional tooth stability with mobility Grade 0 or Grade I.
- Absence of progressive inflammatory or replacement root resorption.
- Absence of clinical or radiographic ankylosis.
- Satisfactory periodontal health and soft tissue adaptation.
- Maintenance of functional and esthetic integration within the dental arch.

Twenty-two of the 24 reimplanted canines fulfilled all success criteria, corresponding to a clinical success rate of 91.7%. One patient (4.2%) demonstrated mild non-progressive external root resorption detected radiographically during follow-up. Another patient (4.2%) exhibited persistent Grade I mobility without evidence of pain, periodontal deterioration, infection, or functional impairment. These two cases were categorized as partial clinical successes because minor complications were present despite preservation of tooth function and retention. Importantly, no cases of ankylosis, severe mobility, progressive root resorption, infection, periodontal breakdown, or tooth loss were observed. Radiographic examinations demonstrated preservation of periodontal ligament integrity and stable alveolar bone support in the majority of cases. Because of the limited sample size and absence of

treatment failures, inferential statistical analyses and survival modeling were not considered appropriate. Therefore, all outcomes are presented descriptively.

Table 4. Survival and Overall Clinical Outcomes (n = 24)

Outcome Parameter	Numberof Cases	Percentage
Completeclinical success	22	91.7%
Partial clinical success	2	8.3%
Tooth survival/retention	24	100%
Tooth loss	0	0%
Ankylosis	0	0%
Progressiveroot resorption	0	0%
Infection	0	0%

3.2 Clinical Findings

Clinical follow-up examinations demonstrated favorable periodontal healing and functional adaptation in most patients. The reimplanted canines maintained satisfactory integration within the dental arch with healthy surrounding soft tissues and absence of clinically significant inflammatory complications.

Mobility Assessment

Tooth mobility was evaluated using the modified Miller mobility classification system during follow-up examinations.

Twenty-two patients (91.7%) demonstrated physiological mobility corresponding to Grade 0 mobility. Two patients (8.3%) exhibited Grade I mobility. No cases demonstrated Grade II or Grade III mobility. The two teeth presenting with Grade I mobility remained clinically stable throughout the observation period and did not show progressive deterioration or associated periodontal pathology.

No patient exhibited traumatic occlusion, excessive mobility, discomfort during function, or evidence of loss of periodontal support.

Periodontal Findings

Periodontal evaluation included assessment of gingival adaptation, probing depth measurements, bleeding on probing, suppuration, and general periodontal health. The periodontal condition remained favorable throughout follow-up. Probing depths were generally within normal physiological limits and did not exceed 3 mm around the reimplanted teeth. No bleeding on probing or suppuration was observed. Gingival tissues demonstrated healthy contour, color, and adaptation, and no evidence of progressive attachment loss was detected. Soft tissue healing was uneventful in most patients, with maintenance of satisfactory mucogingival integration throughout the observation period.

Functional Stability

All reimplanted canines remained functional throughout follow-up. Occlusal stability and acceptable esthetic integration were maintained in every patient. Functional loading was tolerated without evidence of discomfort or progressive mobility. No patient reported persistent pain, masticatory difficulties, speech impairment, or esthetic dissatisfaction related to the treated tooth. Overall, the clinical findings indicated stable periodontal adaptation and favorable functional integration following intentional reimplantation.

Functional Stability

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Table 5. Clinical Findings During Follow-Up (n = 24)

Clinical Parameter	Number of Cases	Percentage
Grade 0 mobility	22	91.7%
Grade I mobility	2	8.3%
Grade II mobility	0	0%
Grade III mobility	0	0%
Healthygingival adaptation	24	100%
Bleeding on probing	0	0%
Suppuration	0	0%
Functional tooth retention	24	100%

3.3 Radiographic Findings

Radiographic assessment was performed using serial

periapical radiographs and cone-beam computed tomography when clinically indicated.

Radiographic evaluation demonstrated preservation of periodontal and alveolar structures in most cases. Favorable healing patterns were observed, including maintenance of periodontal ligament space continuity and stable surrounding bone architecture.

The majority of patients demonstrated a continuous periodontal ligament space and preservation of lamina dura integrity around the reimplanted roots. Alveolar bone levels remained stable, and no significant marginal bone loss was observed.

One patient (4.2%) demonstrated mild external root resorption. The defect remained superficial and non-progressive throughout the follow-up period and was not associated with clinical symptoms or functional impairment. No cases demonstrated moderate or severe inflammatory root resorption, replacement resorption, or circumferential resorption patterns.

Importantly, radiographic evidence of ankylosis was not identified in any patient.

Table 6. Radiographic Findings (n = 24)

Radiographic Finding	Numberof Cases	Percentage
Preservedperiodontal ligament space	23	95.8%
Intact lamina dura	23	95.8%
Stable alveolar bone levels	24	100%
Mild external root resorption	1	4.2%
Moderate or severe root resorption	0	0%
Radiographic ankylosis	0	0%

3.4 Postoperative Complications

Postoperative complications were limited and remained clinically manageable throughout the observation period. Most patients experienced uneventful healing without significant adverse events. Only two minor complications were identified during follow-up.

One patient demonstrated mild external root resorption, while one patient exhibited persistent Grade I mobility. Both findings remained stable and non-progressive throughout follow-up and did not compromise function or tooth retention.

No patient developed postoperative infection, suppuration, abscess formation, progressive root resorption, ankylosis, severe mobility, periodontal breakdown, or delayed tooth loss.

Importantly, none of the observed complications required extraction of the reimplanted tooth or additional corrective surgical intervention.

Table 7. Postoperative Complications (n = 24)

Complication	Number of Cases	Percentage
No complications	22	91.7%
Mild external root resorption	1	4.2%
Persistent Grade I mobility	1	4.2%
Infection	0	0%
Ankylosis	0	0%
Tooth loss	0	0%

3.5 Follow-Up Outcomes

The duration of follow-up ranged from the immediate postoperative period to a maximum of three years depending on patient availability and recall attendance. Throughout the observation period, all reimplanted canines remained retained within the dental arch and continued to function satisfactorily.

Clinical and radiographic follow-up examinations consistently demonstrated stable periodontal healing, preservation of supporting alveolar bone, favorable soft tissue adaptation, and maintenance of functional occlusal relationships. No delayed extractions, catastrophic failures, or progressive pathological changes were observed.

The biological response observed following intentional reimplantation was generally favorable and suggested successful periodontal adaptation under controlled surgical conditions.

Although longer follow-up periods remain necessary to evaluate the potential development of delayed complications such as ankylosis or replacement resorption, the present findings indicate that intentional reimplantation of impacted maxillary canines may provide predictable short- and intermediate-term outcomes when appropriate biological and surgical principles are carefully followed.

Table 8. Overall Follow-Up Outcomes (n = 24)

Outcome Parameter	Result
Total number of patients	24
Clinical success	22 (91.7%)
Partial clinical success	2 (8.3%)
Functional tooth retention	24 (100%)
Primary stability at reimplantation	24 (100%)
Infection	0 (0%)
Ankylosis	0 (0%)
Mild external root resorption	1 (4.2%)
Severe root resorption	0 (0%)
Tooth loss	0 (0%)

4. DISCUSSION

Intentional reimplantation is a biologically sensitive surgical procedure that depends primarily on preservation of periodontal ligament (PDL) vitality and minimization of mechanical trauma during tooth extraction, handling, and reinsertion [19,22,35]. Historically, the technique was regarded as a treatment of last resort because of concerns regarding ankylosis, inflammatory root resorption, and long-term instability. However, advances in atraumatic extraction techniques, microsurgical procedures, endodontic management, and understanding of periodontal wound healing have renewed interest in intentional reimplantation as a conservative tooth-preserving treatment option, particularly in situations where orthodontic traction is not feasible or is associated with a poor prognosis [20,23,25,37–40].

The present retrospective case series evaluated the clinical and radiographic outcomes of intentional reimplantation of impacted maxillary canines performed according to standardized biological and surgical protocols. Clinical success was achieved in 22 of 24 patients (91.7%), while all reimplanted canines remained functional and retained throughout follow-up, resulting in an overall tooth survival rate of 100%. These findings indicate that impacted maxillary canines can remain biologically stable and functionally integrated following intentional reimplantation when appropriate surgical principles are carefully respected.

One of the most important determinants of successful intentional reimplantation is preservation of viable periodontal ligament cells. Andreasen and Kristerson demonstrated that damage to the periodontal ligament during extraction or prolonged extraoral exposure significantly increases the risk of replacement resorption and ankylosis following replantation procedures[41]. Subsequent investigations have confirmed that periodontal ligament vitality directly influences cementum repair, periodontal regeneration, and re-establishment of functional attachment between the root surface and surrounding alveolar bone[42–44]. The periodontal ligament contains fibroblasts, progenitor cells, vascular structures, and collagen fibers that are essential for periodontal healing and long-term tooth stability.

For this reason, atraumatic extraction represented a critical component of the surgical protocol used in the present study. Excessive luxation forces, unnecessary manipulation of the root surface, curettage of the periodontal ligament, and desiccation were carefully avoided. Continuous hydration of the extracted tooth with sterile saline solution was maintained throughout the extraoral phase to preserve cellular viability and reduce the risk of postoperative complications. Similar recommendations have been emphasized in studies evaluating tooth autotransplantation, traumatic tooth avulsion, and intentional reimplantation procedures [26,29,45,46].

Another important prognostic factor is minimization of extraoral time. Experimental and clinical studies have demonstrated that prolonged extraoral exposure markedly decreases survival of periodontal ligament cells and increases the likelihood of inflammatory and replacement root resorption [28,33,47–49]. Consequently, all surgical and endodontic procedures in the present series were organized to minimize extraoral manipulation and facilitate immediate reinsertion of the tooth following completion of root canal treatment and recipient site preparation. Maintenance of root surface hydration combined with reduction of extraoral time likely contributed to the favorable healing outcomes observed in this study.

The role of endodontic management in intentional reimplantation remains an important clinical consideration. In teeth with complete root development and closed apices, pulpal revascularization is unlikely following reimplantation, making root canal treatment necessary to prevent pulpal necrosis and inflammatory complications [20,50,51]. In the present series, extraoral root canal treatment was performed under sterile conditions before reinsertion whenever indicated. This approach allowed elimination of potential endodontic infection while avoiding the need for additional postoperative intervention. No cases of postoperative infection, periapical pathology, or inflammatory complications were identified during follow-up.

Semi-rigid splinting was used in all patients to provide stabilization during the initial healing period while

permitting limited physiological movement. Previous studies have suggested that rigid fixation may increase the risk of ankylosis because functional stimulation of the periodontal ligament is reduced [52,53]. In contrast, semi-rigid stabilization appears to support periodontal healing and regeneration while maintaining adequate tooth stability. Splints were maintained for approximately two to four weeks depending on the degree of primary stability and clinical healing. No clinical or radiographic evidence of ankylosis was detected during follow-up, which may be related to the stabilization protocol employed.

Radiographic outcomes were generally favorable. Preservation of periodontal ligament space and lamina dura continuity was observed in most cases, suggesting maintenance of periodontal attachment and successful alveolar bone healing. Stable alveolar bone support was evident throughout the observation period. Only one patient demonstrated mild external root resorption, which remained superficial and non-progressive without clinical symptoms or functional impairment. Importantly, no cases of severe inflammatory root resorption, replacement resorption, or radiographic ankylosis were identified. These findings support previous observations indicating that careful preservation of periodontal ligament vitality and atraumatic handling significantly reduce the incidence of postoperative complications [19,20,30,31].

The clinical outcomes reported in the present study compare favorably with findings from previous investigations involving intentional reimplantation and tooth autotransplantation. Mainkar reported high survival rates for teeth treated using contemporary intentional replantation protocols [25]. Similarly, Jang et al. demonstrated favorable long-term outcomes for intentionally replanted teeth followed for up to eleven years, with survival rates exceeding 90% [32]. Long-term investigations by Czochrowska and colleagues reported survival rates ranging from approximately 79% to 90% for transplanted teeth when atraumatic surgical techniques and appropriate case selection were applied [40,54]. The 91.7% clinical success rate and 100% tooth survival observed in the present study therefore fall within the upper range of previously reported outcomes and further support the effectiveness of intentional reimplantation when modern biological principles are strictly followed.

A notable strength and novel aspect of the present investigation is its specific focus on impacted maxillary canines. Most published studies evaluating intentional reimplantation have primarily involved teeth with endodontic pathology, periodontal involvement, root fractures, or complex root anatomy. In contrast, evidence regarding intentional reimplantation of impacted maxillary canines remains limited and is largely restricted to isolated case reports and small case series [20,22,23,25]. The present study contributes additional clinical and radiographic evidence from a cohort of 24 patients treated using a standardized surgical and endodontic protocol with follow-up extending up to five years. To the authors' knowledge, few studies have reported outcomes for a comparable number of intentionally reimplanted impacted maxillary canines using a uniform treatment approach. These findings therefore provide meaningful clinical data supporting intentional reimplantation as a potential treatment option in selected impacted canine cases with an unfavorable orthodontic prognosis.

Intentional reimplantation should be considered within the broader context of available treatment options for impacted maxillary canines. Surgical exposure followed by orthodontic traction remains the preferred treatment approach because it preserves the natural periodontal attachment and facilitates eruption of the impacted tooth into the dental arch [14,15,56,57]. Nevertheless, orthodontic treatment may be contraindicated or associated with poor prognosis in cases involving severe displacement, excessive angulation, ankylosis, root dilaceration, proximity to adjacent roots, or anticipated prolonged treatment duration[16–18]. In such situations, intentional reimplantation may provide a valuable alternative that allows preservation of the natural tooth while avoiding extraction and prosthetic replacement.

Compared with extraction followed by implant placement or fixed prosthetic rehabilitation, intentional reimplantation offers several biological advantages. Preservation of the patient's own tooth contributes to maintenance of alveolar bone volume, periodontal proprioception, gingival architecture, and esthetic integration [29,34,40]. These advantages are particularly relevant in adolescent and young adult patients, where implant placement may be complicated by ongoing skeletal growth and long-term esthetic concerns. Maintenance of the natural canine may therefore represent a desirable treatment objective whenever feasible.

Despite the encouraging findings, several limitations of the present study should be acknowledged. The retrospective design inherently limits control over patient selection, treatment standardization, and follow-up consistency. The sample size was relatively small, reducing statistical power and limiting generalizability of the results. Variability in impaction depth, angulation, root morphology, and follow-up duration may also have influenced treatment outcomes. In

addition, standardized patient-reported outcome measures and detailed periodontal indices were not available for all cases.

Another limitation relates to follow-up duration. Although some patients were monitored for up to five years, longer observation periods remain necessary to evaluate late complications such as ankylosis, replacement resorption, and progressive periodontal breakdown, which may develop several years after treatment[28,55]. Future prospective multicenter investigations involving larger patient populations and standardized protocols are required to identify prognostic variables associated with treatment success and to further clarify long-term predictability.

From a clinical perspective, the present findings suggest that intentional reimplantation may serve as a useful adjunctive or salvage procedure in carefully selected patients with impacted maxillary canines that are unsuitable for orthodontic traction. Successful outcomes require comprehensive treatment planning and close collaboration among oral surgeons, endodontists, orthodontists, and restorative clinicians. Thorough radiographic evaluation using CBCT, careful surgical planning, preservation of periodontal ligament vitality, minimization of extraoral time, appropriate endodontic management, and physiologic splinting appear to be fundamental factors contributing to favorable healing and long-term tooth retention.

DECLARATIONS

Conflict of Interest

The author declare no conflict of interest.

Funding

No external funding was received for this study.

Ethical Approval

The study was conducted in accordance with the principles of the Declaration of Helsinki for research involving human subjects.

Written informed consent for treatment and the use of anonymized clinical and radiographic data for scientific publication was obtained from all patients or their legal guardians.

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