

Evaluating Root Canal Treatment Quality by Undergraduate Dental Students at Gulf Medical University

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Abstract

To evaluate the radiographic quality of endodontically treated cases performed by undergraduate dental students at Thumbay dental hospital, Gulf Medical University (GMU) from 2020 to 2022.

The sample consisted of 510 randomly selected postoperative periapical radiographs from patient records at the Thumbay dental hospital Gulf Medical University (GMU). Radiographs were from patients who underwent root canal treatment (RCT) performed by 3rd, 4th and 5th year clinical undergraduate dental students. Evaluation criteria included root canal filling (RCF) length, density, taper and the presence of iatrogenic errors. Inter-examiner agreement was measured using a Cohen's kappa test. A comparison of frequency was calculated using the Chi-square test. P-values ≤ 0.05 were considered significant. Adequate length, density, and taper of the root canal fillings was observed in 77.2%, 34%, and 78.6% of cases, respectively. The rate of acceptable quality was higher for teeth treated by 5th -year students (33.3%) compared to those treated by 3rd -year students (20.5%). Density and taper were more adequate in patients treated by 5th -year students (38.6% and 82.1% respectively) compared to 3rd -year student ($p \leq 0.05$). Significant differences were observed in procedural errors based on tooth location, with higher percentages in the mandible (23.7%) compared to maxilla.

Anterior teeth showed high rates of acceptable quality (36.6%) compared to molars (22.5%). Iatrogenic errors were observed in 19.1% of cases. This study highlights the importance of training dental students to detect and correct procedural errors in root canal procedures at early clinical stage. A notable 29.3% quality improvement achieved with stainless steel K-files, underlines the imperative for enhancing future education approaches to ensure superior results and improved patient care.

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Introduction

Root canal treatment (RCT) is a commonly performed dental procedure for the treatment of infected or damaged pulp¹. This procedure requires a high level of technical expertise and precision to preserve both structural integrity and tooth function².

During training, dental students learn to perform root canal treatments proficiently, managing diverse anatomical variations like curved root canals to prevent errors and ensure precise preparations³. They also learn to select the proper final restoration for each treated tooth⁴, and develop critical skills in evaluating dental complexity, making informed decisions on patient referrals when needed⁵. As emphasized by the European Society of Endodontology (ESE), the level of accuracy achieved by undergraduates during their preclinical and clinical training translates into clinical efficiency later in their professional careers⁶. To promote high-quality undergraduate dental education, the ESE published a set of guidelines in 2006. These

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stated that students should be able to perform non-surgical endodontic treatment on single and multi-rooted teeth and should identify errors that may occur during endodontic treatment^{2,7}.

Education standards require that dental schools ensure graduate students have acquired proficiency in endodontics⁸. The ability to evaluate outcomes and to detect iatrogenic errors based on immediate postoperative radiographs are key to treatment success^{9,10}. Periapical radiographs (PAs) have limitations, including superposition with adjacent tooth structures, particularly for maxillary molars^{11,12}. For all endodontic cases, it is mandatory to obtain high-quality intraoral periapical radiographs (IOPA) that show the entire root, with at least 2-3 mm of the periapical region exposed¹³.

Factors that may impact the quality of root canal fillings (RCFs) include the anatomical characteristics of the teeth, experience level of the practitioner, root canal preparation, obturation, and the quality of record-keeping during treatment^{5,14,15}. Widely used criteria to predict treatment quality and successful outcomes include length, density (homogeneity), taper, and iatrogenic errors.

The purpose of this study was to assess the technical quality of RCT performed by the undergraduate students in GMU.

Materials and Methods

Ethical Approval

Ethical approval of the current retrospective study on evaluating the technical radiographic quality of the RCT performed by undergraduate dental students at Gulf Medical University was obtained from the Research Ethics Committee (Ref.no. IRB/COD/STD/91/April-2022).

Inclusion Criteria

Inclusion criteria were as the follows: (i) Adult patients who received complete RCT on single or multirooted teeth with complete root formation; (ii) Use of a manual stainless-steel (SS)A file in a step-back technique; (iii) received obturation using cold lateral compaction; (iv) performed by undergraduate dental students from GMU; (v) IOPA available, including preoperative, working length, master cone and

postoperative images; (vi) Radiographic images showing the entire length of the root and at least 2-3 mm of the periapical area beyond the root apex.

Exclusion Criteria

Exclusion criteria were as follows:(i) Teeth with incomplete root formation; (ii) deciduous teeth; (iii) cases of incomplete RCTs; (iv) radiographs of poor quality showing ≤ 2 mm of the PA region; (v) those that did not allow proper evaluation due to superimposition of an anatomical structure; (vi) Patients treated with engine-driven Nickel-titanium (NiTi) files; (vii) received treatment by senior doctors.

Root Canal Treatment Protocol

A rubber dam was used for isolation following anaesthesia. Access cavities were prepared using endodontic access burs. Working lengths were determined using either radiographic or electronic methods. Apex locators were preferred when available. The working length was set 0-1 mm short of the apex. Biomechanical root canal preparation was performed using the step-back technique and SS hand K files, regardless of the complexity of the root canal. The master apical file was three sizes larger than the initial binding file. Root canals were irrigated using 3% sodium hypochlorite (NaOCl) and activated with Ethylene Diamine Tetraacetic Acid (EDTA) 17% gel. Prior to obturation, the canals were rinsed with EDTA solution (17%) for 1 min and dried using paper points. A zinc oxide eugenol-based sealer in conjunction with gutta-percha cones was used to fill the root canals. Cold lateral compaction was indicated when root canals were treated with hand files. Glass-ionomer sealer or composites were used for immediate coronal sealing. A postoperative PA radiograph was taken to assess obturation status.

Evaluation of Root Canal Fillings

Technical quality of the RCFs and iatrogenic errors were assessed using DBSWIN imaging software operated using VistaSoft (digital X-ray systems from Durr Dental, Stuttgart, Germany). Following the insertion of patient details images were assessed for resolution, with the best quality images displayed on the system. Root lengths and the distance between the end

of the filling and the root apex were measured. Contrast, colour, and quality of image were controlled to avoid distortion. Radiographs were independently evaluated by a specialist in endodontics and a post-graduate student.

Evaluation Criteria

Root filling were categorized as follows:

1-Length of root fillings

A. Adequate: RCF 0-2mm from radiographic apex.

B. Overfilling: RCF extends beyond radiographic apex.

C. Underfilling: RCF >2mm from radiographic apex.

2-Density of root fillings and homogeneity

A. Adequate: No voids between root filling and root canal walls or in the RF.

B. Inadequate: Voids present between root filling and root canal walls or in the RF.

3-Taper of root fillings

A. Adequate: Consistent taper from the orifice to the root apex.

B. Inadequate: Inconsistent taper from the orifice to the root apex.

4- The presence of iatrogenic errors:

Iatrogenic errors were investigated the postoperative radiographs were:

A. Ledge formation: When the RF is shorter than 1mm from the initial working length or from the original curving of the canal.

B. Canal transportation: When the RCF material is placed external to the root canal curve at the apical third.

C. Missed/untreated canal(s): When an unfilled canal is detected on the PA radiographs.

D. Fractured instrument(s): When the fractured instrument is visible inside the root canal or with its tip protruding into the PA area.

E. Perforation: When there is extrusion of RCF material in any region beyond the root.

Overall quality was deemed " acceptable " if all variables were adequate based on protocol-specified criteria mentioned above.

Statistical Analysis

Statistical analysis was conducted using SPSS version 20. Frequencies and percentages were calculated for categorical variables including patient gender, student level, canal number, tooth type, length, density

(homogeneity), taper and the presence of iatrogenic errors. The Cohens Kappa test (K-value >0.8) was used to determine inter-rater agreement for the three parameters evaluated. The chi-square test was used to confirm differences between "adequate" and "inadequate" variables. A p-value ≤ 0.05 was considered statistically significant.

Results

Inter-rater Agreement

To assess the inter-rater agreement, the following parameters were used: length, density, and taper of the root canal filling. A Cohen's Kappa test was used to measure the level of agreement. K-values were deemed acceptable for all three parameters, namely 0.89 for length, 0.966 for density and 0.927 for taper indicating a strong level of agreement (Table 1).

Parameter	Cohen's kappa (95%CI)
Length quality	0.890
Density quality	0.966
Taper quality	0.927

Table 1. Inter-rater agreement across the three assessed parameters.

Demographic Data

The sample included 84 (16.3%) cases treated by third-year students, 219 (43.0%) cases treated by fourth-year students and 207 (40.7%) cases treated by fifth-year students. Treated cases comprised 385 (75.4%) males and 125 (24.6%) females. In total, 115 (22.6%) of the cases were aged ≤ 30 years, 138 (27.1%) were aged 30-37 years, 129 (25.1%) 38-44 years and 243 were ≥ 45 years. The highest percentage of treated teeth (n=151; 52.1%) were maxillary premolars. The lowest number of treated teeth were mandibular incisors (n=11; 4.6%). The majority (n=205; 40.1%) of treated teeth were single rooted, 147 (28.9%) had two root canals, 134 (26.3%) had three root canals and 24 (4.7%) had more than three root canals (Figure 1).

Quality Of The Root Canal Obturation

Of the 510 treated cases, 393 (77.2%) were of adequate length, 173 (34.0%) were of

adequate density, 400 (78.6%) had an adequate taper, 412 (80.9%) had no procedural errors and 149 (29.3%) were of acceptable overall quality (Figures 2-4).

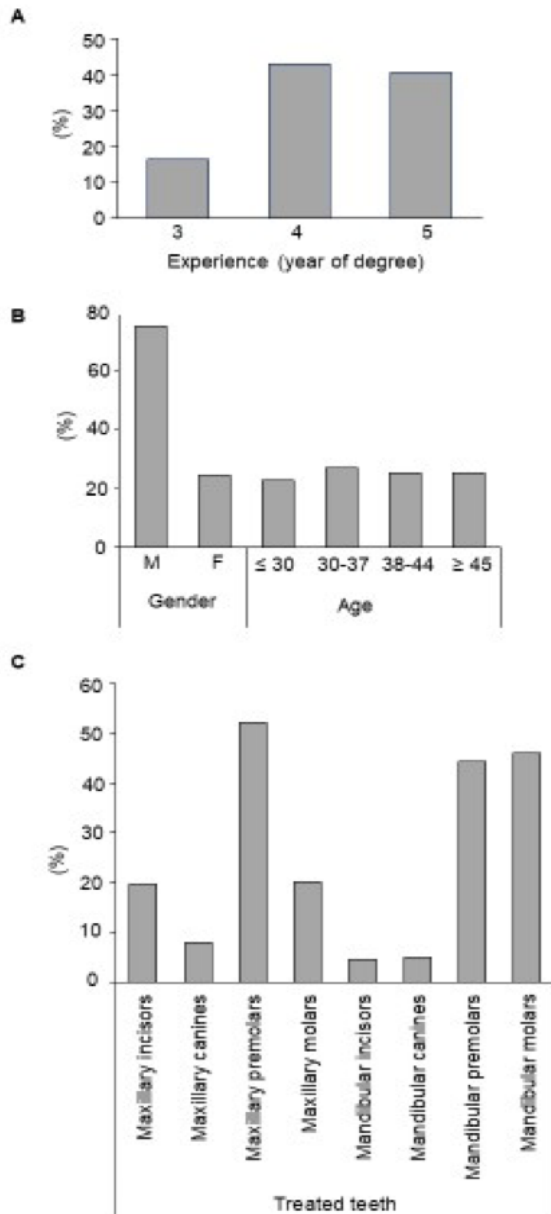


Figure 1. (A) Distribution of students according to experience. (B) Gender and age of the patients. (C) Position and location of treated teeth.

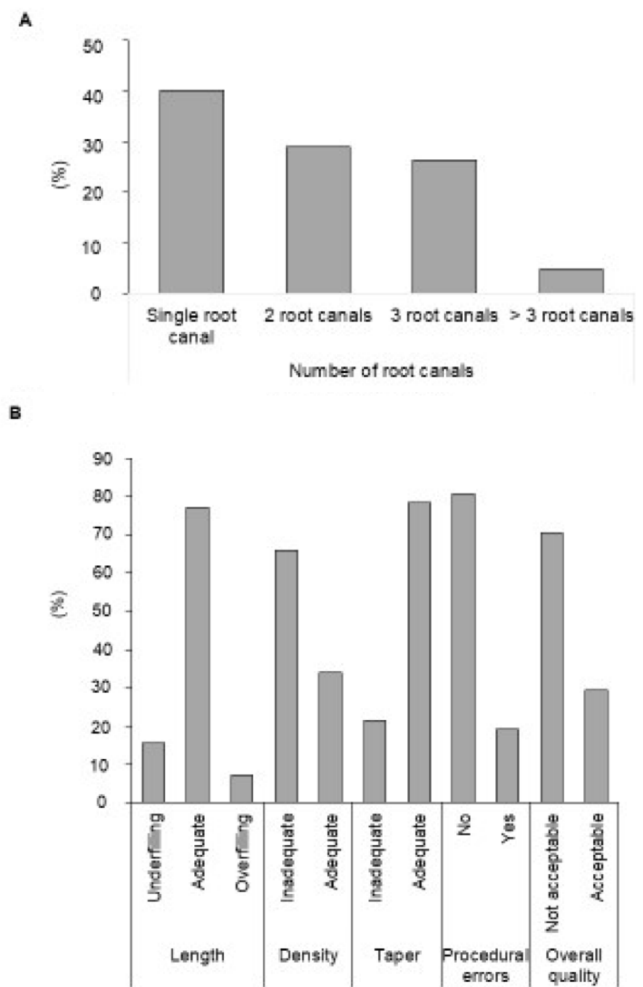


Figure 2. (A) Distribution according to the number of root canals treated. (B) Endodontic treatment quality.

Quality Of Teeth With Respect To Student Level

A significant association between endodontic treatment and the seniority of dental students was observed. Students in 5th year had a significantly higher percentage of adequate density (n=80; 38.6%) compared to 3rd year students (n=19; 22.9%; p=0.035). A significantly higher number of canal tapers were observed for 4th year (n=175; 79.9%) and 5th year (n=170; 82.1%) students compared to 3rd year students (n=55; 66.3%; p=0.013). All other associations were not statistically significant (p ≥ 0.05; Figure 4A).

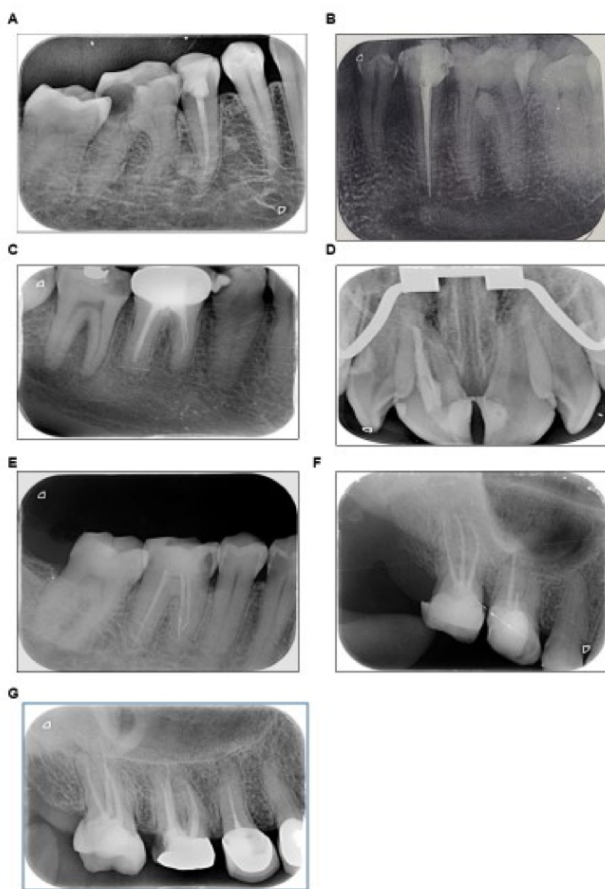


Figure 3. (A) Adequate root filling length, density, taper and no procedure errors of the mandibular 2nd premolar. (B) Overfilled root canal with apical perforation of mandibular second premolar. (C) Inadequate length-under filling of mandibular 1st molar. (D) Inadequate density and taperness of maxillary central incisor. (E) Separated instruments in the mesial canal of mandibular 1st molar. (F) Missed/ untreated canal maxillary 1st molar. (G) Ledge in maxillary 2nd premolar.

Root Canal Treatment And Patient Gender, Age And Tooth Location

No significant association between canal treatment, gender or age were observed for any indication ($p > 0.05$; Figure 4B-5A). A significant association between tooth location and filling length was observed, with a significantly higher percentage of overfilled cases 22 (10.0%) occurring in mandibular teeth ($p = 0.049$). A significant association with filling taper was similarly observed, with a higher percentage of cases with adequate taper 237 (81.7%) found in maxillary teeth ($p = 0.047$). A significantly higher percentage of procedural errors 52 (23.7%) also

occurred in mandibular teeth ($p = 0.019$). Other associations were not statistically significant ($p > 0.05$; Figure 5B).

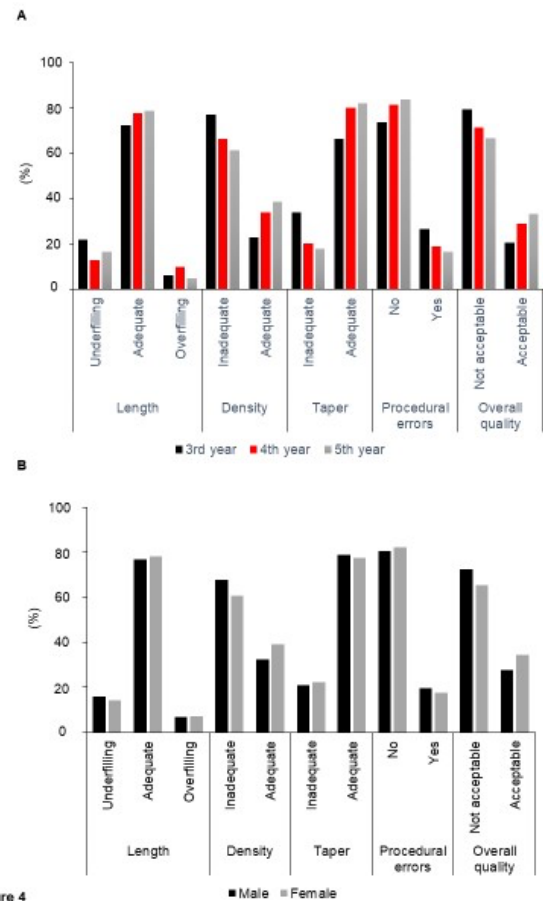


Figure 4

Figure 4. (A) Association between endodontic treatment quality and experience. (B) Association between endodontic treatment quality and patient gender.

Root canal treatment quality and tooth type

A significantly higher percentage of anterior ($n = 88$; 86.1%) and premolars ($n = 197$; 79.4%) showed an adequate length in comparison to molars ($n = 109$; 68.1%; $p = 0.008$). A significantly higher percentage of anterior ($n = 44$; 42.6%) had adequate filling density compared to molars ($n = 44$; 27.5%; $p = 0.043$). Anterior teeth also showed a significantly higher number of adequate taper cases ($n = 88$; 88.1%) compared to premolars ($n = 193$; 77.8%) and molars ($n = 118$; 73.8%; $p = 0.017$). A significantly higher number of procedural errors occurred in molars ($n = 41$; 25.6%) compared to anterior ($n = 17$; 15.8%) and premolars ($n = 40$; 16.1%;

p=0.042). A significantly higher percentage of anterior also showed acceptable quality (n=38; 36.6%) compared to molars (n=36; 22.5%; p=0.039; Figure 6A).

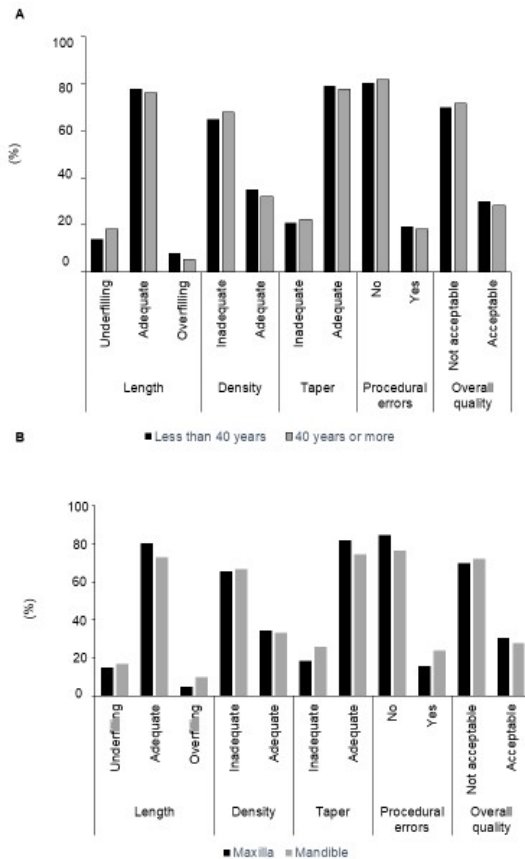


Figure 5

Figure 5. (A) Association between endodontic treatment quality and patient age. (B) Association between root canal treatment quality and tooth location.

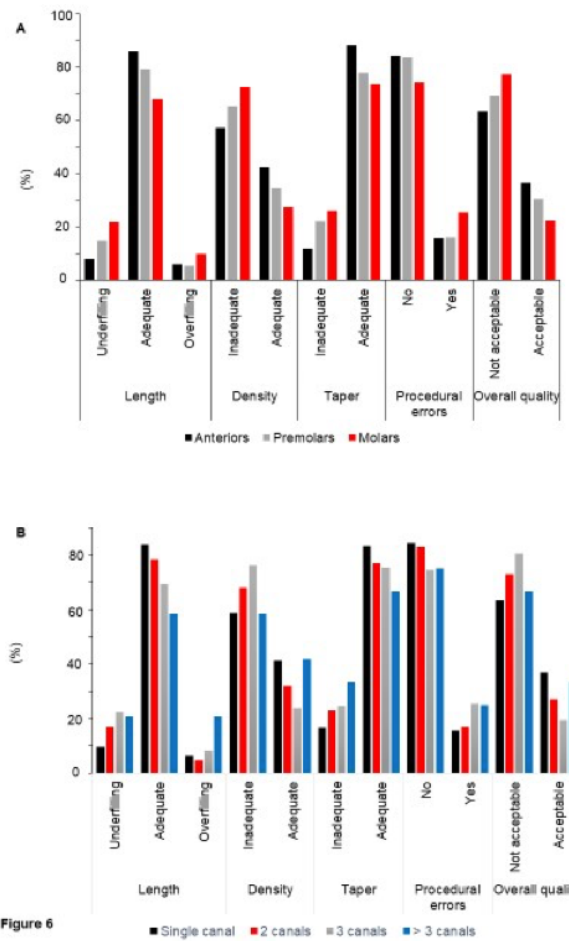


Figure 6

Figure 6. (A) Association between endodontic treatment quality and tooth type. (B) Association between endodontic treatment quality and number of canals.

Association between root canal treatment quality and number of canals

A significantly higher percentage of teeth with single canals (n=172; 83.3%) were of adequate length in comparison to teeth with 3 (n=93; 69.4%) or more (n=14; 58.3%) canals (p=0.003). A significantly higher percentage of teeth with single root canals (n=85; 41.2%) had an adequate density in comparison to teeth with 3 canals (n=32; 23.9%; p=0.008). A significantly higher percentage of teeth with single canals were of acceptable quality (n=75; 36.8%) in comparison to teeth with 3 canals (n=26; 19.4%; p=0.006). Other associations were not statistically significant (p>0.05; Figure 6B).

Discussion

In this study, filling accuracy was 77.2%, surpassing some authors¹⁶⁻¹⁹ but falling short of others²⁰. These differences stem from varying measurement scales, where some define 0.5–2 mm as sufficient while others require 0–3 mm from the filling to the root apex. The study followed a working length range of 0.5-2 mm from the radiographic apex, as recommended by the ESE (2006)². Based on the type of tooth adequate length quality was higher in anterior teeth (86.1%) compared to posterior teeth (68.1%). This may be attributable to the location and anatomical complexity of posterior teeth. Based on tooth location, maxillary teeth showed a higher adequate length (80.3%) than the mandibular teeth (73.1%), possibly due to their higher anatomic variation (narrowness and curvature). No significant differences between the third, fourth, and fifth-year students on length adequacy of RCFs were observed.

Overfilling was determined when root canal obturation material extruded beyond the apex²¹. The total overfilling was 7.1% which was higher than previous studies^{16,20,22}. This could be due to over-instrumentation or the inability to provide a proper taper and excessive pressure during filling²³. In addition, destruction of apical constriction, missing the apical stop during cleaning and shaping due to the lack of length control on SS files²¹ may have influenced the determination of working length²⁴. Overfilling occurred more often in posterior teeth (10%) than anterior teeth (5.9%) and more in mandibular teeth (10%) than maxillary teeth (4.8%).

Underfilling was determined when root canal obturation was shorter than the radiographic apex by ≤ 2 mm²¹. Underfilling was observed in 15.7% of cases, higher than previous studies^{17,24,25}. Underfilling was more prominent in posterior teeth (21.9%) than anterior teeth (7.9%). This was likely due to the curvature of roots in these locations leading to difficulties in preparation and instrumentation.

Adequate density was observed in 34% of studies which was comparable to previous studies^{1,26}. This might be explained by the fact that GMU undergraduate dental students were using NiTi spreaders, which provide better outcomes for lateral compaction, particularly for

curved canals due to their deeper penetration²⁷. The anterior teeth showed a higher density (42%) compared to posterior teeth (27.5%), mainly because of their simple anatomical structures (wide and straight). Homogeneity was dependent on the experience level of the students, with acceptable density in teeth treated by 5th year students (38.6%) higher than 4th year (33.8%) and 3rd year (22.9%).

As recommended by ESE, it is mandatory to prepare root canals in a gradual taper from the crown to the apex while maintaining apical constriction²⁰. Appropriate taperness was observed in 78.6% of our cases. Improved straight-line access in properly shaped teeth may lead to a further depth of insertion of spreaders during gutta-percha administration, thus resulting in a better homogeneity of the filling. In terms of tooth type and adequate taper, anterior teeth showed a high adequacy in taperness (88.1%) than posterior teeth (73.8%) This could be due to improved instrument control in the single wide canal¹⁸. A higher number of adequate tapers were observed in 5th year dental students compared to 3rd and 4th years.

The presence of procedural errors (ledge, canal transportation, missed canal/s, fractured instruments, and perforations) cause obturation of the root canal system^{17,24,28}. Such errors occurred in 19.1% of the cases, similar to previous studies^{16,18,24}. Accordingly, to the tooth type, procedural errors were high in molar teeth (25.6%) compared to anterior teeth (15.8%). This can be attributed to various factors, including the complex form and shape of molar roots, the challenges associated with accessing the treated tooth, difficulty in achieving sufficient coronal access during the procedure and skill level of the students^{24,29}. The highest incidence of procedural error was observed amongst third year students (26.5%). The overall acceptability rate was found to be (29.3%). Multiple factors contributing to the low quality of RCTs have been described in previous studies³⁰. These include the staff to student ratio³¹, professor-to-student ratio^{19,24,30}, case complexity and radiographic projection methods³⁰.

The clinic in GMU maintained an average staff to student ratio of 1:8 and undergraduate dental students there utilize both stainless steel and rotary nickel-titanium files for root canal preparation. However, this study focuses

exclusively on cases involving stainless steel files for the sake of standardization. Different systems were utilized with rotary files; hence, stainless steel files are utilized in this study to ensure a fair comparison. Existing literature suggests that rotary instrumentation systems offer higher technical quality and fewer procedural errors compared to manual instrumentation³². This explains the lower overall quality percentages and higher error incidence observed in our study.

Assessment of the overall parameters (length, density, and taper) showed that year 5 students (33.3%) produced the highest quality rating among all student years. The examination of technical quality in relation to tooth type and RCT showed that anterior root-filled teeth (36.6%) were of highest acceptable quality compared to posterior teeth (22.5%). This finding was consistent with previous studies^{17,30,33,34}. The lowest technical quality of RCFs was found in molars¹⁷. The overall technical quality of the teeth was also significantly associated with the number of canals per tooth.

Limitations

Limitations of this study include its retrospective design, the inherent limitations of radiographic examinations and interpretation as IOPA only offers 2D images. The angle technique and the potential impact of PA pathology on root canal length, as the apical foramen may not align with the radiographic apex due to pathological factors.

Conclusions

Our research underlines the importance of instructing students in the identification and correction of procedural errors in root canal procedures. With a noteworthy 29.3% achieving a satisfactory overall quality rate among GMU dental students using stainless steel K-files, this focuses pedagogical approach holds the potential to enhance future educational methods and interventions. Ultimately, it will elevate students' competency in conducting endodontic treatments, thereby contributing to the advancement of dental care in the future.

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Declaration of Interest

The authors report no conflict of interest.

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