



Radiographic Quality of Root Canal Treatments at Khorfakkan Specialized Dental Center: A Retrospective Cross-Sectional Audit

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Abstract

Background: This clinical audit assessed the radiographic technical quality of root canal treatments performed by endodontists at Khorfakkan Specialized Dental Center (CSDK) between 2022 and 2024, against predefined technical criteria.

Methods: In this retrospective cross-sectional audit conducted at Khorfakkan Specialized Dental Center, 400 randomly selected postoperative intraoral periapical radiographs from treatments completed between 2022 and 2024 were assessed for length, density, taper, and absence of iatrogenic errors using standardized European Society of Endodontology (ESE) criteria against a predefined institutional quality target benchmark of 70% overall acceptability. Inter-examiner agreement was high, with Cohen's kappa = 0.90 ($p < 0.001$). Frequency comparisons were performed using the Chi-square test, with significance set at $p \leq 0.05$.

Results: Adequate length was achieved in 79.0%, density in 85.3%, taper in 88.5%, and absence of iatrogenic errors in 77.5% of cases. Overall, 67.3% of treatments met all four predefined technical quality criteria, falling slightly below the 70% institutional benchmark. Univariable analysis showed significant associations between overall technical acceptability and number of root canals and number of visits.

Conclusions: This clinical audit found that root canal treatments performed at CSDK fell slightly short of the predefined 70% institutional benchmark, with an overall radiographic technical acceptability rate of 67.3%. Because this audit evaluated only radiographic parameters, these findings are strictly limited to technical performance and do not imply long-term clinical success or healing prognosis.

Keywords: Audit; Endodontics; Periapical Radiography; Quality Assurance; Root Canal Filling; Technical Quality

Introduction

Root canal treatment (RCT) is a fundamental procedure in contemporary dentistry, aimed at eliminating pulpal and periapical infection and preserving natural dentition. The long-term success of RCT depends largely on the technical quality of canal preparation

and obturation, particularly with respect to obturation length, density (homogeneity), taper, and the absence of procedural errors [1-3]. Radiographic evaluation remains the most practical and widely accepted method for assessing these parameters and is routinely used in clinical audits and quality assurance studies [4-6].

Despite significant advancements in endodontic practice, including rotary nickel-titanium (NiTi) instrumentation, electronic apex locators, ultrasonic irrigation activation, digital radiography, and bioceramic sealers, variability in the technical quality of root canal fillings (RCFs) continues to be reported [6-10]. Previous studies have shown that operator experience, tooth anatomy, number of canals, and treatment complexity significantly influence technical outcomes [9-13]. Although specialist endodontists generally achieve higher technical standards than general dental practitioners and undergraduate students, posterior teeth and anatomically complex cases remain challenging even in specialist care [14-16].

In the United Arab Emirates (UAE), published literature has largely focused on radiographic evaluations of RCTs performed by undergraduate dental students [17-19]. There is a lack of data evaluating the technical quality of RCTs performed by certified endodontists within government healthcare facilities. Therefore, this retrospective radiographic clinical audit aimed to assess the technical quality of RCTs performed by endodontists at Khorfakkan Specialized Dental Center (CSDK) between 2022 and 2024 and to identify factors associated with acceptable technical outcomes. This audit specifically evaluates cases completed using single cone bioceramic obturation technique, which has become the standardized protocol at CSDK due to its reproducibility and widespread institutional adoption. Evaluating a single technique isolates procedural variables, though it requires careful consideration regarding its generalizability to alternative obturation methods.

Materials and Methods

This retrospective cross-sectional radiographic audit was conducted according to a prespecified audit/study protocol, submitted as supplementary material, in agreement with the STROBE guidelines for observational studies [20] and the Declaration of Helsinki (1975, revised 2000). Ethical approval was obtained from the Ministry of Health and Prevention Research Ethics Committee (MOHAP/DXB-REC/J.F.M/No. 10/2025). Patient data were fully anonymized, and the requirement for informed consent was waived by the ethics committee due to the retrospective study design.

A predefined institutional audit standard was established before data analysis. Overall radiographic technical quality was

considered to meet the audit target when at least 70% of cases fulfilled all four predefined criteria: adequate obturation length, adequate density, adequate taper, and absence of iatrogenic errors. This benchmark was used as a quality-improvement target for the centre and not as a measure of clinical treatment success.

Electronic clinical and radiographic records of 1,560 endodontically treated permanent teeth completed between 2022 and 2024 were screened. Inclusion criteria were adult patients (≥ 18 years), permanent teeth with complete root formation, treatment performed by certified endodontists, use of engine-driven NiTi rotary instrumentation, obturation using a single-cone gutta-percha technique with bioceramic sealer, and availability of diagnostically acceptable preoperative and postoperative periapical radiographs. Of the 1,560 screened teeth, 1,030 were excluded for reasons including missing or incomplete electronic/radiographic documentation, poor-quality or non-diagnostic radiographs, third molars, incomplete root formation, aberrant canal morphology, previous endodontic treatment or retreatment procedures, and alternative obturation techniques. Following screening, 530 teeth met all eligibility requirements.

Following eligibility screening, 530 teeth met the inclusion criteria. The minimum required sample size was calculated for estimating a single proportion using Cochran's formula. Based on an expected prevalence of acceptable radiographic technical quality of 60.4% derived from a previous study [21], with a 95% confidence level and a 5% margin of error, the minimum required sample size was 368 teeth [22]. To improve the robustness of subgroup analyses, 400 of the 530 eligible teeth were randomly selected using a computer-generated random-number sequence.

All treatments were carried out under rubber dam isolation. Working length was determined using an electronic apex locator and confirmed radiographically. Canal preparation was performed using a crown-down technique with ProTaper Gold rotary files, accompanied by sodium hypochlorite irrigation with ultrasonic activation and EDTA lubrication. Obturation was completed using a single-cone gutta-percha technique with CeraSeal bioceramic sealer (Meta Biomed, Cheongju, Korea), followed by immediate coronal sealing.

Postoperative periapical radiographs were independently evaluated by two calibrated examiners blinded to patient and

operator identifiers. Inter-examiner agreement was assessed using Cohen's kappa statistics. Radiographic quality was evaluated according to predefined criteria based on the European Society of Endodontology (ESE) quality guidelines [23] and previous radiographic audit studies [24,25]. Overall technical quality was classified as acceptable only when obturation length, density, and taper were adequate and no procedural errors were present.

Statistical analysis was performed using SPSS software. Categorical variables were summarized as frequencies and percentages with 95% confidence intervals. Associations between technical quality and clinical variables were assessed using Chi-square tests, with statistical significance set at $p < 0.05$. Because the study was designed as a retrospective single-centre audit and the available dataset contained uneven subgroup sizes across operators and clinical variables, the analysis was limited to descriptive statistics and univariable Chi-square tests. No multivariable regression model was performed; therefore, the reported associations should be interpreted as exploratory and not as independent predictors of radiographic technical quality.

Results

The two calibrated examiners demonstrated high inter-examiner reliability with a calculated Cohen's kappa value of $K=0.90$ ($p < 0.001$). A total of 400 endodontically treated teeth were included in the analysis. Most treatments were performed by specialist A, females constituted the majority of cases, molars were the most frequently treated tooth group, nearly half of the sample had three or more canals, and most treatments were completed in one or two visits (Table 1).

Parameter	Value	N	%
Experience	A	218	54.50%
	B	103	25.75%
	C	79	19.75%
Sex	Male	149	37.25%
	Female	251	62.75%
Age group	less than 30	99	24.75%
	30-37 years	86	21.50%
	38-44 years	113	28.25%
	45 years or older	102	25.50%
Arch	Maxillary	213	53.25%
	Mandibular	187	46.75%

Tooth	Anterior	71	17.75%
	Premolar	118	29.50%
	Molar	211	52.75%
Number of root canals	Single root canal	129	32.25%
	2 root canals	76	19.00%
	3 or more root canals	195	48.75%
Number of visits	2 or fewer	240	60.00%
	More than 2	160	40.00%

Table 1: Frequency distribution of demographic variables of participants.

Technical quality of root canal obturation

Overall, 67.3% of RCTs met all predefined criteria and were classified as having acceptable radiographic technical quality. Adequate obturation length was achieved in 79.0% of cases, adequate density in 85.3%, and adequate taper in 88.5%. Procedural errors were absent in 77.5% of treatments.

Parameter	Value	n	%
Length	Underfilling	68	17.00%
	Adequate	316	79.00%
	Overfilling	16	4.00%
Density	Inadequate	59	14.75%
	Adequate	341	85.25%
Taper	Inadequate	46	11.50%
	Adequate	354	88.50%
Procedural errors	No	310	77.50%
	Yes	90	22.50%
Overall quality	Not acceptable	131	32.75%
	Acceptable	269	67.25%

Table 2: Technical quality of root canal obturation.

Among cases with inadequate obturation length, underfilling (17.0%) was more prevalent than overfilling (4.0%). Univariable analysis showed significant associations between overall radiographic technical acceptability and number of root canals ($p < 0.001$) and number of visits ($p = 0.007$). Teeth with single root canals showed higher acceptability than teeth with three or more root canals. Cases completed in two or fewer visits showed higher

acceptability than those requiring more than two visits. Because multivariable adjustment was not performed, these findings are exploratory and should not be interpreted as independent predictors of technical quality.

Associations between endodontic treatment quality, number of root canals, and treatment visits

Statistically significant associations were observed between overall technical quality and number of canals, and number of treatment visits ($p < 0.05$). Teeth with fewer canals and those treated in one or two visits were more likely to meet acceptable technical standards as seen in table 3 and 4.

Parameter	Value	Number of canals						p-value
		Single canal		2 canals		3 canals or more		
		n	%	n	%	n	%	
Length	Underfilling	9 ^A	6.98%	9 ^A	11.84%	50 ^B	25.64%	<0.001*
	Adequate	115 ^A	89.15%	65 ^A	85.53%	136 ^B	69.74%	
	Overfilling	5 ^A	3.88%	2 ^A	2.63%	9 ^A	4.62%	
Density	Inadequate	14 ^A	10.85%	18 ^B	23.68%	27 ^{AB}	13.85%	0.046*
	Adequate	115 ^A	89.15%	58 ^B	76.32%	168 ^{AB}	86.15%	
Taper	Inadequate	7 ^A	5.43%	7 ^{AB}	9.21%	32 ^B	16.41%	0.007*
	Adequate	122 ^A	94.57%	69 ^{AB}	90.79%	163 ^B	83.59%	
Procedural errors	No	112 ^A	86.82%	64 ^A	84.21%	134 ^B	68.72%	<0.001*
	Yes	17 ^A	13.18%	12 ^A	15.79%	61 ^B	31.28%	
Overall quality	Not acceptable	26 ^A	20.16%	24 ^{AB}	31.58%	81 ^B	41.54%	<0.001*
	Acceptable	103 ^A	79.84%	52 ^{AB}	68.42%	114 ^B	58.46%	

Table 3: Association between root canal treatment quality and number of canals.

Parameter	Value	Number of visits				p-value
		2 or fewer		More than 2		
		N	%	n	%	
Length	Underfilling	24	10.00%	44	27.50%	<0.001*
	Adequate	202	84.17%	114	71.25%	
	Overfilling	14	5.83%	2	1.25%	
Density	Inadequate	34	14.17%	25	15.62%	0.774ns
	Adequate	206	85.83%	135	84.38%	
Taper	Inadequate	19	7.92%	27	16.88%	0.010*
	Adequate	221	92.08%	133	83.12%	
Procedural errors	No	200	83.33%	110	68.75%	<0.001*
	Yes	40	16.67%	50	31.25%	
Overall quality	Not acceptable	66	27.50%	65	40.62%	0.007*
	Acceptable	174	72.50%	95	59.38%	

Table 4: Association between root canal treatment quality and number of visits.

Discussion

A retrospective radiographic audit provides a realistic assessment of endodontic technical performance under routine clinical conditions. The observed 67.3% overall acceptability rate sits just below our defined institutional target of 70%. While this demonstrates a solid baseline of care by the center's endodontists, it confirms that targeted corrective measures are necessary to bridge the performance gap. In the present study, the technical quality of root canal fillings (RCFs) performed by endodontists was evaluated using established radiographic criteria: obturation length, density (homogeneity), taper, and the presence or absence of iatrogenic errors, in accordance with the European Society of Endodontology (ESE) guidelines and previous audits [24,25]. Overall, the results demonstrate a generally acceptable technical standard, while highlighting specific areas for improvement, particularly working length control.

Quality of root canal filling

Obturation length

Obturation length is a critical determinant of endodontic success. ESE guidelines recommend that root canal fillings terminate within 0.5-2.0 mm of the radiographic apex to be considered acceptable [25]. In this audit, acceptable obturation length was achieved in 79.0% of cases. This result is higher than that reported in some studies [9,12], yet lower than others involving specialist practice [10,11,13,26]. Variations across studies may be attributed to differences in evaluation criteria, as stricter thresholds (e.g., 1-2 mm) tend to reduce reported acceptability rates [26].

Tooth type significantly influenced obturation length. Anterior teeth demonstrated higher adequacy (90.1%) than posterior teeth (71.6%), a finding consistent with earlier reports [8,10]. This disparity is likely related to the simpler anatomy and better accessibility of anterior teeth, whereas posterior teeth, particularly molars, present multiple canals, curvatures, and restricted access, complicating accurate working length determination.

Regarding arch location, maxillary teeth showed a higher rate of acceptable obturation length (81.96%) than mandibular teeth (75.94%). Although this finding is not entirely consistent with previous studies [9], it may be explained by the greater anatomical complexity of mandibular posterior teeth, including narrower

canals, increased curvature, and lingual inclination, which can limit visibility and access during treatment.

Overfilling

Overfilling, defined as extrusion of obturation material beyond the radiographic apex [6], occurred in approximately 4% of cases, comparable to previously reported rates [26]. Overfilling was more frequent in maxillary teeth and molars. Common contributing factors include overestimation of working length, particularly in cases with apical resorption, excessive canal preparation, inappropriate master cone selection, and excessive compaction forces. Rotary instrumentation may further increase the risk of apical extrusion due to more aggressive apical shaping [13,26].

Underfilling

Underfilling, defined as obturation terminating more than 2 mm short of the apex [25], was more prevalent than overfilling in this study. Underfilled canals were most frequently observed in mandibular teeth (20.9%) and molars (24.17%), consistent with previous findings [9,11,26]. This trend likely reflects the anatomical challenges associated with posterior teeth, including abrupt curvatures, accessory canals, and apical deltas, which increase the likelihood of working length miscalculation. Procedural issues such as ledge formation, canal blockage, calcification, inadequate apical preparation, and poor master cone adaptation may also contribute. These findings emphasize the importance of meticulous working length determination and cone fit verification, particularly in molar teeth [26].

Density (Homogeneity) of root canal filling

Obturation density refers to the homogeneity of the filling material and its adaptation to canal walls without voids [27]. Although evidence regarding its direct impact on prognosis is mixed [28], homogenous fillings have been associated with improved periapical healing and tooth survival [29,30]. In the present study, adequate density was achieved in 85.25% of cases. This outcome is lower than some reports [13] but higher than others [9,12].

Anterior teeth demonstrated higher density adequacy than posterior teeth, likely due to simpler canal morphology. Mandibular teeth also showed higher density adequacy than maxillary teeth, consistent with previous studies [9,11]. Inadequate density, observed in 14.75% of cases, was characterized by voids within

the filling or between the filling and canal walls [31], potentially compromising the seal and increasing the risk of reinfection. The use of the single-cone obturation technique may partly explain these findings, as mismatches between cone size and canal preparation can reduce adaptation and sealing quality [26].

Taper of root canal filling

An adequate taper is defined as a uniform conical shape extending from the coronal to apical region [25]. In this audit, acceptable taper was observed in 88.50% of cases, exceeding rates reported in several previous studies [26,32]. Taper deficiencies were more common in molars than anterior teeth, reflecting the anatomical complexity of posterior teeth, including curved roots and multiple canals. These challenges may hinder consistent shaping, even when advanced NiTi rotary systems are used [33]. Careful preoperative assessment and appropriate instrumentation strategies remain essential for maintaining optimal taper.

Iatrogenic errors

Procedural errors were identified in 22.50% of cases, including canal calcification, instrument separation, and apical transportation. Such errors are more likely in calcified or curved canals, where increased torsional and cyclic stresses raise the risk of canal aberrations [34,35]. Although no significant difference was observed between arches, molars exhibited a higher incidence of errors than anterior teeth, reflecting greater anatomical and technical complexity. These findings underscore the importance of case assessment, judicious use of CBCT in line with ESE guidelines [36,37], and contemporary endodontic techniques to reduce procedural complications.

Overall acceptability and influencing factors

Overall acceptability, defined by adequate length, density, taper, and absence of procedural errors, was achieved in 67.25% of cases, comparable to previous reports using similar criteria [9]. Differences among studies likely reflect variation in evaluation frameworks and thresholds [10]. No significant association was found with patient age or sex [9,10,13]. However, tooth type, number of canals, and anatomical complexity were associated with outcomes, with teeth having three or more root canals showing lower acceptability rates, consistent with earlier findings [12]. Because multivariable adjustment was not performed, these findings cannot confirm independent predictors

of technical quality. The observed associations may be influenced by confounding between tooth type, number of canals, operator allocation, and treatment complexity.

The association between more than two treatment visits and lower technical quality should be interpreted cautiously. Multiple visits should not be interpreted as a direct cause of poorer technical quality. Rather, cases requiring more visits are likely to represent more complex cases, such as teeth with calcified canals, curved roots, persistent infection, or procedural difficulties. Therefore, treatment visits may act as a proxy for case difficulty rather than an independent predictor of technical quality.

This retrospective cross-sectional radiographic clinical audit has several limitations. This was a single-centre audit conducted in a specialized government dental centre; therefore, the findings cannot be generalized to all endodontic services or educational settings across the UAE. However, the study provides useful baseline quality-improvement data for a standardized specialist clinical setting and may support future multicentre audits. Variation in the technical quality of RCTs among endodontists likely reflects multiple factors not fully captured in the analysis, including coronal destruction, canal anatomy, calcifications, periapical pathology, referral timing, and pre-existing procedural errors from external centres. The absence of multivariable analysis limits the ability to determine whether the observed associations were independent of potential confounding variables. In addition, the methodology relied exclusively on two-dimensional periapical radiographs, which may mask voids, overlook buccolingual canal curvature, and obscure certain procedural errors due to anatomical superimposition. Consequently, the findings may overestimate true three-dimensional obturation quality. Finally, restricting the sample to a single-cone bioceramic technique limits external validity. Because all included cases were obturated using the same single cone bioceramic technique and CeraSeal sealer, the effect of sealer type on radiographic quality could not be assessed. Therefore, the findings should be interpreted as technique- and material-specific. Future prospective multicentre studies incorporating case-difficulty assessment, resource utilization, and periapical healing outcomes are recommended.

Conclusions

In this single-centre retrospective radiographic audit, 67.3% of root canal treatments met all predefined technical quality

criteria, falling slightly below the institutional benchmark of 70%. Obturation length, particularly underfilling, represented the main area requiring improvement. Teeth with three or more root canals showed reduced radiographic technical acceptability, likely reflecting greater anatomical and procedural complexity. These findings are limited to immediate radiographic technical quality and should not be interpreted as clinical success, healing outcome, or prognosis. Targeted quality-improvement measures and a structured re-audit are recommended.

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Conflicts of Interest/Disclosures

The author(s) confirm(s) that there is no conflict of interest related to the manuscript.

Availability of Data and Materials

The data supporting the findings of this study are available within the article. The datasets analysed during the current study are not publicly available due to patient confidentiality and institutional restrictions but may be available from the corresponding author on special request and subject to ethical and institutional approval.

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