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Radiographic assessment of the quality of root canal fillings performed by postgraduate residents at Universidad de Los Hemisferios, october 2024–april 2026

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Abstract
Objective: To assess the radiographic quality of root canal fillings performed by residents from the third and fourth cohorts of the Postgraduate Program in Endodontics at Universidad de Los Hemisferios between October 2024 and April 2026.
Materials and methods: This observational, retrospective, cross-sectional study included descriptive analyses and an exploratory analytical component. We analyzed 680 root canal records from 398 digital periapical radiographs of primary endodontic treatments. The principal investigator performed the initial classification, and an endodontist independently assessed the records to determine interobserver agreement. We evaluated the technical quality of root canal fillings by length, density, and taper, and classified them as adequate or inadequate. Statistical analyses included frequency distributions, chi-square tests, Cramér's V, Cohen's kappa, and Gwet's AC1 for taper.
Results: Overall technical quality was adequate in 575 root canals (84.6%). Filling length was adequate in 86.9% of canals, filling density was homogeneous in 97.6%, and taper was adequate in 98.5%. Filling material extending beyond the apex was observed in 12.5% of canals, gutta-percha extrusion in 0.9%, and sealer extrusion ("sealer puff") in 11.8%. The exploratory analysis identified a weak association between tooth group and overall filling quality (χ^2 (5) = 11.354; p = 0.045; Cramér's V = 0.129; 95% CI: 0.078–0.232). Interobserver agreement for overall filling quality was substantial (κ = 0.763; 95% CI: 0.692–0.834).
Conclusions: The overall radiographic quality of root canal fillings was favorable. Filling length was the main parameter requiring improvement. These findings should be interpreted in light of the retrospective design and the potential dependence among root canals belonging to the same tooth, patient, or resident.

Keywords: Root canal obturation, technical quality, periapical radiography, gutta-percha, endodontics

Introduction

Root canal treatment is an essential procedure in conservative dentistry, aimed at eliminating pulpal infection, preventing apical periodontitis, and preserving tooth function in the oral cavity [1,2]. Its purpose is to retain the tooth and promote the health of the periradicular tissues through chemomechanical debridement and three-dimensional sealing of the root canal system [3].

Root canal system obturation aims to achieve a seal that limits the leakage of microorganisms and fluids and helps maintain periapical health. Technical quality is commonly assessed in terms of filling length, density or homogeneity, and taper; deviations in these parameters have been associated with unfavorable endodontic outcomes [3, 6]. The European Society of Endodontology guidelines and clinical audits use standardized radiographic criteria to assess root fillings [7, 11].

The literature describes variations in quality according to tooth type, clinical setting, and level of training. Javed *et al.* [8] reported acceptable filling length in 86.2%, adequate density in 89%, and adequate taper in 94% of 653 root canals; Almnea [12] reported an acceptable overall quality in 87% of 224 root canals in mandibular first molars. Differences by academic level and tooth type have also been reported [13, 14]. El Ouarti *et al.* [15] considered a root filling adequate when it exhibits uniform density, no visible spaces between the filling material and canal walls, termination within 0–2 mm of the radiographic apex, and continuous taper. These authors found an association between inadequate root filling quality and a higher prevalence of apical periodontitis. Recent studies on endodontic education emphasize the importance of objectively assessing competency acquisition and using the findings to guide formative feedback [16, 17]. Specific evidence on postgraduate residents in Latin American settings is limited. Therefore, this study assessed the radiographic quality of root canal fillings performed by residents at Universidad de Los Hemisferios and explored the distribution of this quality across tooth groups.

Materials and Methods

A quantitative, observational, retrospective, cross-sectional study with an exploratory analytical component was conducted in the Postgraduate Program in Endodontics at Universidad de Los Hemisferios. The study sample comprised primary root canal treatments performed by residents from the third and fourth cohorts between October 2024 and April 2026. The institutional database identified 683 patients, 681 treated teeth, and 1,467 filled root canals; 640 digital periapical radiographs were retrieved separately. Available records meeting the eligibility criteria were included, without a prior sample-size calculation or probabilistic sampling. A total of 242 radiographs were excluded due to superimposition (n = 116), incomplete root development (n = 46), insufficient information (n = 63), or inadequate sharpness (n = 17). In total, 398 radiographs were evaluated, yielding 680 root canal records.

Radiographic Assessment Protocol

The unit of analysis was the individual root canal; each radiograph could contribute more than one record. Radiographs were examined using Microsoft Photos on an LCD/LED monitor with a resolution of 1920 × 1080 pixels and an 8-bit grayscale display. Images were initially viewed at 100% magnification, with zoom permitted when necessary, and without individual brightness or contrast adjustments. Assessment was based on radiographic criteria for length (termination 0–2 mm from the radiographic apex), density (homogeneity and absence of visible voids), and taper (a continuous, uniform shape). Overall quality was classified as adequate only when all three criteria met the operational definition. Overfilling beyond the apex, gutta-percha extrusion, and sealer extrusion (sealer puff) were recorded as independent, non-mutually exclusive indicators.

Interobserver calibration

The researcher and an endodontic specialist calibrated the assessment criteria using ten pilot radiographs and then independently assessed the records. The researcher's ratings were used for the primary analysis, while the endodontist's ratings were used for the symmetric agreement analysis; neither observer was considered a reference standard.

Data Collection and Analysis

Data were organized in Excel and analyzed using SPSS 25. Frequencies and percentages were calculated. The association between tooth group and overall quality was examined using Pearson's chi-square test and Cramér's V; with an exploratory interpretation because consistent identifiers were unavailable to adjust for clustering. Agreement was assessed using Cohen's kappa and 95% confidence intervals. Gwet's AC1 was calculated for taper using R and the irrCAC 1.4 package. A p-value < 0.05 was used as the threshold for statistical significance. Access to the records was authorized by the institution on February 25, 2026, and approval was granted by the Universidad Hemisferios Ethics Committee (CEUHE25-191) on March 17, 2026. Data were handled confidentially, without direct identifiers.

Results

Of the 640 retrieved radiographs, 398 met the assessment criteria and contributed 680 analytical records. Mandibular molars were the most frequent group (296; 43.5%), followed by maxillary molars (128; 18.8%). Mandibular incisors and canines accounted for 3.1% (n = 21). Age information was available for 436 records (64.1%); the mean age was 42.56 years (SD = 15.64; range: 9–83). The 18–44-year age group accounted for 212 records (31.2% of the total) (Table 1).

Table 1: Distribution of records by tooth group

Tooth group	n	%
Maxillary incisors and canines	90	13.2
Mandibular incisors and canines	21	3.1
Maxillary premolars	104	15.3
Mandibular premolars	41	6.0
Maxillary molars	128	18.8
Mandibular molars	296	43.5
Total	680	100.0

Source: Prepared by the author.

Overall technical quality was adequate in 575 root canals (84.6%) and inadequate in 105 (15.4%). Filling length was adequate in 591 (86.9%), density was homogeneous in 664 (97.6%), and taper was adequate in 670 (98.5%). Overfilling beyond the apex was present in 12.5% of cases. Gutta-percha extrusion was uncommon (0.9%), whereas a sealer puff was observed in 11.8% of cases. Overall, length accounted for the largest proportion of inadequate findings (13.1%) (Table 2).

Table 2: Main radiographic characteristics

Parameter	Favorable category	n (%)	Unfavorable category	n (%)
Length	Adequate	591 (86.9)	Inadequate	89 (13.1)
Density	Homogeneous	664 (97.6)	Non-homogeneous	16 (2.4)
Taper	Adequate	670 (98.5)	Inadequate	10 (1.5)
Overall quality	Adequate	575 (84.6)	Inadequate	105 (15.4)
Overfilling beyond the apex	No	595 (87.5)	Yes	85 (12.5)
Gutta-percha extrusion	No	674 (99.1)	Yes	6 (0.9)
Sealer extrusion	No	600 (88.2)	Yes	80 (11.8)

Source: Prepared by the author.

The proportion of adequate overall quality ranged from 75.6% in maxillary incisors/canines and mandibular premolars to 90.5% in mandibular incisors/canines. Maxillary molars showed 85.9% adequacy and mandibular molars 87.8%.

The unadjusted analysis indicated a small association between tooth group and overall quality ($\chi^2(5) = 11.354$; $p = 0.045$; Cramér's V = 0.129; 95% CI: 0.078–0.232). One of the 12 cells had an expected frequency below 5 (minimum: 3.24) (Table 3).

Table 3: Overall technical quality by tooth group

Tooth group	Adequate n (%)	Inadequate n (%)	Total
Maxillary incisors/canines	68 (75.6)	22 (24.4)	90
Mandibular incisors/canines	19 (90.5)	2 (9.5)	21
Maxillary premolars	87 (83.7)	17 (16.3)	104
Mandibular premolars	31 (75.6)	10 (24.4)	41
Maxillary molars	110 (85.9)	18 (14.1)	128
Mandibular molars	260 (87.8)	36 (12.2)	296
Total	575 (84.6)	105 (15.4)	680

Source: Prepared by the author.

Overfilling beyond the apex was observed in 85 root canals (12.5%), gutta-percha extrusion in 6 (0.9%), and sealer extrusion or sealer puff in 80 (11.8%). These findings were independent and could coexist. Overfilling beyond the apex was more frequent in mandibular premolars (24.4%) and maxillary incisors/canines (20.0%); sealer puff was most frequent in mandibular premolars (19.5%) and maxillary incisors/canines (17.8%) (Table 4).

Table 4: Findings on filling extent and extrusion by tooth group

Tooth group	Beyond apex n (%)	Gutta-percha extrusion n (%)	Sealer puff n (%)
Maxillary incisors/canines	18 (20.0)	2 (2.2)	16 (17.8)
Mandibular incisors/canines	2 (9.5)	0 (0.0)	2 (9.5)
Maxillary premolars	17 (16.3)	1 (1.0)	16 (15.4)
Mandibular premolars	10 (24.4)	2 (4.9)	8 (19.5)
Maxillary molars	12 (9.4)	0 (0.0)	13 (10.2)
Mandibular molars	26 (8.8)	1 (0.3)	25 (8.4)
Total	85 (12.5)	6 (0.9)	80 (11.8)

Source: Prepared by the author.

Inter-rater agreement for overall technical quality was substantial (κ = 0.763; 95% CI: 0.692–0.834; observed agreement: 94.3%). For length, κ = 0.772; for density, κ = 0.470; for taper, κ = 0.136; for overfilling beyond the apex, κ = 0.886; for gutta-percha extrusion, κ = 0.767; and for sealer puff, κ = 0.870. For taper, despite an observed agreement of 98.2%, Gwet's AC1 was 0.982 (95% CI: 0.972–0.992); positive agreement was 99.1% and negative agreement was 14.3% (Table 5).

Table 5: Interobserver agreement

Variable	Agreement (%)	Cohen's kappa (95% CI)	Interpretation
Length	94.7	0.772 (0.700–0.843)	Substantial
Density	98.4	0.470 (0.207–0.734)	Moderate
Taper	98.2	0.136 (−0.114–0.386)	Low
Overall technical quality	94.3	0.763 (0.692–0.834)	Substantial
Overfilling beyond the apex	97.6	0.886 (0.830–0.941)	Almost perfect
Gutta-percha extrusion	99.6	0.767 (0.510–1.000)	Substantial
Sealer extrusion (puff)	97.5	0.870 (0.810–0.931)	Almost perfect

Source: Prepared by the author.
Note: Agreement was calculated from the 680 paired records. Confidence intervals were based on asymptotic calculations; for gutta-percha extrusion, the upper limit was restricted to 1.000.

Discussion

The 84.6% rate of adequate overall technical quality is close to the 87% reported by Almnea [12] for mandibular first molars and higher than the overall 68.2% described in a systematic review of 16 studies and 12,407 root canals by Almnea *et al.* [18]. These differences should be interpreted in light of the distinct populations and clinical settings included, without attributing them to specialized training, which was not evaluated as a variable. Overall quality incorporates length, density, and taper; therefore, its proportion of fillings rated as adequate overall was lower than that for each parameter assessed individually

Length was the criterion with the highest rate of inadequacy (13.1%), similar to the findings of Javed *et al.* [8], who reported acceptable filling length in 86.2%. Two-dimensional assessment and interpretation of the apical limit may contribute to variability in this classification. Homogeneous density (97.6%) and adequate taper (98.5%) were common. However, the absence of visible gaps on a radiograph does not establish the absence of microscopic voids, as shown by comparisons with three-dimensional methods [19].

The association between tooth group and overall quality was small and should be considered exploratory, since dependence among root canals from the same tooth, patient, or resident was not controlled for. Although the anatomy of posterior teeth may pose greater challenges [4, 20], mandibular molars in this series achieved 87.8% adequate quality. This result cannot be attributed to experience, supervision, or technique because these factors were not measured. Agreement for overall quality was substantial. For taper, the discrepancy between a low kappa value and high observed agreement is consistent with the prevalence imbalance in the inadequate category; Gwet's AC1 supported high overall agreement, although negative agreement was limited. Sealer extrusion (11.8%) was more frequent than gutta-percha extrusion (0.9%), but the data do

not allow it to be linked to any specific material or technique.

These findings may inform periodic audits and formative feedback, particularly regarding working-length determination and control of the apical limit. Radiographic quality should be understood as an observable indicator of a broader clinical process that includes diagnosis, canal preparation, irrigation, and obturation [21, 22].

Conclusions

Adequate radiographic technical quality was observed in 84.6% of the root canals evaluated. Filling length was the parameter most frequently classified as inadequate, whereas density and taper showed favorable proportions. Overfilling beyond the apex was recorded in 12.5% of cases, gutta-percha extrusion in 0.9%, and sealer puff in 11.8%. Agreement for overall quality was substantial; for taper, overall agreement was high, but agreement for the inadequate category was limited. The observed association between tooth group and overall quality was small and exploratory and therefore does not establish an independent effect. The results provide an institutional baseline for audits and educational initiatives, although caution is warranted given the retrospective design and potential dependence among records.

Limitations: The main limitations include the retrospective design, two-dimensional assessment, missing age information, unequal distribution of tooth groups, and possible selection of records due to retrieval or exclusion processes.

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