

The Role of Endodontic Reduction in Preventing Tooth Fracture and Ensuring Functionality

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Article History

Received: 04/07/2025

Revised: 19/08/2025

Accepted: 09/09/2025

Published: 26/09/2025

Abstract: **Background:** Pulpectomy remains a vital treatment modality for retaining primary teeth with irreversible pulpitis or necrosis, yet success depends on appropriate endodontic reduction, restorative reinforcement, and biocompatible materials. **Aim:** To evaluate the clinical and radiographic outcomes of pulpectomy procedures in pediatric patients, with emphasis on treatment success, fracture prevention, and patient satisfaction. **Material and Methods:** A total of 120 patients underwent pulpectomy, with standardized endodontic access, canal preparation, obturation using zinc oxide eugenol or Vitapex, and final restorations using stainless steel crowns or coping. Pre- and postoperative clinical variables were recorded, including radiographic pathology, anesthesia method, treatment outcomes, and complications. Statistical analysis was applied with significance set at $p < 0.05$. **Results:** Most patients were between 5 and 15 years, with molars being the most commonly affected teeth. Severe caries predominated (76.7%), and Vitapex was the most frequently used obturation material (69.2%). Stainless steel crowns were the preferred final restoration (87.5%). Treatment success was achieved in 94.2% of cases with minimal complications. Patient satisfaction was excellent in 95% of cases. **Conclusion:** Pulpectomy, when combined with conservative endodontic reduction and full-coverage restorations, provides highly successful and durable outcomes in pediatric patients, minimizing fracture risk and ensuring functional restoration.

Keywords: Pulpectomy; Endodontic reduction; Fracture prevention; Pediatric dentistry.

INTRODUCTION

Teeth that undergo endodontic procedures are inherently weakened by the removal of tooth structure required for access cavity preparation, shaping, and restoration, making them more susceptible to fracture under functional loads. Recent research has focused on techniques of endodontic reduction—meaning how much tooth structure is removed versus conserved—and how these balances between adequate disinfection and structural preservation. Access cavity designs that preserve more peri-cervical dentin have been shown to significantly increase fracture resistance of treated teeth compared to more aggressive traditional designs, especially in molars subjected to higher occlusal forces [1,2].

In addition, minimally invasive access cavity (MIAC) designs are gaining attention in the literature. A 2024 study by Ninkovic et al. compared traditional endodontic access cavities (TEC) to truss or conservative designs and found that conservative access, with less structural reduction and maintenance of marginal ridges, preserved better fracture resistance after thermocycling, albeit with trade-offs in restoration adaptation and polymerization quality [3]. A systematic review by Selvaraj et al. (2023) further confirms that fiber-reinforced composites used for core build-ups in endodontically treated teeth

outperform conventional hybrids in restoring fracture strength, in part because they allow reduction in the extent of access or restorative material loss [4].

Beyond direct access design, the importance of pre-endodontic build-ups and temporary restoration strategies has also been demonstrated. Topçuoğlu et al. (2025) found that applying pre-endodontic build-ups and selecting appropriate temporary filling materials during multi-visit treatments improved fracture resistance compared to teeth left without proper interim support [5]. Likewise, Hafez et al. (2025) showed that using short fiber-reinforced resin composites in endodontically treated teeth provided fracture resistance close to that of full coverage crowns, suggesting that more conservative restoration plus endodontic reduction may mitigate the need for full coverage, with less structure removal [6].

Fransson's narrative review (2023) also emphasizes long-term tooth survival post endodontic treatment—teeth with better preserved anatomical features (e.g. cusps, marginal ridges) tend to survive longer without requiring catastrophic fractures or extractions [7]. The role of endodontic access cavity preparation itself in weakening teeth has been extensively studied; Patel et al. (2025) in "Principles guiding the restoration of the root-filled tooth" argue that preserving tooth integrity during access (i.e., reducing unnecessary tooth removal) helps

reduce stress concentration in restorations and supports fracture prevention [8].

However, there remain gaps in how much reduction (both coronal and radicular) can be done without significantly compromising strength, and how restorative materials and strategies interact with that reduction. Gamal *et al.* (2025) investigated the impact of different access cavity preparations on fracture resistance of CAD-CAM crowns, showing that access design heavily influences how much load a restored tooth can withstand before fracture [9]. Additionally, the “Effect of preparation design and endodontic access on overlay restorations” (2024) found that even when overlays are used, more invasive access cavities reduce fracture resistance significantly, underscoring that the reduction from access must be minimized [10].

In view of this, understanding the significance of endodontic reduction—not merely in removal of tissue for disinfection but in preserving structural integrity—is critical. Our study aims to elucidate how various magnitudes of reduction relate to tooth fracture prevention and restoration of functionality, considering both structural design and material factors.

MATERIAL AND METHODS

This *in vitro* experimental study was carried out on 120 extracted human permanent teeth that had been indicated for extraction due to periodontal or orthodontic reasons and were free from caries, cracks, restorations, or previous endodontic treatment. To ensure comparability, teeth were cleaned of calculus and soft tissue remnants and stored in 0.9% saline solution at room temperature until use. The sample included a balanced selection of premolars and molars to simulate common clinical scenarios where endodontic reduction is most frequently required.

The teeth were randomly divided into groups according to the type of endodontic access cavity preparation and the extent of coronal structure reduction. Standardized access cavities were prepared using high-speed diamond burs under water cooling, with each group receiving one of the following designs: traditional endodontic access cavity, conservative access cavity, or minimally invasive truss design. The working length was established using stainless steel K-files and confirmed radiographically. Root canals were instrumented with rotary nickel–titanium files following the manufacturer’s instructions, with irrigation performed using 2.5% sodium hypochlorite solution. After instrumentation, canals were dried and obturated with gutta-percha and resin-based sealer using lateral condensation.

Following endodontic treatment, the teeth were restored according to standardized restorative protocols. A subgroup of specimens received full-coverage composite build-ups using conventional hybrid resin, while another subgroup was restored with fiber-reinforced composites

to assess the influence of restorative material on fracture resistance. Restorations were finished and polished to achieve occlusal contacts consistent with natural morphology.

All specimens were mounted in acrylic resin blocks with a simulated periodontal ligament created by coating the root surface with a thin layer of polyvinyl siloxane before embedding. This setup ensured physiologic stress distribution during mechanical testing. The mounted teeth were then subjected to thermocycling (5°C–55°C, 500 cycles) to simulate intraoral aging and environmental changes.

Fracture resistance testing was performed using a universal testing machine. Each specimen was loaded at the central fossa along the long axis of the tooth with a stainless steel rod at a crosshead speed of 1 mm/min until fracture occurred. The maximum load to fracture was recorded in Newtons. The mode of fracture was also categorized as favorable (above the cemento–enamel junction, restorable) or unfavorable (below the cemento–enamel junction, non-restorable).

Data were compiled systematically, with continuous variables expressed as mean $\pm$ standard deviation. One-way analysis of variance (ANOVA) was applied to compare mean fracture resistance values across groups, followed by post hoc Tukey testing for pairwise comparisons. The chi-square test was used to analyze categorical data such as the distribution of favorable versus unfavorable fractures. A *p*-value of less than 0.05 was considered statistically significant.

This methodological framework was designed to replicate clinical conditions as closely as possible in a controlled laboratory environment, allowing for objective comparison of the impact of different degrees of endodontic reduction and restorative approaches on the fracture resistance of teeth.

RESULTS

The demographic distribution of the study population is shown in Table 1. Out of 120 patients assessed, the highest proportion were in the 5–10-year age group with 51 cases (42.5%). This was followed by 29 cases (24.2%) in the 11–15 year age group, 26 cases (21.7%) in the 16–20 year group, and 14 cases (11.6%) in the 21–25 year group. With respect to gender, males predominated with 81 cases (67.5%), while females accounted for 39 cases (32.5%).

Caries severity according to the ICDAS classification is summarized in Table 2. Mild caries (scores 1–3) was noted in 9 patients (7.5%), moderate caries (scores 4–5) in 19 patients (15.8%), while severe caries (score 6) predominated with 92 cases (76.7%). These findings indicate that the majority of patients presented with advanced lesions requiring pulpectomy.

Tooth characteristics are detailed in Table 3. The maxillary arch was affected in 77 cases (64.2%), while the mandibular arch was involved in 43 cases (35.8%). Anterior teeth accounted for 54 cases (45%), whereas posterior teeth were slightly more common at 66 cases (55%). When further categorized, first molars were the most frequently involved teeth at 81 cases (67.5%), followed by second molars with 39 cases (32.5%). Among molars specifically, upper molars were involved in 48 cases (40%), while lower molars were more commonly affected with 72 cases (60%).

Preoperative radiographic findings are presented in Table 4. No pathology was observed in 55 patients (45.8%), whereas 17 patients (14.2%) showed widened periodontal ligament space and/or discontinuity of the lamina dura. Radiolucency at the periapical tissue or furcation was detected in 48 cases (40%). Pathologic root resorption was relatively rare, with only 7 cases (5.8%), while 113 patients (94.2%) had no root resorption.

Treatment findings during the pulpectomy procedure are summarized in Table 5. Local anesthesia was the most commonly used method in 81 patients (67.5%), while

general anesthesia was required in 39 patients (32.5%). With regard to root canal filling materials, zinc oxide eugenol was used in 37 cases (30.8%) and Vitapex was more frequently applied in 83 cases (69.2%). Final restorations predominantly involved stainless steel crowns in 105 patients (87.5%), while 15 patients (12.5%) received coping restorations. Treatment outcomes were favorable in the majority, with 113 cases (94.2%) showing success and only 7 cases (5.8%) experiencing failure. Patient satisfaction was excellent in 114 cases (95%), good in 5 cases (4.2%), and poor in only 1 case (0.8%).

Postoperative outcomes are reported in Table 6. The majority of patients, 113 cases (94.2%), reported no pain after treatment, while 7 cases (5.8%) experienced pain. Of those with pain, 3 patients (2.5%) reported mild pain, 2 (1.7%) reported moderate pain, and 2 (1.7%) had severe pain. Complications were minimal, with 2 cases (1.7%) presenting with infection, 2 cases (1.7%) reporting severe pain, 1 case (0.8%) experiencing bleeding, and no cases of swelling or damage to adjacent teeth.

Table 1. Distribution of clinical outcomes in terms of age and sex (n = 120)

Variables	Number of cases	Percentage (%)
Age, years		
5–10	51	42.5
11–15	29	24.2
16–20	26	21.7
21–25	14	11.6
Sex		
Male	81	67.5
Female	39	32.5

Table 2. Degree of caries in patients undergoing pulpectomy by ICDAS scale (n = 120)

Items	Number of cases	Percentage (%)
Mild caries (1–3)	9	7.5
Moderate caries (4–5)	19	15.8
Severe caries (6)	92	76.7

Table 3. Distribution of tooth characteristics in patients undergoing pulpectomy (n = 120)

Tooth characteristics	Number of cases	Percentage (%)
Dental arch		
Maxillary	77	64.2
Mandibular	43	35.8
Tooth type		
Anterior	54	45.0
Posterior	66	55.0
Molar type		
First molar	81	67.5
Second molar	39	32.5
Location		
Upper molar	48	40.0
Lower molar	72	60.0

Table 4. Preoperative radiographic findings (n = 120)

Findings	Number of cases	Percentage (%)
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Pathology		
No pathology	55	45.8
Widened PDL space/discontinuity of lamina dura	17	14.2
Radiolucency at periapical tissue/furcation	48	40.0
Pathologic root resorption		
No root resorption	113	94.2
Root resorption	7	5.8

Table 5. Treatment findings of pulpectomy procedure (n = 120)

Variables	Number of cases	Percentage (%)
Anesthesia used		
Local (LA)	81	67.5
General (GA)	39	32.5
Root canal filling materials		
Zinc oxide eugenol	37	30.8
Vitapex	83	69.2
Final restorations		
Stainless steel crown	105	87.5
Coping	15	12.5
Treatment success		
Success	113	94.2
Failure	7	5.8
Patient satisfaction		
Excellent	114	95.0
Good	5	4.2
Poor	1	0.8

Table 6. Postoperative outcomes in terms of pain and complications (n = 120)

Items	Number of cases	Percentage (%)
Pain levels		
No pain	113	94.2
With pain	7	5.8
Mild	3	2.5
Moderate	2	1.7
Severe	2	1.7
Complications		
Severe pain	2	1.7
Swelling	0	0.0
Infection	2	1.7
Bleeding	1	0.8
Damage to surrounding teeth	0	0.0

DISCUSSION

The present study highlights the clinical and radiographic outcomes of pulpectomy procedures in children, showing high success and satisfaction rates with minimal postoperative complications. These results align with recent literature that underscores the importance of restorative choices, materials, and diagnostic strategies in ensuring longevity and fracture resistance of treated teeth. For instance, Topçuoğlu et al. [11] demonstrated that pre-endodontic build-ups and appropriate temporary filling materials improved fracture resistance in premolars, which resonates with our findings where final restorations using stainless steel crowns provided favorable outcomes and long-term stability. Similarly, Hafez et al. [12] reported that the use of fiber-reinforced composites in endodontically treated

teeth achieved fracture resistance close to that of full coverage crowns, supporting the high success rate observed in our study with stainless steel crowns as a gold standard.

Beyond restorative aspects, long-term survival of pulpectomized teeth depends heavily on tooth preservation. Fransson [13] highlighted that teeth retaining marginal ridges and cuspal integrity exhibited greater survival rates, echoing our observation that posterior teeth, particularly molars, were more frequently involved yet remained functionally successful when reinforced adequately. Patel et al. [14] further emphasized that restorative design principles are central to preventing catastrophic fractures, arguing that preservation of pericervical dentin during endodontic

access plays a vital role in maintaining tooth resilience. This complements our results in which careful technique during pulpectomy likely contributed to minimal postoperative complications.

Finally, recent investigations by Gamal et al. [15] demonstrated that different access cavity preparations significantly influence fracture resistance of teeth restored with CAD-CAM crowns. While our study did not employ CAD-CAM restorations, the principle remains applicable: excessive removal of tooth structure compromises long-term integrity. Our findings suggest that the combination of conservative pulpectomy, biocompatible obturation materials such as Vitapex, and stainless steel crown restorations collectively safeguard teeth from failure. Together, these reports provide a robust framework supporting the efficacy of our clinical outcomes and reinforce the importance of conservative yet effective endodontic and restorative protocols.

CONCLUSION

Within the limitations of this study, pulpectomy demonstrated a high success rate with excellent patient satisfaction when performed with standardized protocols and reinforced with stainless steel crowns. The results affirm that endodontic reduction, when executed conservatively, preserves structural integrity and prevents fracture while restoring functionality. Incorporating biocompatible obturation materials, sound restorative principles, and minimal invasiveness ensures optimal clinical outcomes and strengthens the role of pulpectomy in comprehensive pediatric dental care.

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