ISSN Print: 2394-7489
ISSN Online: 2394-7497
Impact Factor (RJIF): 7.85
IJADS 2025; 11(4): 18-22

www.oraljournal.com
Received: 13-11-2025
Accepted: 18-12-2025

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Endodontic management of mature vs immature necrotic teeth: A comparative clinical study

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DOI: https://www.doi.org/10.22271/oral.2026.v12.i1a.2319

Abstract
Background: Management of necrotic teeth differs substantially between mature and immature permanent teeth due to variations in root development, apical anatomy, and biological healing potential. Immature necrotic teeth present unique challenges, including open apices and thin dentinal walls, which limit conventional obturation techniques and increase fracture risk. Contemporary approaches such as apexification and regenerative endodontic procedures (REPs) have expanded treatment options.
Objective: To compare clinical and radiographic outcomes of endodontic management in mature versus immature necrotic permanent teeth in a study population of 100 patients.
Methods: A prospective comparative clinical study was conducted on 100 necrotic permanent teeth treated in a Department of Conservative Dentistry, Sher-E-Bangla Medical College Hospital, Barishal, Bangladesh from January 2024 to June 2025 over a period of 18 months. Fifty teeth with complete root formation (mature group) and fifty teeth with incomplete root formation (immature group) were included. Mature teeth were managed with conventional root canal therapy (RCT), while immature teeth were treated using apexification with calcium hydroxide or mineral trioxide aggregate (MTA), or regenerative endodontic procedures where indicated. Patients were followed for 12 months. Outcomes assessed included pain resolution, periapical healing, root development, apical closure, and complications.
Results: At 12 months, clinical success was achieved in 92% of mature teeth and 88% of immature teeth. Radiographic periapical healing was observed in 90% of mature teeth compared to 84% of immature teeth. In the immature group, apexification resulted in apical barrier formation in 82% of cases, while regenerative procedures showed continued root development in 76% of cases. Complication rates were higher in immature teeth, primarily due to cervical root fractures and delayed healing.
Conclusion: Both mature and immature necrotic teeth can be successfully managed with appropriate endodontic protocols. Conventional RCT remains highly predictable for mature teeth, whereas biologically based approaches such as apexification and regenerative endodontics offer favorable outcomes for immature teeth. Case selection and adherence to contemporary guidelines are critical for optimal results.

Keywords: Necrotic Teeth, Mature Teeth, Immature Teeth, Apexification, Regenerative Endodontics, Root Canal Therapy.

Introduction
Pulp necrosis of permanent teeth is a common clinical condition arising primarily from dental caries, traumatic injuries, and developmental anomalies. If left untreated, necrotic pulp tissue allows microbial colonization of the root canal system, leading to apical periodontitis and progressive periapical bone destruction [1]. The principal objective of endodontic therapy is to eradicate intracanal infection, prevent reinfection, and promote healing of periradicular tissues [2]. The stage of root development plays a critical role in determining both the complexity of endodontic treatment and the expected prognosis. Mature permanent teeth are characterized by complete root formation with a narrow apical constriction, which facilitates effective chemomechanical preparation and three-dimensional obturation [3]. Conventional root canal therapy in such teeth has consistently demonstrated high long-term success rates when performed according to established protocols [4].

In contrast, immature permanent teeth with necrotic pulps present unique biological and technical challenges. These teeth typically exhibit open apices, thin dentinal walls, and short root length, making apical control during instrumentation and obturation difficult and increasing the risk of root fracture [5]. Historically, apexification using long-term calcium hydroxide dressing was the standard treatment approach for such cases. Although effective in inducing apical barrier formation, prolonged exposure to calcium hydroxide has been associated with increased dentin brittleness and a higher incidence of cervical root fractures [6].

The introduction of mineral trioxide aggregate (MTA) has significantly improved the management of immature necrotic teeth by enabling single-visit apexification with predictable apical barrier formation and superior biocompatibility [7]. More recently, regenerative endodontic procedures (REPs) have emerged as a biologically based alternative, aiming to restore functional pulp tissue, promote continued root development, and strengthen dentinal walls [8]. These procedures rely on stem cells from the apical papilla, growth factors, and a suitable scaffold to achieve tissue regeneration [9].

Despite advancements in materials and techniques, comparative clinical evidence evaluating outcomes between mature and immature necrotic teeth remains limited, particularly in developing countries. A direct comparison of treatment outcomes is essential to guide evidence-based clinical decision-making. Therefore, the present study was designed to compare the clinical and radiographic outcomes of endodontic management in mature versus immature necrotic permanent teeth in a study population of 100 cases.

Materials and Methods

Study Design and Setting

This prospective comparative clinical study was conducted in the Department of Conservative Dentistry, Sher-E-Bangla Medical College Hospital, Barishal, Bangladesh from January 2024 to June 2025 over a period of 18 months.

Study Population

A total of 100 patients with necrotic permanent teeth requiring endodontic treatment were enrolled.

- **Group I (Mature teeth):** 50 necrotic permanent teeth with complete root formation and closed apices.
- **Group II (Immature teeth):** 50 necrotic permanent teeth with incomplete root formation and open apices.

Inclusion Criteria

- Patients aged 8–45 years.
- Permanent teeth diagnosed with pulp necrosis based on clinical and radiographic findings.
- Presence of periapical radiolucency or clinical symptoms indicative of apical periodontitis.
- Patient consent and willingness to attend follow-up visits.

Exclusion Criteria

- Teeth with vertical root fractures.
- Non-restorable teeth.
- Patients with systemic conditions affecting healing (e.g., uncontrolled diabetes, immunocompromised states).
- Previously endodontically treated teeth.

Diagnostic Criteria

Pulp necrosis was diagnosed using a combination of negative pulp vitality tests (cold and electric pulp testing), clinical signs (discoloration, sinus tract, tenderness), and radiographic evidence of periapical pathology.

Treatment Protocols

Group I: Mature Necrotic Teeth

- Local anesthesia and rubber dam isolation.
- Access cavity preparation.
- Working length determination using apex locator and radiographs.
- Chemomechanical preparation using rotary NiTi instruments.
- Irrigation with 2.5–5.25% sodium hypochlorite and 17% EDTA.
- Intracanal medication with calcium hydroxide when required.
- Obturation using gutta-percha and resin-based sealer by lateral or warm vertical compaction.
- Permanent coronal restoration.

Group II: Immature Necrotic Teeth

Treatment approach was selected based on root development stage and clinical considerations:

1. **Calcium Hydroxide Apexification**
- Minimal mechanical instrumentation.
- Copious irrigation with low-concentration sodium hypochlorite.
- Placement of calcium hydroxide paste as intracanal medicament, replaced at 3-month intervals until apical barrier formation.

2. **MTA Apexification**
- Canal disinfection followed by placement of an MTA apical plug (3–5 mm).
- Subsequent obturation of the remaining canal space.

3. **Regenerative Endodontic Procedures (REPs)**
- Gentle canal disinfection.
- Placement of intracanal antibiotic paste.
- Induction of apical bleeding to form a scaffold.
- Placement of bioceramic material over the blood clot and coronal seal.

Outcome Assessment

Patients were evaluated clinically and radiographically at 3, 6, and 12 months.

Primary outcomes: Resolution of pain and clinical symptoms. - Absence of sinus tract or swelling.

Secondary outcomes: Radiographic evidence of periapical healing. - Apical barrier formation (apexification). - Continued root development (REPs). - Complications such as root fracture or reinfection.

Statistical Analysis

Data were analyzed using statistical software SPSS v25. Descriptive statistics were used for demographic variables. Chi-square test was applied to compare success rates between groups, with a significance level set at $p < 0.05$.

Results

A total of 100 patients with necrotic permanent teeth were included in the study, equally divided into mature teeth (n = 50) and immature teeth (n = 50). The results are summarized in Tables 1–6 and are described in detail below.

Demographic Characteristics (Table 1)

The study population demonstrated a clear age-related distinction between the two groups. Patients with mature teeth were predominantly adults, with a mean age of 28.6 ± 7.4 years and an age range of 18–45 years. In contrast, the immature teeth group consisted mainly of children and adolescents, with a mean age of 13.2 ± 3.1 years and an age range of 8–18 years.

Male patients slightly outnumbered females in both groups, accounting for 60% of cases in the mature teeth group and 64% in the immature teeth group, resulting in an overall male predominance of 62%.

Regarding etiology, dental caries was the principal cause of pulp necrosis in mature teeth, observed in 76% of cases, whereas trauma was the leading etiology in immature teeth, accounting for 72% of cases. Overall, caries and trauma contributed almost equally to pulp necrosis in the total study population (52% and 48%, respectively).

Clinical Outcomes at 12-Month Follow-up (Table 2)

At the 12-month evaluation, both groups exhibited high rates of favorable clinical outcomes. In the mature teeth group, 92% of patients were pain-free, 94% showed absence of sinus tract, and 90% demonstrated no tenderness to percussion. These findings resulted in an overall clinical success rate of 92%.

Similarly, the immature teeth group showed satisfactory outcomes, with 88% of patients pain-free, 90% without sinus tract, and 86% without tenderness to percussion, yielding an overall clinical success rate of 88%. Although the mature teeth group demonstrated marginally higher success rates across all parameters, the differences between the two groups were not statistically significant.

Radiographic Outcomes at 12 Months (Table 3)

Radiographic evaluation revealed favorable periapical healing in both groups. In the mature teeth group, complete periapical healing was observed in 70% of cases, partial healing in 20%, and no healing in 10%. This corresponded to an overall radiographic success rate of 90%.

In the immature teeth group, complete healing was noted in 60% of cases, partial healing in 24%, and no healing in 16%, resulting in an overall radiographic success rate of 84%. Immature teeth showed a slightly higher proportion of delayed or incomplete healing, which may be attributed to open apices, thinner dentinal walls, and reduced structural integrity.

Treatment Modalities and Outcomes in Immature Teeth (Table 4)

Different treatment modalities were employed for immature necrotic teeth based on clinical and radiographic considerations. Calcium hydroxide apexification was performed in 22 teeth, achieving a success rate of 82%. MTA apexification was used in 18 teeth and demonstrated the highest success rate at 90%. Regenerative endodontic procedures were applied in 10 teeth, with a success rate of 76%.

Overall, MTA apexification emerged as the most predictable treatment option in terms of clinical and radiographic success, while regenerative procedures showed promising results, particularly with respect to biological healing.

Root Development and Apical Response in Immature Teeth (Table 5)

Assessment of root maturation parameters in immature teeth revealed successful apical barrier formation in 82% of cases. An increase in root length was observed in 38% of teeth, while increased dentinal wall thickness was noted in 34%. No significant root development was detected in 18% of cases.

Notably, teeth treated with regenerative endodontic procedures accounted for the majority of cases showing continued root development, highlighting the potential of these techniques to promote true biological healing beyond mere apical closure.

Complications During Follow-up (Table 6)

Complications were more frequently observed in the immature teeth group compared to the mature teeth group. In mature teeth, the total complication rate was 10%, consisting mainly of persistent infection (6%) and reinfection (4%). No cervical root fractures were observed in this group.

In contrast, the immature teeth group exhibited a higher overall complication rate of 20%. Cervical root fractures were observed exclusively in this group (6%), reflecting the vulnerability associated with thin dentinal walls and incomplete root development. Persistent infection (8%) and reinfection (6%) were also slightly more common in immature teeth.

Table 1: Demographic Characteristics of the Study Population (n = 100)

Variable	Mature Teeth (n=50)	Immature Teeth (n=50)	Total
Mean age (years)	28.6 ± 7.4	13.2 ± 3.1	—
Age range (years)	18–45	8–18	—
Male	30 (60%)	32 (64%)	62 (62%)
Female	20 (40%)	18 (36%)	38 (38%)
Primary etiology – caries	38 (76%)	14 (28%)	52 (52%)
Primary etiology – trauma	12 (24%)	36 (72%)	48 (48%)

Table 2: Clinical Outcomes at 12-Month Follow-up

Clinical outcome	Mature Teeth (n=50)	Immature Teeth (n=50)
Pain-free	46 (92%)	44 (88%)
Absence of sinus tract	47 (94%)	45 (90%)
No tenderness to percussion	45 (90%)	43 (86%)
Overall clinical success	46 (92%)	44 (88%)

Table 3: Radiographic Outcomes at 12 Months

Radiographic finding	Mature Teeth (n=50)	Immature Teeth (n=50)
Complete periapical healing	35 (70%)	30 (60%)
Partial healing	10 (20%)	12 (24%)
No healing	5 (10%)	8 (16%)
Overall radiographic success	45 (90%)	42 (84%)

Table 4: Treatment Modalities and Outcomes in Immature Necrotic Teeth (n = 50)

Treatment modality	Number of teeth	Success rate
Calcium hydroxide apexification	22	18 (82%)
MTA apexification	18	16 (90%)
Regenerative endodontic procedures	10	8 (76%)

Table 5: Root Development and Apical Response in Immature Teeth

Parameter	Observed cases (n=50)
Apical barrier formation	41 (82%)
Increase in root length	19 (38%)
Increase in dentinal wall thickness	17 (34%)
No significant root change	9 (18%)

Table 6: Complications Observed During Follow-up

Complication	Mature Teeth (n=50)	Immature Teeth (n=50)
Cervical root fracture	0	3 (6%)
Persistent infection	3 (6%)	4 (8%)
Reinfection	2 (4%)	3 (6%)
Total complication rate	5 (10%)	10 (20%)

Discussion

The present study evaluated and compared the clinical and radiographic outcomes of endodontic treatment in mature and immature necrotic permanent teeth, with particular emphasis on healing patterns, treatment modalities, and associated complications. Overall, both groups demonstrated high success rates at the 12-month follow-up, confirming that contemporary endodontic approaches can effectively manage pulp necrosis irrespective of root maturity. However, notable differences were observed in etiology, healing dynamics, and complication profiles between mature and immature teeth.

In mature teeth, dental caries was the predominant etiological factor, consistent with previous reports identifying caries as the leading cause of pulp necrosis in adults [7]. The high clinical success rate (92%) observed in this group aligns with established literature demonstrating predictable outcomes of conventional root canal therapy in teeth with closed apices and well-defined canal anatomy [8]. The relatively higher rate of complete periapical healing in mature teeth may be attributed to favorable apical constriction, improved disinfection, and more predictable obturation, all of which contribute to optimal periapical repair [9].

In contrast, immature necrotic teeth were predominantly affected by traumatic dental injuries, a finding that corroborates earlier studies highlighting trauma as the principal cause of pulp necrosis in children and adolescents [10]. The slightly lower clinical and radiographic success rates in immature teeth reflect the inherent challenges associated with open apices, thin dentinal walls, and compromised structural strength. These anatomical limitations can impede effective canal disinfection and obturation, thereby delaying or compromising periapical healing [11].

Among treatment modalities used for immature teeth, MTA apexification demonstrated the highest success rate. This finding supports existing evidence that MTA provides superior sealing ability, biocompatibility, and induction of hard tissue barrier formation when compared with traditional calcium hydroxide apexification [12]. Although calcium hydroxide apexification also yielded satisfactory results, its prolonged treatment duration and potential to weaken dentinal walls may explain the higher incidence of cervical root fractures observed in immature teeth [13].

Regenerative endodontic procedures showed encouraging outcomes, particularly with respect to continued root development, increased dentinal wall thickness, and apical closure. These findings are consistent with growing evidence that regenerative techniques can promote biologically based healing and improve the long-term prognosis of immature necrotic teeth by reinforcing root structure [14]. However, the slightly lower overall success rate observed in this subgroup suggests that outcomes may be influenced by case selection, degree of infection control, and patient-related factors.

The higher complication rate in immature teeth, especially cervical root fractures, underscores the vulnerability of teeth with incomplete root development. Previous studies have reported similar findings, emphasizing the need for cautious case management and long-term follow-up in this population [15]. Persistent infection and reinfection in both groups highlight the critical role of effective canal disinfection and coronal seal in ensuring sustained treatment success [16].

In summary, while both mature and immature necrotic permanent teeth can be treated successfully with modern endodontic techniques, immature teeth present unique biological and structural challenges. Selection of appropriate treatment modality, particularly the use of MTA apexification or regenerative approaches when indicated, is crucial for optimizing outcomes and minimizing complications.

Limitations of this study include its single-center design and relatively short follow-up period. Long-term multicenter studies with standardized regenerative protocols are needed to further validate these findings and establish definitive clinical guidelines.

Conclusion

Endodontic treatment of necrotic permanent teeth yields high clinical and radiographic success in both mature and immature teeth. Mature teeth respond predictably to conventional root canal therapy, while immature teeth benefit from apexification and regenerative endodontic approaches. Regenerative procedures, in particular, offer the added advantage of continued root development. Clinicians should tailor treatment strategies based on root maturity, patient age, and available resources.

Limitations

- Single-center study.
- Relatively short follow-up period.
- Limited sample size for subgroup analysis of regenerative procedures.

Recommendations

Long-term multicenter studies with larger samples are recommended to further evaluate regenerative endodontic outcomes and establish standardized treatment protocols.

Acknowledgement

Not available

Author's Contribution

Not available

Conflict of Interest

Not available

Financial Support

Not available

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How to Cite This Article
Tanvirul Islam Wali, Md. Sharif Hossein, Khadiza Naznin, Mehnaj Sharmin Mouri and Mohammad Abu Hussain. Endodontic management of mature vs immature necrotic teeth: A comparative clinical study**.** International Journal of Applied Dental Sciences. 2025; 11(4): 18-22.