Original Article

A Comparative Analysis of Root Canal Preparation Methods: Assessing Obturation Quality in Rotary Versus Manual Techniques

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ABSTRACT

Objective: To compare the radiographic quality of root canal obturation in molar teeth prepared using rotary and manual instrumentation techniques performed by undergraduate dental students.
Study Design: Cross-sectional analytical study.
Place and Duration of Study: This study was conducted at the College of Dentistry, Qassim University, Saudi Arabia, from August 21, 2024, to March 10, 2025.
Methods: A total of 60 digital periapical radiographs of molars were retrospectively allocated into two groups based on the root canal instrumentation techniques. Group 1 (n=30): manual stainless-steel files using step-back technique and Group 2 (n=30): ProTaper Gold (PTG) rotary nickel-titanium (NiTi) files using crown-down technique. All canals were obturated using cold lateral condensation with AH Plus sealer and appropriate gutta-percha points. The quality of obturation was assessed based on three parameters: length, density, and taper. A T-score (0–3) was calculated for each case. Statistical analysis was performed using Chi-square and Mann-Whitney U tests, with a p-value < 0.05 considered statistically significant.
Results: Adequate obturation in terms of length, density, and taper was observed in 63.33%, 46.67%, and 36.67% of teeth in the manual group, and in 83.33%, 90%, and 93.33% of teeth in the rotary group, respectively. Statistically significant differences were found in all three parameters between the two groups ($p < 0.05$ for length; $p < 0.001$ for density and taper). The overall T-score distribution also showed a significant difference favoring the rotary technique ($p < 0.001$). No statistically significant associations were observed between obturation quality and either gender or tooth location within the arch ($p > 0.05$).
Conclusion: Rotary instrumentation resulted in significantly better radiographic quality of root canal obturation compared to manual techniques. These findings support the integration of rotary systems into undergraduate endodontic training to enhance treatment outcomes.
Key Words: Root canal obturation, rotary instrumentation, manual technique, undergraduate students, T-score, radiographic assessment

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INTRODUCTION

Successful endodontic treatment depends on the fundamental principles of cleaning, shaping, and achieving a three-dimensional seal during obturation.[1]

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The cleaning and shaping process includes thoroughly removing the contents of the root canal to create a continuous, uniformly tapered shape while maintaining the canal's diameter as narrow as possible. Root canal shaping requires the use of different instruments, each specifically designed to fulfill a unique role in achieving optimal final preparation. Effective use of these instruments in endodontics relies on the clinician's expertise and a comprehensive understanding of their characteristics and motion mechanics. For several decades, root canal instrumentation was performed exclusively using stainless steel hand instruments until the introduction of engine-driven nickel-titanium (NiTi) files revolutionized the practice. The benefits of root canal instrumentation using NiTi files, particularly cutting efficiency and capacity to achieve conservative preparations, are well-established in the literature.[2,3] However, their use remains largely limited to experienced clinicians and postgraduate training, with

most undergraduate programs not fully incorporating the application of rotary NiTi systems.[4]

Despite the proven advantages of NiTi rotary instruments, manual techniques with stainless steel files remain prevalent in undergraduate dental training. Resistance to adopting engine-driven NiTi root canal preparation systems in these programs stems from concerns over instrument fracture and equipment costs.[5] However, growing evidence supports the excellent outcomes achieved by students using NiTi instruments, driving a gradual shift toward incorporating these techniques.[6,7] Few studies have compared the obturation quality of root canal treatments achieved by undergraduate students as a result of root canal preparation with traditional manual stainless-steel instruments versus engine-driven rotary NiTi instruments, with variable findings.

In the Middle Eastern region, limited research has focused on the comparative effectiveness of manual and rotary instrumentation in obturation quality when performed by less experienced operators, such as undergraduate students.

This study aimed to assess the quality of obturation achieved with manual and rotary instrumentation techniques during root canal treatment performed by 5th-year dental students at the College of Dentistry, Qassim University, Saudi Arabia.

METHODS

This cross-sectional study was conducted at the Alrass dental clinics of the College of Dentistry, Qassim University, Saudi Arabia. The study protocol was approved by the Committee of Research Ethics, Deanship of Graduate Studies and Scientific Research, Qassim University, Saudi Arabia (registration no. 24-01-06).

The sample size was calculated based on a previous study by Jalees et al.,[8] which reported a difference in obturation quality between rotary (86.7%) and manual (53.3%) techniques. The formula for comparing two independent proportions was used:

$$n = \frac{(Z_{\alpha/2} + Z_{\beta})^2 \, X \, [P_1(1 - P_1) + P_2(1 - P_2)]}{(P_1 - P_2)^2}$$

Where $P_1 = 0.867$, $P_2 = 0.533$, $Z_{\alpha/2} = 1.96$ for 95% confidence, and $Z_{\beta} = 0.84$ for 80% power. Using these values, a minimum of 26 teeth per group was required to achieve 80% power at a 5% significance level. To allow for potential exclusions, 30 molars were included in each group.

The digital periapical radiographs of molar teeth taken using the paralleling technique immediately after root canal obturation were included in this study. For clear radiographic interpretation, only good-quality radiographs were included where anatomical structures and obturation materials within the canals were not over-projected. The DIGORA Optime (Sordex, Helsinki, Finland) workstation was used to read the image sensor plates. SCANORA software was used to analyze the images without any enhancement. The radiographic images were assessed on a digital monitor (Hewlett-Packard ProDisplay P232 matrix of 1920 × 1080 pixels; Hewlett-Packard, CA) at 8X magnification inside the dark room.

Teeth with root resorption, severely curved roots, sclerosed canals, and retreatment cases were excluded. Sixty radiographs were selected using a non-probability sampling method and subsequently allocated into two groups using a group allocation technique. In Group-1 (n=30), the root canals were prepared with manual stainless-steel (SS) files (K-files, Mani Inc., Tochigi, Japan) using the step-back technique. Whereas in Group-2 (n=30), the root canals were prepared with full sequence Protaper Gold rotary Nickel Titanium (NiTi) files (Dentsply Sirona, Ballaigues, Switzerland) using crown down technique. The obturation in Group 1 was performed with ISO gutta-percha points (Meta Biomed, Cheongju, South Korea) and AH plus sealer (Dentsply Sirona, Konstanz, Germany) using the cold lateral condensation technique. Whereas the obturation in Group 2 was performed with Protaper gold corresponding gutta-percha points (Dentsply Sirona, Ballaigues, Switzerland) and AH Plus sealer (Dentsply Sirona, Konstanz, Germany) using the cold lateral condensation technique.

The radiographs were independently evaluated by two pre-calibrated specialist examiners with more than 10 years of experience who were not aware of the instrumentation technique used (consensus was reached at 96%). In case of disagreement, the case was discussed with another senior examiner.

The quality of the root canal fillings (RCF) was assessed based on the following three parameters: 1) distance from the filling's endpoint to the radiographic apex, 2) density of the root canal filling, and 3) taper of the root canal filling.[9]

A scoring system (T-score) was developed to evaluate the adequacy of these parameters. The T-score was calculated by assigning points to each parameter (adequate = 1, inadequate = 0) and summing them. A T-score of 3 indicated an "ideal" obturation, with all three parameters deemed adequate. A T-score of 2 was assigned when two parameters were adequate, 1 when only one was adequate, and 0 when none were adequate, categorizing the obturation as "poor."[8,10] The primary outcome focused on comparing the T-scores between the two groups.

The data were analyzed using IBM SPSS Statistics for Mac version 30.0 (IBM Corp., Armonk, NY, USA). A non-parametric Mann-Whitney U test was applied to compare differences between independent groups due to the non-normal distribution of continuous variables, while the Chi-Square test was employed to evaluate

associations between categorical variables. A *P*-value < 0.05 was considered statistically significant.

RESULTS

A total of 60 molar teeth (28 males, 32 females) were included in this study. In group 1 (manual) there were 7 (23.33%) males and 23 (76.67%) females. Whereas in group 2 (rotary) there were 21 (70%) males and 9 (30%) females. The average age of patients was 42± 8 years in group 1 and 45± 6 years in group 2.

The inter-examiner reliability k-values were 0.92 for the length of the root filling, 0.97 for its density, and 0.98 for its taper.

In group 1, the length, density, and taper of root canal filling were adequate in 19 (63.33%), 14 (46.67%) and11 (36.67%) of teeth respectively. Whereas In group 2, the length, density and taper of root canal filling were adequate in 25 (83.33%), 27 (90%) and 28 (98.33%) of teeth respectively. Statistically significant differences were observed in all three parameters—length ($p < 0.05$), density ($p < 0.001$), and taper ($p < 0.001$) — with superior outcome in the rotary instrumentation group compared to the manual group (Table 1).

Evaluation of the overall technical quality of root fillings, based on T-Scores, revealed a statistically significant difference ($p < 0.001$) favoring the rotary preparation technique. However, no statistically significant differences were observed with respect to tooth location within the arches ($p = 0.29$) or gender-related variations ($p = 0.261$) (Table 2).

Table No.1. Comparison of obturation quality between two groups (Chi square test of independence)

Obturation quality	Points	Group 1 (Manual) n (%)	Group 2 (Rotary) n (%)	Total n (%)	p-value
Length of RCF					
Adequate	1	19 (63.33)	25 (83.33)	44 (73.33)	< 0.05*
Underfilled	0	9 (30)	1 (3.34)	10 (16.67)	
Overfilled	0	2 (6.67)	4 (13.33)	6 (10)	
Density of RCF					
Adequate	1	14 (46.67)	27 (90)	41 (68.33)	< 0.001*
Inadequate	0	16 (53.33)	3 (10)	19 (31.67)	
Taper of RCF					
Adequate	1	11 (36.67)	28 (93.33)	39 (65)	<0.001*
Inadequate	0	19 (63.33)	2 (6.67)	21 (35)	

*Statistically significant value

Table No.2. Comparison of T-scores between two groups (Mann-Whitney U test)

	variable	n	Mean rank	p-value
T-Score	Manual	30	21.35	< 0.001*
	Rotary	30	39.65	
T-Score	Mandibular molars	34	30.75	0.29
	Maxillary molars	26	29.25	
T-Score	Male	28	31.70	0.261
	Female	32	28.30	

*Statistically significant value

DISCUSSION

This study aimed to evaluate and compare the radiographic quality of obturation in molars prepared using two root canal preparation techniques: rotary and conventional methods. The data for the present study comprised periapical radiographs obtained as part of routine clinical procedures from patients who underwent root canal treatment at the Alrass dental clinics, Qassim University. These radiographs were not specifically taken for research purposes. To minimize the risk of radiographic misinterpretation, images with superimposed canal fillings or over-projection of anatomical structures were largely excluded. The study included all permanent maxillary and mandibular molars that required root canal treatment, either based on clinical diagnosis or as part of elective endodontic therapy. Molars with severely curved roots, sclerosed canals, indications for retreatment, or apical root resorption were excluded from the sample.

The frequency of teeth exhibiting adequate obturation quality was higher in those prepared using the rotary instruments. A statistically significant difference was observed across all three parameters—length, density, and taper of obturation—when root canals were prepared with the rotary instrumentation technique compared to the manual instrumentation technique.

These findings align with previous studies that have consistently reported improved technical quality of obturation when using rotary instrumentation systems

compared to conventional manual techniques.[2,10] The enhanced taper and more consistent canal shaping achieved by rotary systems may contribute to better adaptation of the obturation material and a more predictable seal.

In the present study, taper exhibited the most pronounced difference between the two instrumentation techniques. This finding is consistent with Robia et al.[10] and Jalees et al.[8], who reported that rotary systems are more effective than hand files in maintaining canal curvature and producing a uniform taper—both of which are critical for achieving successful obturation.

The enhanced taper and fewer procedural errors observed with rotary instrumentation are attributable to the metallurgical and geometric properties of modern NiTi files. As Srivastava et al.,[11] explained, thermos-mechanically treated alloys used in rotary systems such as Protaper Gold offer increased flexibility and resistance to cyclic fatigue, improving canal centering ability and reducing the risk of apical transportation or ledge formation. This allows even less experienced operators, such as dental students, to achieve clinically acceptable shaping outcomes, which was evident in our results.

Nonetheless, the Protaper Gold remains highly effective in achieving precise canal shaping and high-quality obturation. In our study, the rotary group achieved significantly more obturations with T-scores of 2 or 3, indicating that the overall technical outcome is greatly improved with rotary systems. This is consistent with previous clinical findings by Tekin et al.,[12] and Javeed et al.,[13] who also observed higher rates of technically acceptable fillings in student-performed cases using rotary instruments.

The findings of this study align with those of Ribeiro et al.,[14] who, in a comprehensive meta-analysis, reported that only 26% of molars treated by undergraduate students using manual instrumentation achieved acceptable obturation quality. This low success rate highlights the inherent limitations of stainless-steel hand files, particularly in molars with complex anatomy. These findings are in agreement with the literature and emphasize that structured training in rotary endodontics should be a pedagogical priority in undergraduate education.[15-18]

The significantly higher rates of technically acceptable obturations observed in the rotary group support the growing evidence that NiTi rotary systems, such as ProTaper Gold, provide superior shaping consistency, improved canal centering, and enhanced obturation quality compared to manual techniques.

In a recent multinational survey, Nagendrababu et al.,[19] emphasized the global variability in endodontic education and advocated for wider integration of modern tools and techniques, including rotary instrumentation, magnification, and enhanced irrigation protocols. According to their survey, only 75% of institutions taught rotary instrumentation in both pre-clinical and clinical settings. Furthermore, they emphasized that students benefit from supervised use of advanced techniques to build confidence and competence before graduation.

Although there was a baseline imbalance in gender distribution between the groups, statistical analysis revealed no significant association between gender and obturation quality ($p = 0.261$), nor between tooth location and obturation quality ($p = 0.29$). These findings suggest that the observed differences in T-scores are attributable to the canal preparation technique rather than anatomical location or gender-related factors.

The results of this study support the integration of rotary NiTi systems into undergraduate curricula. However, concerns regarding instrument fracture, cost, and training time persist. Literature emphasizes that modern rotary systems—especially those designed with heat-treated alloys—have significantly reduced the incidence of file separation and procedural errors, making them safer and more predictable for student use.[11,20]

Although the rotary technique showed significantly better performance in all evaluated domains, the manual instrumentation still yielded acceptable outcomes in a notable proportion of cases. This suggests that while rotary systems offer superior performance, manual instrumentation remains a viable option in settings where rotary systems are unavailable.

Limitations of the present study should be acknowledged. First, the evaluation of obturation quality was based on two-dimensional radiographs, which may not fully capture three-dimensional filling adequacy, particularly in curved or accessory canals. While the T-score system provides a practical and validated method for assessing obturation quality, future studies could consider incorporating cone-beam computed tomography (CBCT) imaging for more detailed analysis. However, CBCT imaging may not be the most preferred method for assessing obturation quality due to concerns related to radiation and cost. Other studies have indicated that periapical radiography remains the gold standard for evaluating the quality of obturation.[21-23] Second, this was a single-center study with a relatively small sample size and was limited to molars; therefore, the findings may not be generalizable to anterior teeth or other tooth types with differing anatomical complexities.

CONCLUSION

Within the limitations of this study, rotary instrumentation was found to significantly improve the radiographic quality of root canal obturation in molars compared to manual techniques. Superior outcomes were observed in all assessed parameters—length, density, and taper of root canal fillings—when rotary

systems were employed. These findings support the incorporation of rotary instrumentation into undergraduate dental education, as it may enhance technical quality and treatment outcomes. Further studies with larger sample sizes and clinical follow-up are recommended to validate these results and assess their long-term clinical implications.

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Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Muhammad Zubair Ahmad, Yazeed Sulaiman Alqowaiei
Drafting or Revising Critically:	Muhammad Zubair Ahmad, Yazeed Sulaiman Alqowaiei
Final Approval of version:	All the above authors
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REFERENCES

1. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004; 30: 559-567.
2. Cheung GS, Liu CS. A retrospective study of endodontic treatment outcome between nickel-titanium rotary and stainless steel hand filing techniques. J Endod 2009;35: 938-943.
3. Setzer FC, Kwon TK and Karabucak B. Comparison of apical transportation between two rotary file systems and two hybrid rotary instrumentation sequences. J Endod 2010;36:1226-1229.
4. Çelik G, Özdemir Kısacık F, Yılmaz EF, et al. A comparative study of root canal shaping using protaper universal and protaper next rotary files in preclinical dental education. PeerJ 2019;7:e7419.
5. Martins RC, Seijo MO, Ferreira EF, et al. Dental students' perceptions about the endodontic treatments performed using NiTi rotary instruments and hand stainless steel files. Braz Dent J 2012;23:729-736.
6. Jungnickel L, Kruse C, Vaeth M, et al. Quality aspects of ex vivo root canal treatments done by undergraduate dental students using four different endodontic treatment systems. Acta Odontol Scand 2018;76:169-174.
7. Peru M, Peru C, Mannocci F, et al. Hand and nickel-titanium root canal instrumentation performed by dental students: a micro-computed tomographic study. Eur J Dent Educ 2006;10: 52-59.
8. Jalees M, Noor N, Javed K, et al. Comparison of quality of root canal obturation in single rooted teeth prepared by manual and rotary method. Pak Oral Dent J 2018;38:362-365.
9. Barrieshi-Nusair KM, Al-Omari MA and Al-Hiyasat AS. Radiographic technical quality of root canal treatment performed by dental students at the Dental Teaching Center in Jordan. J Dent 2004;32:301-307.
10. Robia G. Comparative radiographic assessment of root canal obturation quality: manual verses rotary canal preparation technique. Int J Biomed Sci 2014;10:136-142.
11. Srivastava S. Root Canal Instrumentation: Current Trends and Future Perspectives. Cureus 2024;16:e58045.
12. Alperen TEKİN YEH, Şeyda ERŞAHAN, Nur Sena ARIKAN. Technical quality of root canal treatment performed by undergraduate students using rotary instruments versus hand instruments: A Retrospective Study. Selcuk Dent J 2023;10:468-473.
13. Javed MQ, AlAttas MH, Bhatti UA, et al. Retrospective audit for quality assessment of root fillings performed by undergraduate dental students in clinics. J Taibah Univ Med Sci 2022;17: 297-303.
14. Ribeiro DM, Réus JC, Felippe WT, et al. Technical quality of root canal treatment performed by undergraduate students using hand instrumentation: a meta-analysis. Int Endod J 2018;51:269-283.
15. Algahtani FN, Barakat RM, Alqarni LM, et al. Undergraduate Endodontic Training and Its Relation to Contemporary Practice: Multicenter Cross-Sectional Study in Saudi Arabia. Int J Clin Pract 2023;2023: 7484570. 20230104.
16. Hänni S, Schönenberger K, Peters OA, et al. Teaching an engine-driven preparation technique to undergraduates: initial observations. Int Endod J 2003;36:476-482.
17. Abu-Tahun I, Al-Rabab'ah MA, Hammad M, et al. Technical quality of root canal treatment of posterior teeth after rotary or hand preparation by fifth year undergraduate students, The University of Jordan. Aust Endod J 2014;40:123-130.
18. Arbab-Chirani R and Vulcain JM. Undergraduate teaching and clinical use of rotary nickel-titanium endodontic instruments: a survey of French dental schools. Int Endod J 2004;37:320-324.

19. Nagendrababu V, Gopinath VK, Nassar M, et al. A multi-national survey-based evaluation of undergraduate/predoctoral endodontic education. Int Endod J 2024 20241028. DOI: 10.1111/iej.14160.
20. Chaniotis A and Ordinola-Zapata R. Present status and future directions: Management of curved and calcified root canals. Int Endod J 2022;55 Suppl 3: 656-684.
21. Eleftheriadis GI and Lambrianidis TP. Technical quality of root canal treatment and detection of iatrogenic errors in an undergraduate dental clinic. Int Endod J 2005; 38: 725-734.
22. Er O, Sagsen B, Maden M, et al. Radiographic technical quality of root fillings performed by dental students in Turkey. Int Endod J 2006;39: 867-872.
23. Vukadinov T, Blažić L, Kantardžić I, et al. Technical quality of root fillings performed by undergraduate students: a radiographic study. Scientific World J 2014; 2014:751274.