Original Article

Comparison of Quality of Root Canal Obturation in Single-Rooted Teeth Performed by Undergraduate Students Using Manual and Rotary Methods (Cross-Sectional Study)

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Abstract

Objective: The study aimed to reveal the influence of different root canal instrumentation methods (manual and rotary) on the features of root canal obturation, as well as determine which method gives the superior quality of obturation.

Methods: A total of 165 case sheets of endodontically treated teeth (incisors, canines, and single-rooted premolars) were included in our samples from the outpatients in the University of Sulaimani, College of Dentistry, each with the radiograph of the treated tooth attached to it. The case sheets were separated into manual and rotary groups. The evaluation was done for three parameters (homogeneity, taperness and length of filling material).

Results: The results show a statistically significant ($p < 0.05$) relationship between manual and rotary instrumentation regarding all three parameters evaluated. There is a higher ratio of adequate length of filling material, adequate homogeneity, and adequate taperness in rotary instrumentation than in manual instrumentation.

Conclusions: This study concludes that rotary NiTi instrumentation improves the quality of root canal obturation regarding the 3 parameters. The findings advocate for the inclusion of rotary NiTi instruments in the undergraduate dental curriculum to enhance endodontic treatment outcomes. In the future, more resources are needed regarding the homogeneity of the obturation by different instrumentation and obturation techniques.

Keywords: *Root canal treatment, Obturation, Manual instrumentation, Rotary instrumentation.*

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Introduction

With the increasing importance of preserving the natural teeth, root canal therapy (RCT) is now commonly performed in regular dentistry practice[1]. RCT is conducted to address and resolve the infection in the root canal and to prevent any infection around the apex of the tooth root[2].

Successful root canal treatment is related with clinical procedures that may not follow appropriate requirements and thus do not sufficiently regulate the infection of the root canal due to anatomical distinctions such as isthmuses, lateral canals, recesses, and dentinal tubules; these anatomical variations are typically unapproachable by the instrumentation and antimicrobial agents used during endodontic therapy[3].

The procedure of cleaning and shaping involves mechanical and chemical preparation to remove both organic and inorganic substances using endodontic files and chemicals[4]. Previously, this was done using a standardized method called manual instrumentation, which involved the use of stainless steel hand files. However, during repeated use, it has been revealed that Stainless steel (SS) hand instruments possess restricted flexibility, leading to potential operational errors such as transportation, ledges, or perforations[6]. Additionally, these changes no longer comply with the ISO standards established in 1958 for manual instruments. Nickel-titanium (NiTi) rotary instruments were introduced in the field of endodontics as a solution to the limitations of stainless-steel hand files[7]. The concept of using NiTi alloy for endodontic instruments was first conceived in 1975[8], in the field of endodontics. NiTi alloys have a lower modulus of elasticity compared to stainless steel (SS), allowing for the use of these tools in curved canals with a reduced likelihood of procedural error. Advancements in technology have led to significant changes in the design of the active part of these instruments, including variations in taper and differences in helical angle and cut angle. These instruments incorporate design characteristics that enable doctors to carry out shaping treatments with greater ease, speed, and predictability. However, the implementation of NiTi rotary instruments in undergraduate training has faced challenges due to concerns about instrument fractures and the high cost of infrastructure. This opposition persists despite multiple reports suggesting a low incidence of such complications[9].

The taper of the file influences the shaping techniques used in root canal procedures. When the taper of the root canal increases, it creates more space for irrigation fluids. This allows for a more thorough cleaning process, making the procedure more effective, Additionally, it aids in the obturation of the root canal, resulting in a higher quality of obturation. Simultaneously, a larger taper leads to the removal of a greater quantity of dentin from the walls of the canal. Obturation, also referred to as the filling of the root canals, is a crucial stage in achieving successful root canal therapy. The previous stage of cleaning and shaping has a direct impact on the capacity to fill a root canal. Most approaches utilize a core filling material and sealer to achieve thorough obturation[10]. An ideal root canal obturation should have a 3-dimensional seal of the canal, with no overfill or underfill, and minimal or no voids because inadequate obturation can result in treatment failure[11].

With any obturation technique, several criteria can be used to measure the quality of root canal obturation. The criteria include the distance from the filling material to the radiographic apex, the density of the root-filling material (including any voids), and the taper of the canal, all of which influence the technical quality of the root-filling. The assessment of the technical outcome of RCTs has primarily relied on radiographic evaluation methods. To avoid leakage and enhance the strength of the tooth, it is crucial to achieve a consistent and filled seal from the top to the bottom third of the root canal. The optimal working length should be within a range of 0.5 to 2mm from the radiographical image of the root apex. In addition, employing a rotary file technique for root canal instrumentation will result in a more conical preparation of the channel and enhance the quality of obturation[12].

The objective of this study was to demonstrate the impact of different root canal instrumentation methods (manual and rotary) on the characteristics of root canal obturation and to determine which method yields better outcomes when performed by undergraduate students.

Materials and methods

A random sample of a total of 165 case sheets (73 rotary instrumentation case sheets and 92 manual instrumentation case sheets) was collected. This included radiographs of single-rooted teeth (incisors, canines, single-rooted premolars) that were endodontically treated by 5th-grade undergraduate students in the College of Dentistry, class 2023-2024, using both manual and rotary methods. The radiographs were all periapical radiographs of endodontically treated teeth taken using the bisecting technique and both traditional and digital radiographs were included. This study took about 9 months.

The included periapical radiographs were only of single-rooted teeth. Only case sheets with good quality radiographs, which were taken digitally, were included. Any case sheets with poor quality radiographs or which did not include radiographs of final root canal obturation and radiographs of multiple-rooted teeth were excluded from our research.

The undergraduate students, all in the 5th grade, administered the treatments and took radiographs of the cases used. Radiographs were evaluated by four observers in the 5th class. Two observers evaluated the manual and rotary radiographs using a rotary instrument made from nickel-titanium by the Orodeka company, which was manufactured in China, and assigned scores. The other two observers then reevaluated the radiographs.

The clinical examination, diagnosis, and RCT protocol were conducted under the supervision of endodontists and restorative specialists.

Root canal treatment procedure

In every instance, rubber dam isolation was used along with a local anesthetic. The access cavity was prepared using straight-line access and the step-back technique with a Stainless-steel K-file (Dentsply, Rogen dental) for manual instrumentation. For rotary cases, this was achieved using the FKG Rotary device and FKG NiTi rotary files. Root canal irrigation was done with sodium hypochlorite and normal saline[13].

After shaping and cleaning, the root canal was dried using a paper point (Rogen dental, Meta-Biomed). Obturation was performed using the lateral condensation technique for manual cases, while single cone obturation and modified single cone techniques were employed for rotary cases, utilizing Gutta Percha (Rogen Dental, Meta-Biomed, HTM) (D-line). The type of sealer used was zinc oxide-eugenol under the trade name (EugeSeal safe endo) in a thick consistency.

Evaluation of the root canal filling:

Evaluating the quality of root canal fillings was based on the post-operative radiographs.

Radiographs were evaluated by four students (5th grade), two of whom evaluated rotary instrumentation and manual instrumentation radiographs and both recorded the scores for each radiograph using the criteria shown in Table 1. Then the two other students re-evaluated the radiographs and recorded the scores for each radiograph, using the same criteria and without seeing the scores previously recorded by the other two students. Finally, all the scores were evaluated and compared to ensure accuracy. Minimal differences in scores were found in a couple of cases and the final decisions were made by an endodontic specialist.

The assessment of the root canal fillings was conducted based on the measurement of the distance between the end of the filling and the radiographic apex of the tooth (referred to as the length of the filling), the uniformity of the filling within the canal, and the taper of the filling. The evaluation criteria used are those established by Barrieshi-Nusair et al. The specific descriptions of these indices can be found in Table 1[14].

A T-score system was utilized to evaluate the quality of root filling, specifically the length of the root canal filling. Scores of 0, 1, and 2 were assigned to indicate the quality of the fillings. Conversely, scores (0, 1) were assigned to assess the uniformity of the root canal filling and scores (0, 1) to evaluate the taper of the root canal filling. To obtain a more precise understanding, please refer to Table 1[9,15,16].

Statistical analysis

The statistical analysis was conducted using SPSS 26.0 software (IBM SPSS Statistics, Chicago, IL) with a significance level set at $P < 0.05$. After two weeks, a thorough reexamination of all the results took place, and the level of agreement between the measurements was assessed using the Kappa test. The chi-square test was used to determine the association between rotary and manual instrumentation.

Results

In this study, 165 patients with a mean age of 34.7 ± 14.5 (range, 13-73) years, comprising 94 women (57%) and 71 men (43%), were examined. The interrater reliability for the working length was 0.986, with an asymptotic standard error of 0.014. At the same time, for the taper and the homogeneity of the gutta-percha, there was a perfect agreement with the value of (1) and standard error of (0).

There was a statistically significant relationship between the manual and rotary instrumentation regarding the working length ($x^2(2,165) = 8.2$, $p = 0.014$), as shown in Figure 6. The ratio of adequately filled canals for the rotary instrumentation technique was significantly higher (82%) than for conventional manual instrumentation (65.2%), and the frequency ratio of overfilled canals seemed to be higher in manual conventional technique (17%) than for rotary instrumentation cases (4%). The ratio of underfilled canals was higher in manual instrumentation (17%) than for rotary-treated cases (13%).

Regarding the homogeneity of gutta-percha, a statistically significant relationship was observed ($\chi 2$ (1, 165) = 49.328, $p = 0.001$), as shown in Figure 4. The ratio of the inadequate density of obturation in rotary

instrumentation cases was significantly lower (17%) than for manual instrumentation (72%), and the ratio of adequate density was significantly higher in rotary instrumentation (82%) than in manual instrumentation (27%).

As for the taperness of the root canal filling, there was also a statistically significant relation between the manual and rotary instrumentation($x^2(1,165) = 18.5$, $p=0.001$), as shown in Figure 5.

The ratio of adequate taperness in rotary instrumentation was higher (50%) as compared to manual instrumentation (32%), and the ratio of inadequate taperness in rotary instrumentation (32.1%) was almost half of that recorded for manual instrumentation (62.5%).

For a more detailed understanding of the results, please refer to Table 2.

Table 1: Description of the indices, length, homogeneity, and taper of root canal filling.

Variables	Criteria	Definition
Length of root canal filling	0 (under)	Root canal filling end > 2mm from the radiographic apex (Figure 2).
	1 (adequate)	Root canal filling ends < 2mm from the radiographic apex (Figure 1).
	2 (over)	Root canal filling beyond the radiographic apex (Figure 3).
Homogeneity of root canal filling	0 (inadequate)	not uniform homogeneity of root filling and the presence of voids (between root canal filling materials) and canal space (between tooth and root canal filling material) (figure 4).
	1 (adequate)	Uniform homogeneity of root filling without voids (between root canal filling materials) and canal space (between tooth and root canal filling material) (Figure 1).
Taper of root canal filling	0 (inadequate)	Non-harmonious taper from the coronal to the apical part of the root canal filling (Figure 5).
	1 (adequate)	Harmonious taper from the coronal to the apical part of the root canal filling (Figure 1).

Table 2: The results of the evaluation for the 3 parameters of both manual and rotary instrumentation.

Cases	No.	Length		Homogeneity		Taperness	
Manual	92	adequate	(60) cases [ratio=65,2%]	Adequate	(25) cases[ratio=27%]	adequate	(32) cases [ratio=34.7%]
		underfilled	(16) cases[ratio=17%]				
		overfilled	(16) cases [ratio=17%]	Inadequate	(67) cases [ratio=72%]	inadequate	(60) cases [ratio= 65.2%]
Rotary	73	adequate	(60) cases[ratio=82%]	Adequate	(60) cases [ratio=82%]	adequate	(50) cases [ratio= 68.4%]
		underfilled	(10) [ratio=13%]				
		overfilled	(3) cases [ratio=4%]	Inadequate	(13) cases [ratio=17%]	inadequate	(23) cases [ratio=31.5%]
Total	165	adequate	[72.7%]	Adequate	[51.5%]	adequate	[49.7%]
		underfilled	[15,8%]				
		overfilled	[11.5%]	Inadequate	[48.5%]	inadequate	[50.3%]

Figure 3: shows the comparison of adequacy and inadequacy of the working length of the root-filled material between manual and rotary instrumentation.

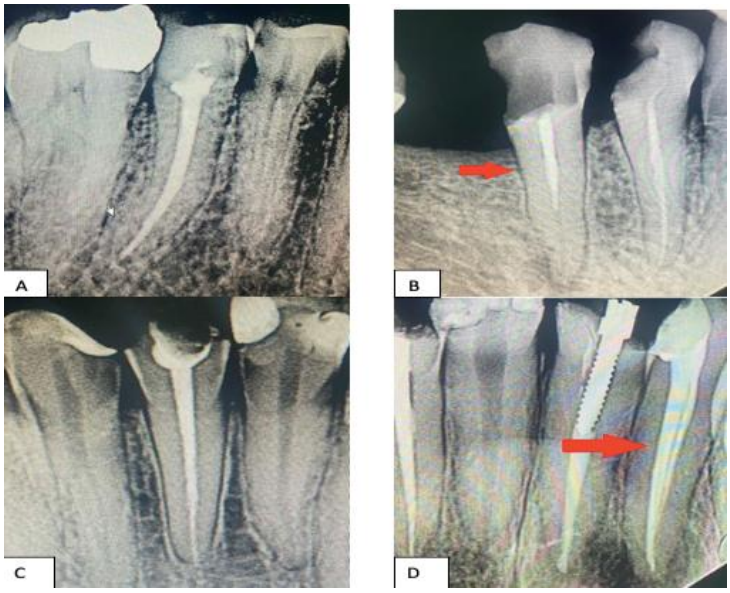
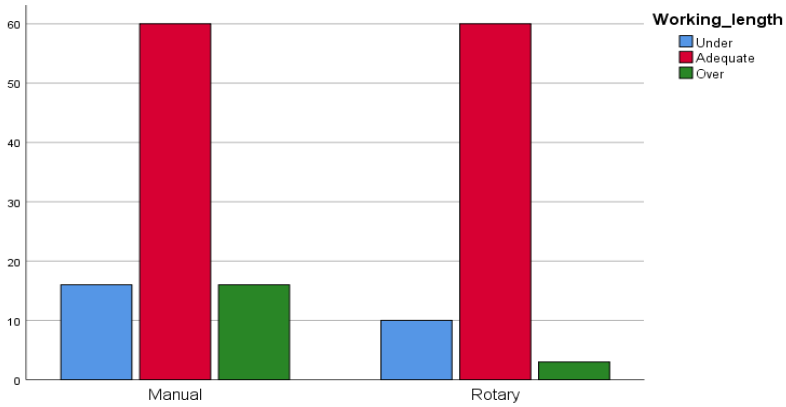


Figure 1: (A) Adequate length, harmonious taper, uniform homogeneity of root canal filling. (B) Root canal filling is located more than 2mm away from the radiographic apex and is not adequately filled. (C) A root canal filling that extends beyond the radiographic apex. (D) Lack of uniformity and inadequate homogeneity in the root filling as well as the presence of spaces between the materials used to fill the root canal represented by the red arrow.

Figure 2: Non-harmonious taper from the coronal to the apical part of the root canal filling.



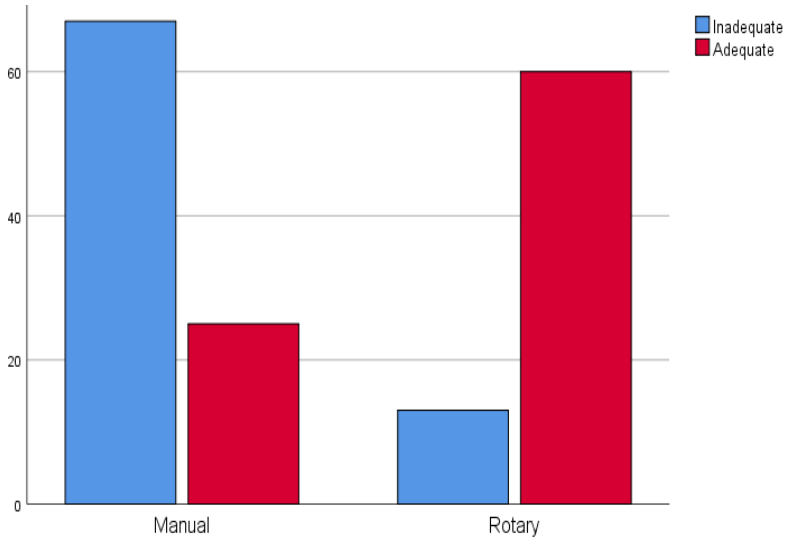


Figure 4: Shows the comparison of adequacy and inadequacy of the homogeneity of the root-filling material between manual and rotary instrumentation.

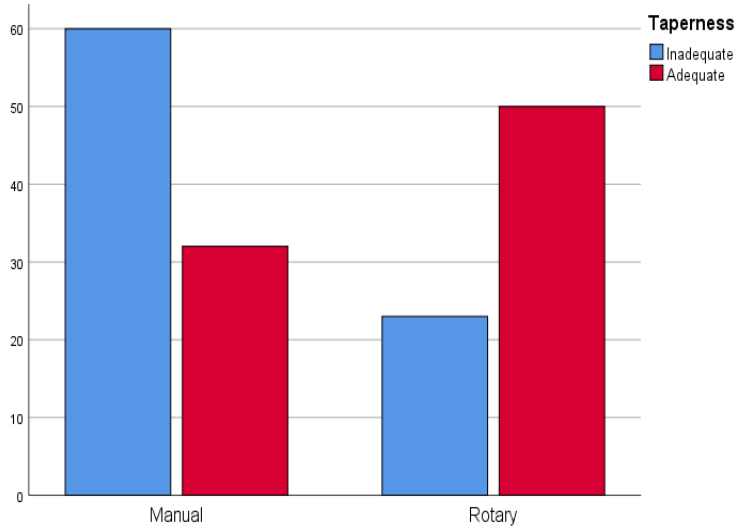


Figure 5 shows the comparison of adequacy and inadequacy of the taperness of the root-filling material between manual and rotary instrumentation.

Discussion

There are two types of instrumentation: the recently used rotary NiTi files with rotary devices and the earlier conventional manual instrumentation using stainless-steel files or NiTi hand files.

Several studies have reported that when inexperienced dental students perform chemo-mechanical preparation the step-back technique may result in insufficient preparation of the root canal or increased procedural mistakes, such as apical transportation, strip perforations, and ledges[17,18]. Certain authors have argued that NiTi instruments have significantly enhanced the quality of root canal shaping compared to stainless steel, as they create a well-tapered root canal shape that is ideal for obturation[12]. A comparison of quantitative and qualitative data indicated that students achieved better canal preparation results with rotary instrumentation[6].

Additionally, various root canal obturation materials with distinct characteristics are routinely used for obturating endodontically instrumented teeth, employing several techniques for obturation.

Using the cold lateral condensation technique may result in voids and incompletely filled canals due to its sensitivity[18]. Voids in close proximity to potentially infected canal walls can potentiate microleakage and, ultimately, the failure of root canal treatment[19].

This study aimed to assess the relationship between the radiographic quality of obturation in single-rooted teeth following instrumentation with conventional stainless steel hand files and rotary NiTi files.

In this study, we have compared the obturation quality in incisors, canines, premolars that typically have a single-root achieved by two types of canal instrumentation (rotary instrumentation and manual conventional stainless steel hand file instrumentation). The quality of obturation using the related techniques (cold lateral condensation technique implemented with hand instrumentation and single cone obturation technique and modified single cone obturation technique used with rotary instrumentation) was compared based on evaluation of periapical radiographs using bisecting technique regarding length of root canal obturation, homogeneity of the canal obturation, and taperness of the root canal obturation.

This study showed a significant relationship between conventional stainless steel file hand instrumentation and rotary NiTi file instrumentation regarding the length of root canal filling material. Significantly higher frequency of adequately filled canals was observed with rotary instrumentation technique than for Conventional manual instrumentation, as shown in Table 2. In addition, there appeared to be a higher frequency ratio of overfilled canals with the manual conventional technique than for rotary instrumentation cases, as shown in Table 2, and the ratio of underfilled canals was higher in manual instrumentation than for rotary treated cases (Table 2).

These findings support those of Robia G.'s study[9] and others[20,21], in contrast to Govindaraju et al and others who found no substantial relationship between the length of obturation and type of instrumentation[22,23,24]. Although Govindaraju et al observed a higher frequency of under-filling of root canals in rotary-treated cases(%13.3) compared to manual (%6.7)[22,23], this might be the result of differences in sample size and type of tooth being treated. Meanwhile, their results were the same as ours regarding the overfilling and adequate filling of canals[22]. Robia G's study[9] found no difference in the frequency of overfilling canals between manual and rotary instrumentation. This result could possibly be due to variations in the obturation technique used and the limited sample size.

Our second comparison parameter was the homogeneity(density) of obturation material. Some researchers considered the lateral adaptation of the root filling material with the dentin wall as a criterion and mostly agreed that if a void was extant between the filling and the canal walls, the density of filling should be regarded as insufficient. These studies stated that inadequate density may result in failure of RCT because of microleakage along the root canal[9,19].

In this study, a highly significant relation has been achieved regarding homogeneity for the rotary system in comparison to conventional hand stainless steel files, and inadequate density of obturation in rotary instrumentation cases was significantly lower than for manual instrumentation cases (Table 2). These results are corroborated by Govinda Raju et al, who concluded that more satisfactory obturation quality is achieved with the rotary system than the manual instrumentation technique[22]. Furthermore, Robia G., in 2011, reported significantly higher occurrence of cases with adequate density (83.3%) in the rotary group than in the manual group(46.7%), while revealing inadequate density of 16.7% among rotary cases (and 53.3% for manual instrumentation cases[9,21].

In contrast, several studies, such as Ul Ehsan et al, reported that the type of instrumentation did not significantly affect the homogeneity of obturation; the frequency of adequate density was not significantly higher for the rotary group than for the manual group[23-26]. This result was perhaps due to variations in the operator's skills and years of experience.

This study showed a significant relationship between the root canal taperness of obturation and the two types of instrumentation system. A higher frequency of adequate taperness of obturation was observed following the use of rotary instrumentation than conventional manual instrumentation, and a higher inadequate taperness of obturation ratio was observed for hand instrumentation than for the rotary system. (Table 2).

These results corroborate the results of Khan et al who found 84% of adequate taperness was achieved following the use of rotary instrumentation and 30% for manual instrumentation, while only 16% of rotary-treated cases had inadequate taperness in comparison to 70% for conventional hand instrumentation [24].

Our results were comparable to those of Jalees et al., who reported a significant difference in root canal filling taper between the two types of instrumentation techniques[23].

Additionally, several studies have reported a significant relationship between the taperness of root canal fillings and the application of the rotary system versus conventional manual hand instrumentation. These studies showed that the rotary method had higher

acceptable obturation results and significantly greater effectiveness compared to the manual conventional method[9,19,20,21,23,25].

In this study, we detected a significant relationship between the type of instrumentation and the overall quality of root canal obturation. We determined substantial differences between the two groups (manual, rotary) in the overall quality of obturation.

Under the conditions of this study, inexperienced dental students were more effective at obturating single root canals using the rotary instrumentation method. There was a significantly higher frequency of cases having ideal obturation with the rotary group as compared to the manual group. This result has been supported by many previous studies[20,24,25,27,28], such as Robia G in 2011 also reported a significant relation in T-score between the rotary against manual group (p-value, 0.001), concluding better quality of obturation in the rotary group in comparison to the manual group[9].

Additionally, Jalees et al. stated that the T-score, indicating the general quality of obturation, revealed a statistically significant relationship (p-value, 0.025) between the two groups. A higher frequency of cases with T-score 3 (reflected as having ideal obturation) existed in the rotary group (46.7%) compared to the manual group (20.0%)[23].

While some studies reported no significant relation in quality of instrumentation following the use of rotary and manual instrumentation[29], that could have been because Ni-Ti hand files were used by the conventional manual instrumentation group. The current study's advantages lie in evaluating the quality of root canal obturation accomplished by undergraduate students using manual and rotary methods.

This comparison highlights the effectiveness of various techniques in achieving optimal root canal treatment outcomes. Understanding the differences in quality between manual and rotary instrumentation methods can contribute to the development of dental education curricula and inform clinical practice guidelines, potentially improving patient care and outcomes. Additionally, the study may identify areas where further training or refinement of techniques is needed for undergraduate students.

Overall, their mechanical efficiency and ergonomic benefits make rotary files a preferred choice for many endodontic procedures.

Regarding limitations of this study, generally, obturation quality was evaluated by intraoral periapical radiographs via the bisecting technique, which only provides a two-dimensional image of a three-dimensional form.

Long-term follow-up is essential to assess the clinical and radiographic success of treatments performed using two dissimilar instrumentation methods, as the disinfection procedure performed during treatment may not have been adequately reflected.

Several types of single-rooted teeth were examined for the quality of obturation, including premolars, canines, lateral incisors, and central incisors, which have different canal shapes and which would have affected the specificity of the study. Additionally, while the results may not have accurately represented students' actual skills in accomplishing adequate obturation forms, using only one type of tooth would have resulted in a very limited sample.

In terms of clinical relevance, this study addresses several important areas for both dental education, including skill development and curriculum improvement, and patient care, such as the quality of root canal treatment, patient safety, and comfort.

Conclusion

This study concludes that rotary NiTi instrumentation improves the quality of obturation in terms of length, homogeneity, and taper, particularly when performed by inexperienced dental students. The findings advocate for the inclusion of rotary NiTi instruments in the undergraduate dental curriculum to enhance endodontic treatment outcomes.

Due to their ergonomic benefits and mechanical efficiency, rotary files are often the preferred choice for many endodontic procedures. Future research could be enhanced by including a larger sample size and focusing on a specific type of single-rooted tooth, leading to more specific and reliable results.

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