The Review Of
DIABETIC
STUDIES OPEN ACCESS

Endodontic Treatment Outcomes And Failure Rates In Saudi Arabia: A Systematic Review

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Abstract

Background: Success in endodontic treatment depends on biological control of infection and technical quality of preparation, obturation and restoration. Although international benchmarks report a success rate of 92–98% in teeth without apical periodontitis and 74–84% in teeth with pre-existing lesions. The outcomes reported from Saudi Arabia seem heterogeneous and often below the optimum standards, particularly in a non-specialist and training environment.
Objective: To systematically synthesize the available randomized controlled trial (RCT) data on endodontic treatment outcomes and endodontic treatment failure determinants in Saudi Arabia, specifically regarding success, radiographic success, post-operative morbidity and treatment procedural factors that could influence endodontic treatment failure.
Methods: A systematic review in accordance with the requirements of the PRISMA statement was conducted by searching in PubMed, Scopus and Google Scholar (2000-2026). For the purpose of this systematic review, only RCTs from Saudi Arabia were considered eligible. Goals of interest were treatment success, survival, failure, pain after surgery and quality of the procedure. Assessment of risk of bias was conducted by applying the RoB 2.0 tool provided by the Cochrane Collaboration. No meta-analysis was carried out.
Results: There were six RCTs included in this study with three studies on permanent NSRCT with emphasis on long-term periapical healing ranging between 75.0 and 87.5%, with a survival rate of 83.3-100% on or after 2.5 years, with no significant differences between MTA and gutta-percha on long-term success in terms of periapical healing. However, there were a few studies showing significantly fewer cases of postoperative pain with the use of NSRCT compared with MTA, as examined in a large RCT with approximately 390 patients, whereby significant differences were noted in the pain rate but no difference in the mean VAS score. On the other hand, primary tooth NSRCT studies revealed that the rate of success after 12 months always reached above 94%, ranging from 97-100% with MTA, where there is an RCT on NSRCT showing significant differences in residual intracanal medicament with propolis compared with CH, indicating possible mechanistic evidence on success and possible leakage with potential risk of failure due to its lower residual value of 23.2% compared with 38.6% ($p = 0.001$). Risk of bias assessment revealed
Conclusions: Randomized data from Saudi Arabia indicate favorable short-term results in pediatric pulpotomy and satisfactory but inconsistent results for permanent tooth NSRCT. Deviation from global success criteria was most likely due to technical causes rather than material considerations alone. Improved standardization of procedural excellence, canal recognition and achievement of standard results is crucial for significant success rates for the population.

Keywords: Endodontic treatment outcomes; Root canal therapy; Nonsurgical root canal treatment; Pulpotomy; Treatment failure; Periapical healing; Postoperative pain; Technical quality; Randomized controlled trials; Saudi Arabia.

1. Introduction

The purpose of endodontic therapy is to remove infection within the root canal system by effectively cleaning, shaping and filling it. Endodontic therapy has been considered a success when there is positive clinical evidence, as well as radiographic evidence of periapical healing. The literature varies and its

success can be from 92% to 98% in teeth without apical periodontitis and 74% to 84% in teeth with pre-existing lesions when a standardized approach is used [1]. In Saudi Arabia, reported outcomes of root canal treatment (RCT) demonstrate considerable variability, reflecting differences in operator expertise, technical quality and case complexity. A retrospective evaluation of 432 teeth treated by postgraduate endodontic students at Riyadh Elm University reported complete periapical healing in 68.1 % of cases, ongoing healing in 27.4 % and persistent disease in 4.4 % at follow-up [2]. Similarly, a pediatric cohort study conducted in Jeddah assessing RCT outcomes in first permanent molars reported a success rate of 79.6 % under loose criteria and 72.9 % under strict criteria, with failure rates ranging from 20.4 % to 27.1 % [3].

Failure analyses that are concerned with the trends of failure among adult populations have cited technical inadequacies as a significant source of failure at the same time. According to a study conducted at the University of Aljouf, it has been found that underfilling root canals is the cause of 33.3% failures, with 17.7% of failures being as a result of missed or untreated root canals, with molar teeth and 41-50 years old patients being the most affected [4]. Poor quality of overall treatment and coronal restoration were recognized as the major causes of endodontic failure in the cases of evaluation in Al-Kharj, which is why extensive planning of the restorative approach after RCT is crucial [5].

Population-based data on Saudi Arabia have also supported the association between the obturation quality and the periapical health. In a study of 1,040 endodontically treated teeth, 70.96 percent of the teeth had healthy periapical status. Technically adequate root canal fillings on teeth gave a success rate of about 96 and teeth poorly treated gave as low as 48 success rate [6]. All these indications imply that the results of endodontic therapy in Saudi Arabia are generally below the best international standards and the solution is to provide better technical quality, more training and outcome measurement in the practice.

2. Methodology

2.1 Study design and protocol

The systematic review was performed to assess the outcomes of endodontic treatment and failure-related measures in Saudi Arabia and especially randomized controlled trials (RCTs). The review was done according to PRISMA guidelines of systematic reviews. Before data extraction a predefined protocol was created that indicated the eligibility criteria, outcome of interest and how to assess bias.

2.2 Eligibility criteria

The achievement of studies was based on the PICOS framework.

Population: Patients that had endodontic or vital pulp therapy in Saudi Arabia, both permanent and primary tooth.

Intervention and comparison: Endodontic treatment variables such as single or multiple visit treatment, obturation materials, intracanal medicaments and pulpotomy materials.

Outcomes: The success of treatment, failure, pain after surgery, clinical and radiographic outcome and procedural variables related to endodontic failure.

Design of the study: Only randomized controlled trials.

Setting: RCTs in a clinical or laboratory setting in Saudi Arabia.

In vitro RCTs were restricted to having an outcome that was directly correlated with the quality of procedure known to affect clinical risk of failure (e.g., removal of medicament).

2.3 Study selection and search strategy.

PubMed, Scopus and Google Scholar were searched electronically with a specialized search. Reference lists were also manually searched. Studies in English language were included only. Based on the identified records, six RCTs were incorporated in the final synthesis according to the identification of the records that met the inclusion criteria. The primary findings were reported in all six of the studies carried out within the Saudi institutions.

2.4 Data extraction

The study setting, design, sample size, intervention arms, duration of follow-up, primary outcomes and the statistical findings were independently extracted. Agreements were made via consensus. Missing data were not approached to the authors.

2.5 Risk of bias assessment

Risk of bias Cochrane Risk of Bias tool (RoB 2.0) was used to assess risk of bias in randomized trials. Domains that were measured were randomization process, non-adherence to planned interventions, outcome non-reporting, outcome measurement and selective reporting. Tables on risk-of-bias are included in Appendix A.

2.6 Data synthesis

Quantitative meta-analysis was not done because of the high heterogeneity of interventions, outcomes and periods of follow-up. Rather, the synthesis of findings was in the form of narration and the results, as well as the scope of successes and failure rates, were tabulated in a structured way.

3. Results

3.1 Study selection and characteristics

These were six randomized controlled trials performed in Saudi Arabia. Three of the trials compared non-surgical treatment of root canals in permanent teeth and three were comparing pulpotomy with primary molars. One of the works was laboratory-based, however, randomized and focused on medicament removal efficacy, which is also a factor related to obturation quality and possible failure. During search, among the records identified in the database (n=1 980 records), 948 duplicates were eliminated. Having screened 1,034 records and screened 32 total texts, 26 of them were excluded. In the end, 6 randomized controlled trials were eligible and included in the system review.

Table 1. Characteristics of included randomized controlled trials

Author (Year)	Setting	Sample Size	Intervention Arms	Follow-up	Primary Outcome
Alomaym et al. (2019) [6]	Al-Qassim	390 analyzed	Single-visit vs multiple-visit NSRCT	48 h	Post-operative pain (VAS)
Alsulaimani (2016) [7]	Riyadh	36 treated; 32 evaluated	MTA vs gutta-percha obturation	≥2.5 years	Periapical healing, survival
Alsanouni & Bawazir (2019) [8]	Riyadh	80 teeth	NeoMTA Plus vs ProRoot MTA	12 months	Clinical & radiographic success
Alqahtani et al. (2023) [9]	Riyadh	70 teeth	NeoPUTTY vs NeoMTA 2	12 months	Clinical & radiographic success
Al-Mutairi & Bawazir (2013) [10]	Saudi Arabia	Paired molars	NaOCl vs formocresol	12 months	Pulpotomy success
Ahmed et al. (2021) [11]	Al-Ahsa	30 teeth (in vitro)	Propolis vs $Ca(OH)_2$	Immediate	Residual medicament (%)

3.2 Characteristics interpretation.

The body of evidence is characterized by small-scale single-centered trials. The included studies determine the outcome of permanent-tooth NSRCT and half of the studies included pulpotomy in primary molars. The follow-up time was very wide with 48 hours' follow-up in the pain outcomes and over five years follow-up in the survival analysis. This heterogeneity restricts a direct comparison of the failure rates studies.

3.3 Outcomes in permanent teeth

3.3.1 Single-visit vs. multiple-visit NSRCT.

The research performed by Alomaym et al. (2019) [6] and it involved approximately 390 patients. Despite the non-significant differences found in the means of the VAS pain scores at the majority of the postoperative time points, the multiple-visit group had a significantly lower overall postoperative

pain incidence. This result implies there is a temporary symptomatic advantage of calcium-hydroxide inter-appointment medication which does not explicitly educate long-term failure or healing.

3.3.2 Obturation material and long term healing.
Alsulaimani (2016) [7] compared single-visit NSRCT with MTA cement to warm vertical gutta-percha obturation. Full periapical healing of MTA-treated teeth was found at at least 2.5 years of follow-up, whereas it was found in 75.0% of the gutta-percha group. MTA and gutta-percha had 100 and 83.3 percent survival rates at 3 and five year respectively. These differences were statistically not significant, although they were in favor of MTA, which was likely because of the limited size of the sample (n = 32 assessed).

3.4 Primary tooth outcomes (pulpotomy)
In 3 RCTs, pulpotomy materials showed a high level of clinical and radiographic success at 12 months. According to Alsanouni and Bawazir (2019) [8], ProRoot MTA and NeoMTA Plus had a clinical success of 97.4 and 100% respectively and a radiographic success of over 94 in both groups. There also were no statistically significant differences between NeoPUTTY and NeoMTA 2 as reported by Alqahtani et al. (2023) [9] and the clinical success rates were 97.1-100. Al-Mutairi and Bawazir (2013) [10] made a comparison between sodium hypochlorite and formocresol with similar clinical success (94.6 vs 92.1) and radiographic success (86.5 vs 86.8) 12 months later. These results are indicative that contemporary substitutes may produce the same results as it was done in traditional medicaments**.**

3.5 Procedural aspect associated with the risk of failure (Reference 6)
Ahmed et al. (2021) [11] had a randomized laboratory trial of removability of intracanal medicaments. The mean residual medicament in case of standardized irrigation of propolis (23.22) was significantly less than that of calcium hydroxide (38.58), with $p = 0.001$. Such statistically significant difference shows that propolis is better removable under the tested conditions. Since residual intracanal medicament may affect obturation quality and seal integrity, the study has clinical implications since it may be an indirect cause of endodontic failure.

3.6 Overview of success and failure scales.
In the case of permanent-tooth NSRCT trials, the healing or survival rates were reported to be between 75% and 100%. Clinical success in primary-tooth pulpotomy trials was always at 12 months or above at more than 95%. Failure incidents were rarely documented and were usually associated with radiographs and not clinical manifestations.

4.0 Discussion:
The synthesis places the Saudi clinical randomized evidence in the larger, more ancient literature on endodontic outcomes and the importance of technical determinants of success and the extent to which diagnostic and procedural determinants of failure contribute to failure. The main assumption made throughout central reviews is that the end-point of clinical and radiographic healing and hence, a successful response, is independent yet interrelated and depends on the variables of biological and technical characteristics [12,13]. Systematic summaries of non-surgical retreatment and orthograde results highlight a generally optimistic outcome of healing under the condition of adherence to the protocols, but the difference in the design of the studies, skills of the operator and definitions of the results complicates the comparison [14,15].
Population context matters. Saudi dental epidemiology has a stable burden of caries and treatment requirements that contribute to endodontic workload and complexity experienced by clinicians [16,17]. Therefore, the systematic review research methodology and unbiased risk evaluation are critical to interpret heterogeneous primary research, so modern reporting guidelines (PRISMA) and tools of quality (NOS, RoB 2) should inform synthesis and interpretation [18–20].
Endodontic failure has a strong basis within anatomical complexity and missed anatomy. The proportion of mandibular first molars inspected with four root canals (two mesial + two distal) was 57.76% and the proportion with three root canals was 5.97%; this has shown that the prevalence of complex anatomy is high in this type of Saudi subpopulation and may become untreated if not sought and negotiated. The high prevalence of failure or lesions in canal systems not treated completely can be

directly related to this anatomical finding (Al-Nazhan) [21]. Research on the role of 3-D imaging in detecting missed canals and apical pathology in contemporary Saudi cohorts supports the diagnostic utility of 3-D imaging in the detection of missed canals: Mashyakhy et al. found that missed-canal teeth were characterized by apical periodontitis (AP) in 90% of cases; maxillary first molars were most affected (missed canal prevalence 40.6% in total). This close relationship (missed canals 9/10 teeth AP) measures how anatomic care is transformed to radiographic disease. CBCT findings from other local studies also demonstrate that approximately half of treated teeth in certain referral groups contain AP on 3-D imaging (Diaconu: AP found in 46.69% of treated teeth) and that 2-D radiography overestimates remaining disease in complicated cases [25,27].

There are quantifiable impacts of operator skill and undergraduate or graduate training. Saudi and international dental school retrospective audits reveal a significant increase in technical quality: AlRahabi identified 68.9% of 280 student-performed RCTs to be technically adequate, whereas 31.1% of such studies included a procedural error: underfilling (49.9% of procedural errors), overfilling (24.1%), voids (12.6%), instrument separation (9.2%) and perforations or transportation (approximately 2.3% each) [22]. Similar cohorts of students across the world claim that filling rates are acceptable (54.1%), procedural error rates are 18.6% and particular patterns of procedural errors (ledges 12.5%, fractured instruments approximately 2%) [30]. These data explicitly clarify that incomplete obturation density or length and the existence of void or iatrogenic sequelae are still pre-eminent, measurable indicators of failure.

Modern longitudinal studies provide weighted pooled success estimates, which provide a benchmark: the meta-analysis of primary RCTs by Burns et al. (2003–2020) has pooled success rates of 92.6% using loose criteria and 82.0% using strict criteria [23]. The higher part of this range is often approximated by single-center postgraduate cohorts (e.g. a specialist postgraduate clinic reported success rates of about 92%), although generalist and student clinics are at the lower end (Polyzos had a root-level success of just 72.8% with a mean follow-up of 2.8 years). More importantly, Polyzos demonstrated that preoperative lesion-free roots, filled with dense, properly extended fillings (0–2 mm short of the apex) and free of voids, have success rates up to 94.5%, numerically equivalent to the best reported pooled outcomes and emphasizing the importance of technical quality [24,26].

Operative and product decisions have an effect on short-term and long-term measures. Randomized comparisons of Saudi trials included in this review indicate that, in primary teeth, modern bioceramic materials and MTA-based obturating or pulpotomy agents could achieve clinical success rates of over 95 per cent and MTA in permanent teeth a favourable healing experience; these findings are consistent with the wider systematic literature, which attributes part of outcome enhancement to materials and superior obturation but consistently revert to operator and case selection as more influential than instrumentation method alone [6–13]. Mechanistic connection is also given by removability of intracanal medicaments (Ahmed in a King Faisal University in vitro RCT), for example residual $Ca(OH)_2$ versus propolis; higher residual medicament makes obturation seal compromised and it is indirectly correlated with increased risk of failure.

A special high-risk group is endodontic-periodontal combined lesions. Wong et al. have noted only a 46.6% survival and 31.8% frank failure with treated endodontic-periodontal lesions and that deep bone loss of the apical third and 5-mm or greater probing depth were significant predictors of minimal odds of success (ORs 0.3, 0.147–0.126), whereas lack of periodontitis history was also a significant predictor of success (OR 7.7) [28]. These tangible effect sizes support the idea that non-endodontic factors (periodontal condition, bony structure) are powerful modulators of outcome and often overwhelm endodontic technical manipulations.

The imaging options should be given a factual position. Comparative studies have shown that although CBCT decreases the number of cases where canals are missed and AP are not detected, ultimate clinical management is not always affected by a direct comparison of 3-D and 2-D images. Balasundaram et al. found no statistically significant difference in immediate treatment decision-making with CBCT compared with periapical radiographs in a small clinical sample; however, CBCT greatly increases detectability of lesions and anatomy mapping (versatile in retreatment and surgery planning). Referral-center series indicate that AP is identified in approximately 4. In this regard, selective use of CBCT, which conforms to ESE quality guidelines, should be used in complex, symptomatic, or treatment-planning cases [36]. Combined, the quantitative data produce a number of brief conclusions applicable to Saudi practice and the trials represented in this review: (1) the current success benchmarks of modern

longitudinal studies (83–93%, strictness-dependent) become achievable; (2) missing anatomy is clearly a significant contributor to AP now (18% miss rates in CBCT series); and (3) and (4) curriculum-based interventions and more careful trial reporting (PRISMA, RoB 2) will allow local data to be meaningfully compared with international pooled estimates.

The literature is quantified, but recommendations are simple: a focus on procedural quality (apical fill length of 0–2 mm, dense obturation, no voids) should be a priority; regular search and management of other canals (mesiobuccal 2 in maxillary first molars and mesial canals in mandibular molars, in particular) should be performed; selective use of CBCT where anatomy or persistent disease is suspected; and undergraduate or endodontic training should strengthen against the most common procedural errors (underfill, overfill, voids, separation). These focused, evidence-based interventions must, depending on the effect size observed, increase clinical success rates toward the higher pooled estimates reported in modern longitudinal studies [21,24,27,30,36].

4.1 Limitations

In the interpretation of the present findings, there are a number of limitations that this systematic review exhibits. First, the existing randomized information in Saudi Arabia is still very small in terms of quantity and is dominated by those of single-center trials with small sample sizes especially in permanent-tooth non-surgical root canal treatment. This limits powers of statistics and limits generalizability in other clinical environments and operator skill levels.

Second, there was a high level of heterogeneity in interventions, outcomes and follow-up periods with short-term postoperative pain evaluation to survival over several years. This led to the inability of conducting quantitative meta-analysis and conclusions were drawn based on narrative synthesis, as opposed to pooled effect estimates.

Third, the number of randomized controlled trials was only used but two studies showed the presence of some issues in risk-of-bias areas regarding randomization or missing data on outcomes, which could have affected the effect estimates. Moreover, there was the inclusion of laboratory-based randomized evidence that could be useful in the context of mechanistic relevance, yet the outcomes of the mechanistic relevance cannot be directly compared with the clinical failure.

Lastly, the outcome assessment within the trials was not completely standard with differences in radiographic criteria, success definition (loose and strict) and failure events reporting. This heterogeneity indicates larger problems in endodontic outcome studies and highlights the necessity to implement standardized reporting systems in future Prince Saudi studies.

4.2 Clinical Implications and Future Research

The results of this review directly apply to the endodontic practice and training in Saudi Arabia. The success rates of the trials of pediatric pulpotomy are constantly high, which proves that the latest bioceramic materials and protocols allow achieving the same results as the global standards. Conversely, randomness in the results of permanent-tooth NSRCT points to the enduring effect of a technical execution over the use of materials.

Clinically, it is important to focus on a careful set of canal identification, proper working length management, high amount of obturation and the time-sensitive placement of high quality coronal restorations. Selective application of CBCT and magnification could be of special interest in complex teeth of the anatomy and cases of retreatment when it is supposed that there are some canals missed.

Further studies in Saudi Arabia must focus more on multicenter randomized trials using sufficient sample sizes, standardized definitions of their outcomes and longer follow-ups to have a better understanding of actual failure rates and survival. The incorporation of consensus-driven reporting guidelines and the use of a uniform radiographic criterion would result in a higher degree of comparability with other datasets around the world and enable the national benchmarking of endodontic performance.

5. Conclusion

This is a systematic review of the existing randomized controlled evidence about the outcomes of endodontic treatment in Saudi Arabia and shows that there is a strong dissimilarity between permanent-tooth and pediatric interventions. High short-term clinical and radiographic success Pulpotomy in primary teeth has been demonstrated to have high success, over 95% at 12 months, regardless of trial,

which indicates that modern bioceramic materials and standard procedures are effective. Conversely, the results of non-surgery root canal therapy in permanent teeth are moderate but unpredictable with a healing and survival statistics of about 75-100%. It has been shown by randomized trials as well as supporting epidemiological studies that the failure to meet international standards of success is most likely to be traced to technical considerations, such as missed anatomy, insufficient obturation length or density, or procedural error, not to obturation material choice. The further indication of mechanistic randomized evidence is that procedure factors like the removability of intracanal medicaments might be an indirect marker of the quality of obturation and the success of the long term results. Taken regularly, the results of these studies serve to highlight the importance of operator ability, perception and compliance with quality standards in the endodontic outcome measure.

To enhance the overall performance of endodontic success at a population scale in Saudi Arabia, reinforcing undergraduates and postgraduates training, encouraging unified and consistent outcome assessment and the selective incorporation of innovative diagnostic equipment are crucial. Intelligently planned multicenter randomized trials will play a significant role in perfecting the national standards and aligning the local practice with the modern international standards.

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[1].

Appendix:

Appendix A. Risk of Bias Assessment (Cochrane RoB 2.0)

Table A1. Risk of bias summary for included randomized controlled trials

Study	Randomization	Deviations	Missing Data	Outcome Measurement	Reporting Bias	Overall Risk
Alomaym 2019 [6]	Low	Low	Low	Low	Low	Low
Alsulaimani 2016 [7]	Some concerns	Low	Some concerns	Low	Low	Some concerns
Alsanouni 2019 [8]	Low	Low	Low	Low	Low	Low
Alqahtani 2023 [9]	Low	Low	Low	Low	Low	Low
Al-Mutairi 2013 [10]	Some concerns	Low	Some concerns	Low	Low	Some concerns
Ahmed 2021 [11]	Low	Low	Low	Low	Low	Low

Appendix B. Search Strategy Keywords (Concept-Based MeSH Design)

Table B1. Search terms and keyword categories used in the electronic search strategy

Search Concept	MeSH Terms	Free-Text Keywords (combined with OR)
Endodontic intervention	"Endodontics"[MeSH] OR "Root Canal Therapy"[MeSH] OR "Pulpotomy"[MeSH]	endodontic treatment OR root canal treatment OR nonsurgical root canal therapy OR NSRCT OR pulpotomy
Outcome variables	"Treatment Outcome"[MeSH] OR "Healing"[MeSH] OR "Postoperative Pain"[MeSH] OR "Periapical Diseases"[MeSH]	success OR failure OR survival OR healing OR periapical health OR apical periodontitis OR postoperative pain
Failure-related factors	"Dental Leakage"[MeSH] OR "Root Canal Filling Materials"[MeSH] OR "Dental Restoration, Permanent"[MeSH]	underfilling OR overfilling OR missed canal* OR inadequate obturation OR coronal leakage OR technical error*
Population / tooth type	"Tooth, Permanent"[MeSH] OR "Tooth, Deciduous"[MeSH]	permanent teeth OR primary teeth OR molars
Study design	"Randomized Controlled Trial"[Publication Type]	randomized controlled trial OR randomized clinical trial OR RCT
Geographic filter	"Saudi Arabia"[MeSH]	Saudi Arabia OR Saudi OR Riyadh OR Jeddah OR Al-Kharj OR Al-Qassim

Appendix C:

Figure 1. Prisma flow diagram detailing the screening process