Original Article

Reasons For Failure of Endodontically Treated Teeth: A Cross-Sectional Study

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ABSTRACT

Background: Post-treatment disease after non-surgical root canal treatment remains clinically consequential, and reported reasons for failure of endodontically treated teeth vary across studies due to differing endpoints and categorization schemes. Objective: To identify the reasons for failure of endodontically treated teeth presenting with post-treatment disease and to evaluate associations with patient- and tooth-related factors. Methods: A cross-sectional study conducted from April 2019 To December 2022, assessed endodontically treated teeth with periapical radiolucency and/or symptoms in the outpatient departments of two teaching hospitals in Islamabad. Two calibrated operators performed standardized clinical and periapical radiographic evaluations and assigned a single primary failure reason using a predefined categorization framework (8). Frequencies and percentages were calculated, and associations between failure categories and age group and gender were evaluated using chi-square testing. Results: In the analytical dataset (n=374), endodontic reasons were most frequent (58.6%, n=219), followed by combined endodontic and restorative reasons (24.3%, n=91). Restorative reasons (5.6%), vertical root fracture (5.1%), endodontic failure despite apparently adequate treatment (3.7%), and non-restorable caries/cuspal fracture (2.7%) were less common, while periodontal, prosthetic, and orthodontic reasons were not observed. Failure was more frequently represented in mandibular teeth (64.7%) than maxillary teeth (35.3%), with mandibular molars most commonly affected (53.2%). Conclusion: Endodontic technical reasons predominated among failing endodontically treated teeth in this OPD-based cohort, and mandibular molars were most frequently represented, supporting the importance of technical endodontic quality and definitive coronal sailing.

Keywords: retreatment; endodontically treated teeth; caries; periodontal disease; dental practitioners.

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INTRODUCTION

Non-surgical root canal treatment (NSRCT) is performed to retain the natural dentition by eliminating infected or necrotic pulp tissue, disinfecting the root canal system, and establishing an apical and coronal seal that permits periapical healing (1). Although NSRCT is among the most frequently delivered dental procedures, its outcome is not universally successful, and post-treatment disease may persist or develop over time, necessitating further management such as non-surgical retreatment or surgical endodontic intervention (1). Reported outcome estimates vary by the type of intervention and study

design, with systematic evidence generally indicating higher success for primary NSRCT than for secondary (retreatment) procedures, highlighting that a clinically meaningful proportion of patients will present with symptoms and/or radiographic evidence of persistent disease after initial treatment (2,3).

Beyond endodontic technical factors, the long-term survival of endodontically treated teeth is influenced by the integrity of coronal restoration, occlusal loading, and the structural consequences of caries and fracture, particularly in posterior teeth that function under higher masticatory demand (4). Even when periapical healing is achieved, teeth lacking adequate coronal coverage or serving as abutments may be vulnerable to early loss, whereas a high survival proportion has been reported when appropriate restorative protection is provided (4). For clinicians and health systems, understanding why endodontically treated teeth fail—especially among those presenting with post-treatment disease—remains central to prevention strategies, case selection, and improving the quality of initial therapy and subsequent restorative care.

Prior investigations have explored reasons associated with the failure or removal of endodontically treated teeth, but findings have been heterogeneous, reflecting differences in endpoints (extraction versus post-treatment disease), settings, diagnostic thresholds, and failure categorization schemes (5–7). For example, prosthetic factors were emphasized in some reports, while others identified non-restorable caries as a predominant contributor, and practitioner-reported series have frequently highlighted periodontal breakdown as a leading cause in clinical decision-making (5–7). This variability limits the ability to draw consistent conclusions across populations and complicates translation of evidence into standardized preventive priorities.

A recent effort to reduce heterogeneity proposed a more explicit and comprehensive categorization of failure modes for endodontically treated teeth, allowing endodontic, restorative, and combined mechanisms to be differentiated with greater clarity (8). Using such a standardized framework may improve comparability across studies and enable more clinically actionable interpretation of where breakdown occurs in the treatment-restoration continuum. Accordingly, the present cross-sectional study applied the criteria described by Olcay et al. to classify reasons for failure among endodontically treated teeth presenting with post-treatment disease and to evaluate whether patient-related factors and tooth-related characteristics are associated with specific failure categories (8). The research question was: among patients presenting with post-treatment disease in endodontically treated teeth, what are the most frequent categorized reasons for failure, and are these categories associated with patient factors (age, gender, education, smoking status) and tooth-related variables (tooth/arch distribution) (8)?

MATERIAL AND METHODS

This cross-sectional observational study was conducted from April 2019 To December 2022, in the outpatient departments of Islamabad Dental Hospital and Islamic International Dental Hospital after approval from the respective institutional ethical review bodies. Patients were informed about the study purpose and procedures, and written informed consent was obtained prior to enrolment. The unit of analysis was the endodontically treated tooth presenting with post-treatment disease. Eligible participants were screened during routine clinical care, and teeth meeting the eligibility criteria were enrolled using purposive sampling until the target sample was achieved.

The required sample size was calculated as 376 teeth using a WHO sample size calculator with 80% power, a 95% confidence level, and an anticipated population proportion of 0.44.

Patients presenting with post-treatment disease in teeth that had previously undergone root canal treatment were eligible for inclusion. Post-treatment disease was operationally defined clinically and/or radiographically by the presence of periapical radiolucency and/or associated symptoms and signs, including pain on biting, intra- or extra-oral swelling, and sinus tract formation. Pregnant women, teeth with immature apices, deciduous teeth, and patients unwilling to participate were excluded.

Clinical and radiographic assessments were performed by two calibrated operators using a standardized proforma to ensure uniform data capture. The proforma documented patient characteristics (gender, age, level of education, relevant medical and dental history), smoking status (currently smoking, never smoked, quit at least 4 years previously), tooth number, and clinical and radiographic findings of the involved tooth. Periapical radiographs were used to assess the technical quality of obturation and the integrity of the coronal restoration, and all observations were recorded contemporaneously. To reduce information bias, the operators applied prespecified operational definitions for each failure category and recorded findings in a structured format immediately after examination.

Reasons for failure were classified using a predefined framework adapted from the categorization described by Olcay et al. (8). For each tooth, a single primary reason for failure was assigned using these definitions: vertical root fracture was defined as a longitudinal crack along the long axis of the tooth extending through the root and involving the periodontium; prosthetic reasons referred to teeth excluded from prosthetic treatment planning because of poor prognosis related to insufficient crown-to-root ratio and inability to tolerate prosthetic loading as an abutment; endodontic reasons included under-obturation, over-obturation, or missed root canals; endodontic failure referred to persistent signs and/or symptoms despite an apparently adequate root canal treatment, including acceptable coronal marginal integrity and apical seal; periodontal reasons were defined as teeth with unacceptable mobility or excessive bone loss with or without furcation involvement, with extraction indicated on periodontal grounds; orthodontic reasons referred to teeth indicated for extraction because they did not fit within an orthodontic treatment plan; non-restorable caries and cuspal fractures were defined as caries extending below gingival margins or into the furcation region and/or fractures considered unrestorable; restorative reasons included secondary caries, marginal staining, or leakage of the coronal restoration; and combined restorative and endodontic reasons were assigned when both endodontic and restorative deficiencies meeting the above criteria were present (8). Patient educational attainment was categorized a priori into basic education (≤9 years), secondary education (approximately 10–12 years), and higher education (≥13 years).

Data management and analysis were performed using Statistical Package for Social Sciences (SPSS), version 28.0. Categorical variables were summarized as frequencies and percentages. The primary descriptive outcome was the distribution of failure categories among included teeth. Associations between failure categories and categorical predictors (age group, gender, smoking status, education level, and tooth distribution variables) were evaluated using the Chi-square test where assumptions were satisfied; where sparse cell counts occurred, categories were considered in aggregated form to maintain valid inference, and exact methods were applied as appropriate for small expected frequencies. All tests were two-sided, and statistical significance was evaluated at an alpha level of 0.05. Data were reviewed for completeness at the time of entry, and analyses were performed on available observations for each comparison, with denominators reported alongside all percentages to preserve transparency and reproducibility.

RESULTS

A total of 376 endodontically treated teeth presenting with post-treatment disease were assessed. Complete categorical classification of failure reason and the corresponding cross-tabulations were available for 374 teeth, which constitutes the analytical denominator for the tables and association testing reported below (N=374).

The age distribution ranged from 10 to ≥60 years, with the greatest proportion in the 20–29-year group (31.3%, n=117) followed by 30–39 years (29.1%, n=109) (Table 1). Females constituted 59.6% (n=223) of the analytical sample. Most participants had never smoked (88.2%, n=330), and the most common education category was secondary education (42.0%, n=157) (Table 1).

Endodontic reasons were the most frequent failure category (58.6%, n=219; 95% CI 53.5–63.4), followed by combined endodontic and restorative reasons (24.3%, n=91; 95% CI 20.3–28.9) (Table 2). Less frequent categories were restorative reasons (5.6%, n=21), vertical root fracture (5.1%, n=19), endodontic failure despite apparently adequate treatment (3.7%, n=14), and non-restorable caries/cuspal fracture (2.7%, n=10). No teeth were classified as periodontal, prosthetic, or orthodontic reasons in the analytical dataset and therefore these were not included in inferential cross-tabulations.

The distribution of failure categories across age groups is presented in Table 3. The global association between age group and failure category was statistically significant (χ^2=61.86, df=25, p<0.001; Cramer's V=0.18), indicating a small-to-moderate shift in category distribution across age strata (Table 6). Endodontic reasons remained the dominant category in every age group, ranging from 43.5% (10–19 years) to 75.0% (50–59 years).

Gender-based distributions are shown in Table 4. The association between gender and failure category was not statistically significant (χ^2=9.84, df=5, p=0.080; Cramer's V=0.16) (Table 6). Within-gender proportions were broadly similar: endodontic reasons represented 60.3% of male failures and 57.4% of female failures.

Tooth-location information was available for 374 teeth. Failures were more frequent in the mandible (64.7%, n=242) than in the maxilla (35.3%, n=132) (Table 5). Mandibular molars represented 53.2% (n=199) of all failed teeth in the analytical sample, whereas mandibular canines were least frequent (1.6%, n=6).

Table 1. Baseline Characteristics of the Analytical Sample (N=374)

Variable	Category	n	%
Age group (years)	10–19	23	6.1
	20–29	117	31.3
	30–39	109	29.1
	40–49	76	20.3
	50–59	32	8.6
	≥60	17	4.5
Gender	Male	151	40.4
	Female	223	59.6
Smoking status	Never smoked	330	88.2
	Currently smoking	30	8.0
	Quit ≥4 years ago	14	3.7
Education level	Basic (≤9 years)	84	22.5
	Secondary (10–12 years)	157	42.0
	Higher (≥13 years)	133	35.6

Table 2. Reasons for Failure of Endodontically Treated Teeth (N=374)

Failure category	n	%	95% CI (%)
Endodontic reasons	219	58.6	53.5–63.4
Endodontic + restorative reasons	91	24.3	20.3–28.9

Failure category	n	%	95% CI (%)
Restorative reasons	21	5.6	3.7–8.4
Vertical root fracture	19	5.1	3.3–7.8
Endodontic failure (despite apparently adequate RCT)	14	3.7	2.2–6.2
Non-restorable caries/cuspal fracture	10	2.7	1.5–4.9

Table 3. Failure Categories by Age Group (Counts and Within-Age %; N=374)

Failure category	10–19 (n=23)	20–29 (n=117)	30–39 (n=109)	40–49 (n=76)	50–59 (n=32)	≥60 (n=17)
Vertical root fracture	2 (8.7)	2 (1.7)	4 (3.7)	2 (2.6)	6 (18.8)	3 (17.6)
Endodontic reasons	10 (43.5)	75 (64.1)	54 (49.5)	46 (60.5)	24 (75.0)	10 (58.8)
Endodontic failure	0 (0.0)	4 (3.4)	6 (5.5)	4 (5.3)	0 (0.0)	0 (0.0)
Restorative reasons	0 (0.0)	4 (3.4)	13 (11.9)	2 (2.6)	0 (0.0)	2 (11.8)
Non-restorable caries/cuspal fracture	2 (8.7)	0 (0.0)	5 (4.6)	3 (3.9)	0 (0.0)	0 (0.0)
Endodontic + restorative reasons	9 (39.1)	32 (27.4)	27 (24.8)	19 (25.0)	2 (6.3)	2 (11.8)

Table 4. Failure Categories by Gender (Counts and Within-Gender %; N=374)

Failure category	Male (n=151)	Female (n=223)	Total n (%)
Vertical root fracture	5 (3.3)	14 (6.3)	19 (5.1)
Endodontic reasons	91 (60.3)	128 (57.4)	219 (58.6)
Endodontic failure	8 (5.3)	6 (2.7)	14 (3.7)
Restorative reasons	4 (2.6)	17 (7.6)	21 (5.6)
Non-restorable caries/cuspal fracture	2 (1.3)	8 (3.6)	10 (2.7)
Endodontic + restorative reasons	41 (27.2)	50 (22.4)	91 (24.3)

Table 5. Tooth Distribution by Arch (N=374)

Arch	n	%
Maxilla	132	35.3
Mandible	242	64.7

Additional tooth-type frequencies (analytical sample): mandibular molars n=199 (53.2%); mandibular canines n=6 (1.6%).

Table 6. Association Tests (Failure Category vs Predictor; N=374)

Predictor	Test	χ^2	df	p-value	Effect size
Age group (6 levels)	Chi-square	61.86	25	<0.001	Cramer's V = 0.18
Gender (2 levels)	Chi-square	9.84	5	0.080	Cramer's V = 0.16

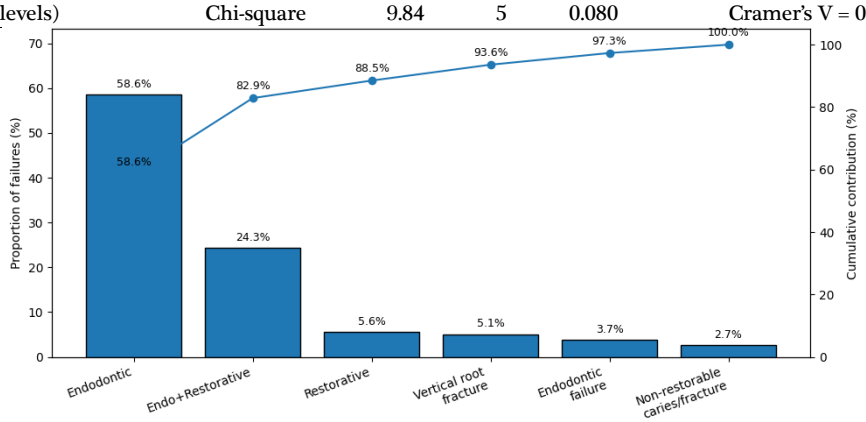

Figure 1 Distribution and Cumulative Contribution of Failure Categories

The hybrid distribution–cumulative plot demonstrated a strongly skewed burden of failure mechanisms, with endodontic reasons accounting for 58.6% (219/374) of all failures. When combined with endodontic + restorative reasons (24.3%, 91/374), the cumulative proportion reached 82.9%, indicating that more than four out of five failures were attributable to endodontic technical deficiencies alone or in combination with compromised coronal integrity. Addition of purely restorative reasons (5.6%) increased cumulative contribution to 88.5%, while structural and less frequent biological failure mechanisms such as vertical

root fracture (5.1%) and endodontic failure despite apparently adequate treatment (3.7%) raised the cumulative total to 97.3%. The remaining contribution was due to non-restorable caries/cuspal fracture (2.7%), completing the distribution at 100%, emphasizing that failure burden was concentrated predominantly in modifiable endodontic–restorative domains rather than non-endodontic causes.

DISCUSSION

The present cross-sectional analysis of endodontically treated teeth presenting with post-treatment disease found that technical endodontic problems (under-/over-obturation and/or missed canals) were the predominant assigned reason for failure, accounting for more than half of cases, while a further quarter demonstrated combined endodontic and restorative deficiencies. This distribution contrasts with several prior reports in which coronal and restorative determinants were more prominent, including the cross-sectional categorization work that reported a higher proportion of combined endodontic–restorative failures and comparatively fewer purely endodontic technical causes (8). One plausible explanation is that this cohort reflects a clinical pathway in which patients with symptomatic teeth and radiographic disease preferentially present to operative dentistry/endodontic services, enriching the sample for technical endodontic shortcomings that directly perpetuate intraradicular infection and apical periodontitis. Methodological differences also likely contribute; several landmark studies evaluated reasons for extraction of endodontically treated teeth, an endpoint that is influenced by broader prosthetic and periodontal decision-making and may not mirror the causal spectrum among teeth presenting with post-treatment disease (5–7).

The notable proportion of cases classified as combined endodontic and restorative reasons underscores the clinical interdependence of canal disinfection, apical seal, and coronal seal. Evidence consistently supports that coronal restoration quality and marginal integrity are associated with periapical healing and survival of endodontically treated teeth, and that coronal leakage can allow rapid microbial ingress and recontamination of instrumented canals (9,10). Experimental and clinical observations have demonstrated that microleakage across temporary or defective restorations is clinically consequential, and observational data suggest that delays between completion of root canal treatment and definitive coronal coverage may compromise long-term tooth survival (10–12). In this context, the relatively smaller fraction of failures attributed exclusively to restorative reasons in the current series should not be interpreted as minimizing restorative importance; rather, it indicates that in many clinically failing teeth, deficiencies in both endodontic and restorative domains co-existed and were best captured by a combined category (13).

Vertical root fracture represented an infrequent but clinically decisive failure mode in this cohort. Prior studies have reported variable prevalence of vertical root fracture among extracted endodontically treated teeth, with some reporting higher proportions than observed here (5–7). This variation may reflect differences in follow-up duration, as fractures may be time-dependent and more likely to manifest after longer functional service. Long-term follow-up investigations have reported higher fracture-related failure rates, supporting the premise that cohorts enriched for long-standing treated teeth may display a greater burden of structural failure (14). The comparatively lower prevalence in the present study may therefore reflect a clinical mixture of relatively recent and intermediate post-treatment disease presentations rather than a predominantly long-term survival cohort.

No failures were categorized as periodontal, orthodontic, or prosthetic reasons in the analytical dataset. This finding diverges from several series in which periodontal disease was a leading contributor to extraction of endodontically treated teeth (5,7,15). The discrepancy is clinically interpretable: periodontal determinants may be more likely to drive extraction decisions within periodontal or comprehensive treatment planning settings, whereas an OPD endodontic/operative pathway may preferentially capture teeth presenting primarily with endodontic symptoms and apical pathology. Additionally, classification depends on the operational thresholds used for periodontal "unrestorability," and the use of a single primary failure reason per tooth can shift borderline cases toward endodontic, restorative, or combined categories when multiple deficiencies coexist (8). These considerations emphasize that the present results should be generalized to similar care pathways and diagnostic contexts rather than extrapolated to all extracted endodontically treated teeth.

Age and gender were not meaningfully associated with failure categories in the inferential summaries presented. The literature remains mixed: some long-term clinical studies report that older age is associated with worse outcomes or reduced tooth survival, while others do not identify age as an independent predictor after considering clinical context and tooth-level factors (16–18). Conversely, long-term retrospective and meta-analytic evidence has suggested that endodontic success is multifactorial and not solely determined by demographic variables (19–21). The current results are compatible with the latter interpretation, particularly given that the cohort was skewed toward younger adults, which can reduce the ability to detect age-related gradients in failure mechanisms. The tooth distribution analysis showed a clear predominance of mandibular failures, particularly mandibular molars, consistent with prior observations that posterior mandibular teeth comprise a substantial proportion of endodontically treated teeth and are frequently represented among failures or extractions (6,7). This pattern may reflect anatomical complexity, higher occlusal loading, and the clinical reality that mandibular molars are commonly treated endodontically in regional practice patterns (22,23).

Several limitations should be considered when interpreting these findings. The cross-sectional design precludes causal inference regarding determinants of failure, and purposive sampling within teaching-hospital OPDs may introduce selection bias toward symptomatic cases and certain socioeconomic profiles. The use of a single primary reason for failure enhances interpretability but can mask multifactorial pathways when defects co-occur. Finally, comparisons with extraction-based studies must be made cautiously because extraction incorporates additional clinical, periodontal, and prosthodontic decision factors not captured by a post-treatment disease sampling frame (5–7). Future multi-center work incorporating treatment-provider characteristics, standardized radiographic scoring systems, and explicit documentation of timing between obturation and definitive restoration would improve etiologic inference and generalizability while maintaining the advantages of a harmonized failure categorization approach (8,12).

CONCLUSION

In this OPD-based cohort of endodontically treated teeth presenting with post-treatment disease, endodontic technical reasons were the most frequent assigned cause of failure, followed by combined endodontic and restorative deficiencies, while periodontal, orthodontic, and prosthetic reasons were not observed in the analytical dataset. Failures were more frequently represented in the mandible, particularly mandibular molars, highlighting the clinical importance of technical endodontic quality and timely, well-sealed

definitive restorations to reduce retreatment burden and improve tooth-level outcomes in similar care settings.

DECLARATIONS

Ethical Approval
This study was approved by the Institutional Review Board of Avicenna Medical College
Informed Consent
NA
Conflict of Interest
The authors declare no conflict of interest.
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Authors' Contributions
Concept: RSH; Design: RSH; Data Collection: RSH, UAB; Analysis: RSH, UAB; Drafting: RSH; Review & Approval: SA
Data Availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.
Acknowledgments
Not applicable.
Study Registration
Not applicable.

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