ORIGINAL ARTICLE

OUTCOME OF ENDODONTIC PROCEDURES PERFORMED BY DENTAL INTERNS USING STAINLESS STEEL AND NiTi FILES: A 10- YEAR RETROSPECTIVE STUDY

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Background: Preparation of root canal according to its desired anatomy and complete disinfection is a laborious task. Several factors influence the endodontic treatment including operator's skill and knowledge, anatomy of the tooth, the instruments and equipment used. In the past stainless-steel instruments were used to prepare the root canal but it causes many iatrogenic errors. Nickel titanium instruments evolved to overcome the iatrogenic damages caused by stainless steel instruments. Keeping this in mind a comparative study was conducted on the clinical work of dental intern using stainless steel files and progressively taper nickel titanium instruments. The objective of this study was to compare the performance of interns using either stainless Steel or progressively tapered hand operated NiTi instruments. **Methods:** This retrospective study included post-treatment radiographs of root canal treatments performed by interns by using either stainless steel files or NiTi Protaper files, in the endodontic department of Hamdard University Dental Hospital, Karachi, Pakistan. It was a 10-year audit, from 2008 to 2018, of endodontic performance. A total of 1219 post treatment radiographs of good quality and showing at least 2mm periapical area beyond the root apex were included. In SS group, preparation were performed by step back method, while in NiTi group the Protaper instruments for hand were used. Scoring criteria was used to evaluate technical quality. The data was analysed using SPSS for windows version 17.0. Chi-square test was used to determine difference in proportions between the outcomes in SS and NiTi groups at $p \leq 0.05$. **Results:** A total of 1219 radiographs were included out of which 584 (47.9%) belonged to SS and 635 (52.1%) to NiTi group. Overall satisfactory performance was in 553 (45.4%) teeth. Treatment done with NiTi was only marginally better than that achieved with SS files (NiTi n=298 (46.9%), SS n=255 (43.7%)). In the SS group, there were more overfills and internal and external transportation ($p<0.001$). NiTi reported more cases of inadequate lateral seal and separated instruments ($p<0.05$). **Conclusion:** Endodontic performance of interns was not improved with progressive taper NiTi manual instruments.

Keywords: Dental Interns; Endodontic performance; Nickle Titanium Protaper; Stainless steel

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INTRODUCTION

Preparation of root canals with stainless steel (SS) files is an operator dependent and skill intensive procedure. The skills and experience of operator play a major role in determining the treatment outcomes in these preparations.[1] Stainless steel instruments are known to cause several iatrogenic damages such as transportation, zip, rip, ledge and canal blockade to name a few.[2] The technique sensitivity of these files has resulted in the innovation in the design and composition of endodontic files resulting in shift towards universal usage of nickel titanium (NiTi) instruments.[3] However, due to financial restraints the stainless steel endodontic instruments are still in clinical use in the developing world.[4,5]

Every year, dental interns deputed in the academic institutions perform endodontic treatment as a part of their mandatory one year house job. These young dentists are required to perform endodontic treatment on variety of cases using stainless steel files. It is a common belief of the hospital authorities that by doing so, they will learn the basics of root canal therapy. It is usually also a cost effective measure of recruiting clinical service providers on a time bound contract for the hospital administration. Given the lack of experience of these young clinicians, it is reasonable to assume that a lot of iatrogenic mishaps will occur. These observations were confirmed by an audit of endodontic performance of these interns.[6] Similar experiences have been reported by various researchers across the globe. A satisfactory performance ranging from 13–33% has been reported.[7–10]

Keeping these drawbacks of stainless steel files in mind, the Department of Operative Dentistry at Hamdard College of Medicine and Dentistry introduced progressively tapered hand operated NiTi instruments to be used by dental interns. The

rationale behind this decision was based on the research that reported a favourable outcome and a drastic decrease in procedural errors during endodontic procedures performed by these NiTi instruments.[11] Although, previous studies have compared the performance of students in using both types of instruments, these studies were either done on simulated resin blocks or had a small sample size.[12–14] We conducted this study on performance of dental interns in a clinical setting. In addition, we could not find another study on dental students that reported use of progressively tapered hand operated instruments over a long period and with a sample of over one thousand teeth. We also report on a 10-year audit, from 2008 to 2018, of endodontic performance by these dental interns.

The objective of this study was to compare the performance of interns using either of the two endodontic instruments, i.e., SS and progressively tapered hand operated NiTi instruments. We scored the post-operative radiographs of endodontic procedures according to a 'scoring criteria'. Our null hypothesis was that there is no difference in quality of treatment, using either the SS instruments or progressively tapered hand operated NiTi instruments.

MATERIAL AND METHODS

This retrospective study included post-treatment radiographs of root canal treatments performed by interns in the endodontic department of Hamdard University Dental Hospital, Karachi, Pakistan. Institutional review board granted the approval for conducting the study (Ref: HCM&D/751/2018). All the treatments were performed under the supervision of two trained senior instructors. The treatments with stainless steel instruments were performed during years 2008-2012, while the ones by NiTi instruments were performed during 2014-2018.

We calculated sample size on the basis of findings of Gluskin *et al*. who reported canal transportation after use of flexo file or GT NiTi files by novice operators.[15] We considered following parameters: Canal transportation with flexo file no 25 (0.08±0.09) vs GT rotary file no 25 (0.06±0.09) in the apical third. Using OpenEpi Version 3 open source calculator for comparing two means, at 99% confidence interval and a power of 80%, a sample of 473 for each group and an overall sample of 946 was calculated. Data was inflated to include 1219 radiographs (SS=584, NiTi=635) that satisfied the inclusion criteria of our study.

We identified potential confounders that could influence the outcome of our study. One of the most important was the effect of operator's skills. Although all interns were exposed to similar training, it is logical to assume some may achieve greater skill levels than others. However, this effect could not be studied since data was not collected at operator level. The effect of intern's duration of clinical rotation on outcome of root canal therapy was identified. The interns are assigned for a 6 week rotation in Endodontics. During this period, their performance is assumed to improve and this aspect may be a subject for future research. Another confounder was the effect of number of times each set of files was used on the frequency of errors and this effect could not be studied since this was a retrospective audit.

In the stainless steel group, all the canals were prepared with a standard step back technique and root fillings were done with the help of lateral condensation technique using a calcium hydroxide-based root canal sealer (Sealapex, Kerr Dental Inc., USA). Briefly, after local anaesthesia and access opening, working length was obtained with a bisecting angle radiographic method. Stainless steel K type files (Mani Inc., Utsunomiya City, Japan) were used for canal preparation and completed with a master apical file which was three files larger than the initial binding instrument. Two to three larger files were used to flare the canal with each instrument taken 1mm shorter to working length. Copious irrigation with 2.5% sodium hypochlorite was used between each file. For obturation a master gutta percha cone corresponding to the master apical file was used. The same master cone was used to coat sealer into the canal. Finger spreader and corresponding accessory gutta percha points were used to complete the obturation. Following this a hot instrument was used to sear off the excess gutta percha and access cavity was filled with a temporary restorative material.[16]

The preparations in NiTi group were done with hand operated, progressively tapered instruments (Protaper Universal Hand Files, Dentsply Sirona, USA). The root fillings were preformed using matching tapered cone technique using above mentioned sealer. Briefly, protaper universal instruments for hand were used as per manufacturer's instructions. After access opening and radiographic working length determination, Shaper 1 (S1), Shaper 2 (S2), and Finisher 1 (F1) were taken to full length using clockwise and pull movements. Files were periodically wiped off the debri with gauze. Irrigation (2.5% Sodium hypochlorite) was used after each file. A gauging criterion was used to decide the master file. Obturation was performed with a protaper cone corresponding to the master file.[17]

A total of 1219 post treatment radiographs of good quality and showing at least 2 mm periapical area beyond the root apex were included in the study. Radiographs not meeting the criteria were discarded.

Since conventional radiography is practiced, selected radiographs were converted into digital format by photographing them with a digital SLR camera (Nikon D500 with Sigma Macro Lens 105 mm EX DG). The camera setup was mounted on a tripod for the sake of reproducibility. Photographed images were digitally modified to enhance the contrast and brightness with the Microsoft Office Picture Manager. Resultant images were imported to Microsoft PowerPoint for final viewing on a 14.1-inch LCD screen as a full screen image. One trained and calibrated endodontist observed the radiographs. The calibration process involved two raters viewing and scoring together 30 radiographs representative of iatrogenic mishaps under study. A consensus was developed if there was a difference in scoring. In case of multi-rooted teeth, worst score of individual root was recorded as score for that particular tooth. For scoring iatrogenic errors, where a root exhibited more than one error, both were recorded. The criteria given below were used to evaluate the technical quality.

Criteria modified from Kirkevang, Eleftheriadis and Khabbaz was used and described as follows.[18–20]

Apical taper/flare

a. Adequate: adequate width of gutta percha in apical third and a gradually tapering canal
b. Inadequate: less than adequate width of gutta percha in apical third

Length of Root Filling

a. Adequate fill, if 0–2 mm from radiographic apex
b. Short fill, if <2 mm from radiographic apex
c. Over fill, if root filling was found beyond the apex

Lateral seal of root filling

a. Adequate seal, if no void present along the entire length of root filling
b. Inadequate seal, if voids present anywhere along the length of root filling

Iatrogenic errors

a. No error, if a homogenous root filling was following original anatomy of a curved root and ending 0–2 mm from radiographic apex
b. Internal Transportation, if the root filling was not following original anatomy of a curved canal
c. External Transportation, if root filling was found beyond the apex
d. Unprepared apical third, if canal appeared blocked in apical third
e. Separated instrument, if a separated endodontic instrument was observed in the canal
f. Perforation, if root filling was observed along lateral or medial walls of root or in furcation area

Coronal seal

a. Adequate if appeared sealed radiographically and at least 4 mm of thickness
b. Inadequate if radiographic signs of less than 4mm thickness, partial or complete absence of a coronal restoration

The unit of analysis in our study was individual tooth. In case of multi-rooted teeth, the canal with worst score was considered. The data was analysed with the help of SPSS version 17.0 Frequency distribution of the categorical variables were computed. Chi square test was applied to determine the difference in proportions between the outcomes in SS and NiTi groups at $p \leq 0.05$.

RESULTS

We included a total of 1219 radiographs of teeth on which root canal treatment done out of which 584 (47.9%) belonged to SS and 635 (52.1%) to NiTi group. The basic data of our study is presented in table no 1 which shows almost all groups of teeth are represented. We also included 2nd molars since those interns that performed acceptable endodontics in first molars are later allowed second molar endodontic treatment as well. We wanted to include as many cases as possible so that a good mix of cases could be analysed. In order to calculate inter-examiner reliability, 10% of the radiographs were reviewed by two trained dentists. Cohen's kappa was run to observe the agreement. There was a good agreement between the two examiners, $\kappa = 0.69$, $p<0.001$.

Our overall results are summarized in table 2 which shows a satisfactory performance in 553 (45.4%) teeth. This table also shows that overall treatment done with NiTi was only marginally better than that achieved with SS files. Table 3 reports the comparison between SS and NiTi on various aspects of treatment quality, e.g. taper, length, lateral seal and coronal seal. There were more overfills in SS group, while NiTi had significantly more underfills. Similarly, NiTi reported more cases of inadequate lateral seal. Table 3 also reports specifically on the comparison of iatrogenic errors. There were significantly more cases of internal and external transportation in SS group, while separated instruments were found significantly more in NiTi group. Table-4 exhibits a cross tabulation of outcome with tooth type. Except for central incisors, Niti was more successful than SS. None of the comparison was statistically significant. Internal and external transportation was found more in SS group in first molars, while instrument separation was more common in NiTi group in first molar compared to other tooth groups.

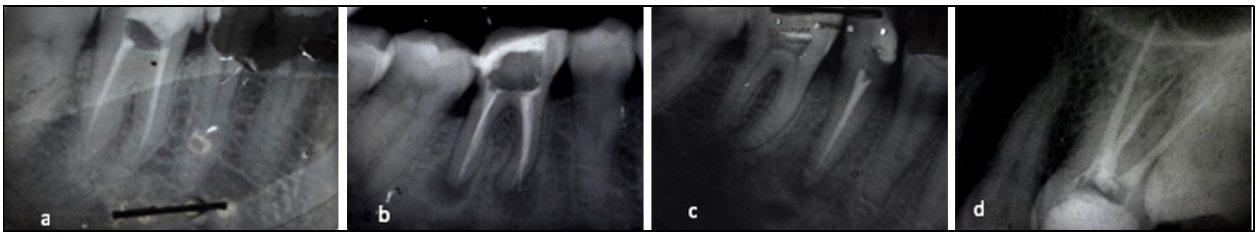

Figure-1: Representative cases from SS group. (a) Internal transportation (b) External transportation (c) Un-prepared apical third in a premolar (d) Adequate fill in a molar

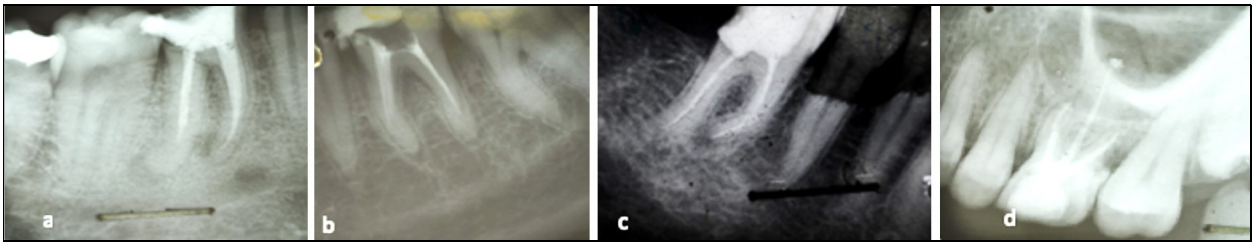

Figure-2: Representative NiTi cases (a) Blocked canal (b) Internal transportation (c) Separated instrument (d) Adequate fill in molar

Table-1: Frequency and percentage according to tooth type, location and file system

Arch		Tooth							Total	
		Central Incisor	Lateral Incisor	Canine	First Premolar	Second Premolar	First Molar	Second Molar		*p* value
Maxilla	SS	74	46	25	56	60	65	0	326	.056
	NiTi	61	47	41	84	48	72	1	354	
Total		135 (19.9)	93 (13.7)	66 (9.7)	140 (20.6)	108 (15.9)	137 (20.1)	1 (0.1)	680 (100)	
Mandible	SS	7	5	8	21	61	149	7	258	.016
	NiTi	7	5	9	52	53	153	2	281	
Total		14 (2.6)	10 (1.9)	17 (3.2)	73 (13.5)	114 (21.2)	302 (56)	9 (1.7)	539 (100)	
File System	SS	81	51	33	77	121	214	7	584 (48)	
	NiTi	68	52	50	136	101	225	3	635(52)	
	Total	149 (12.2)	103 (8.4)	83 (6.8)	213 (17.5)	222 (18.2)	439 (36)	10 (0.8)	1219 (100)	.001

Table-2: Overall adequate results according to tooth type and file system

	Anterior	Premolars	Posterior	Total
SS	97 (28.9)	97 (22.2)	61 (13.5)	255 (43.7)
NiTi	102 (30.4)	131 (30.1)	65 (14.4)	298 (46.9)
Total	199 (59.4)	228 (52.4)	126 (28)	553 (45.4)

Table-3: Detailed presentation of procedural and iatrogenic errors. Int trans= internal transportation, ext trans= external transportation, u apical 3rd= unprepared apical third, sep inst= separated instrument, perf= perforation

	Taper		Length		Lateral Seal		Coronal Seal		Iatrogenic Errors					
	Adequate	Inadequate	Adequate	Short	Overfill	Adequate	Inadequate	Adequate	Inadequate	Int Trans	Ext Trans	U Apical 3rd	Sep Inst	Perf
SS	293 (24)	291 (23.9)	304 (24.9)	205 (16.8)	75 (6.2)	377 (30.9)	207 (17)	493 (40.4)	91 (7.5)	56 (4.6)	48 (3.9)	277 (22.7)	50 (0.4)	4 90.3)
NiTi	327 (26.8)	308 (25.3)	304 (24.9)	284 (23.3)	47 (3.9)	323 (26.5)	312 (25.6)	572 (46.9)	63 (5.2)	9 (0.7)	1 (0.1)	287 (23.5)	30 (2.5)	1 (0.1)
Total	620 (50.9)	599 (49.1)	608 (49.4)*	489 (40.1)	122 (10)	700 (57.4)*	519 (42.6)	1065 (87.4)*	154 (12.6)	65 (5.3)*	49 (4)*	564 (46.3)	35 (2.9)*	5 (0.4)
p value			*p*<0.001			*p*<0.001		*p*<0.001		*p*<0.001	*p*<0.001		*p*<0.001	

Table-4: Detailed presentation of overall quality according to tooth group and file system

	SS		NiTi		Total	
	Adequate	Inadequate	Adequate	Inadequate	Adequate	Inadequate
Central	55 (67.9)	26 (32.1)	41 (60.3)	27 (39.7)	96 (64.4)	53 (35.6)
Lateral	27 (52.9)	24 (47.1)	32 (61.5)	20 (38.5)	59 (57.3)	44 (42.7)
Canine	15 (45.5)	18 (54.5)	29 (58)	21 (42)	44 (53)	39 (47)
1PM	40 (51.9)	37 (48.1)	75 (55.1)	614 (4.9)	115 (54)	98 (46)
2PM	57 (47.1)	64 (52.9)	56 (55.40)	45 (44.6)	113 (50.9)	109 (49.1)
1M	59 (27.6)	155 (72.4)	65 (28)	162 (72)	122 (27.8)	317 (72.2)
2M	2 (28.6)	5 (71.4)	2 (66.7)	1 (33.3)	4 (40)	6 (60)
Total	255 (43.7)	329 (56.3)	298 (46.9)	337 (53.1)	553 (45.4)	666 (54.6)

DISCUSSION

A 10-year retrospective study of endodontic treatments performed by interns is reported and presents it as comparison of outcome between SS and NiTi. This was the first study that compared the effects of using Protapers (progressive tapered hand NiTi) files with a large sample size and over a long time period. The data of study was partially presented in a conference.[6] The data revealed a dismal performance of interns. Therefore, it was later decided to stop using the SS files and switch to NiTi. Considerations were given to rotary NiTi. However, the department at that time didn't have enough resources, and a popular brand was available for hand use as well. Therefore, Protaper for hand use was universally adopted for interns only. It may be noted here that in their 4th year of training, the undergraduate students are still taught step back technique with SS files on the extracted teeth. During their mandatory internship year which constitutes the 5th year of training, the interns are first given a hands-on demonstration of NiTi files after which they all allowed to start treating the actual patients in the out-patient's department.

Our overall results revealed an acceptable endodontic score in 553/1219 (45.4%) of cases. There were 256/584 (43.7%) acceptable cases in SS and 297/635 (46.9%) in the NiTi groups. The acceptable score was found in 59.5%, 52.4% and 28% cases from anterior, premolar and molar teeth, respectively. Our overall results reveal an acceptable score in 45.4% of cases with 43.7% for SS and 46.9% for NiTi. The acceptable score was found in 59.5%, 52.4% and 28% cases from anterior, premolar and molar teeth respectively. These results suggest that the intended benefit of adopting the NiTi was only marginal. Somewhat similar conclusions were drawn by Haug *et al* who reported similar performance with either SS or NiTi, manual or rotary instrumentation.[22] In their study they concluded that it's the case difficulty rather than the method that determined the outcome. In present study, although the frequency of errors was somewhat similar, the type of error exhibited a different trend. Over instrumentation followed by loss of working length was the most common error in our study.

These results are in agreement with the findings of a recent meta-analysis.[21] The meta-analysis included those studies that were performed with manual instrumentation only. It is logical to assume that since the use of these hand instruments require a lot of manual dexterity, the in-experienced interns performed equally poorly with both types of instruments. If we compare the SS stratum of our study with other studies done on SS, we observe a great diversity in the reported outcomes. The highest percentage of adequate cases was reported by Tronstad.[23] They reported adequate performance in 91% cases with similar results in all groups of teeth. Somewhat similar results were reported by Benenati also.[24] Both of these studies were based on follow-ups. The reason for better performance in these studies may be due to better training, operators' experience and case selection.

In contrast, Elsayed reported adequate performance of students in only 24.2% of cases.[25] These results are inferior to what we have presented in this paper. Elemam and Aliuddin reported adequate results in 53% which is somewhat similar to our overall result of 45.4%.[26, 27] However, our interns performed poorly in molars as compared to their study (28% vs 43%). Adequate length of root filling was similar to our results, however taper and density was better than our results.

Some studies have not reported overall adequate results making it difficult to compare and draw any inferences. For instance, a study by Hendi did not report on their overall results.[28] They found apical transportation as the most common error. Whereas we observed inadequate taper as the most common finding.

Donnelly reported a 57% and 45% acceptable performance with NiTi instruments in anterior and posterior teeth respectively.[29] This is comparable to results of present study (60% anterior, 46% posterior). Similarly, our results partially agree with those reported by Fong *et al.*[30] They used rotatory version of protaper universal in their study. While the performance in anterior (60% vs 60.8%) and premolars (55.2% vs 66.7%) is certainly comparable, but among molars (28% vs 68.2%) showed that our interns performed poorly in molar endodontics. Sub-analysis of our data revealed that canal taper (17.1%) and canal length (14.8%) were major contributors to poor performance in molars. This difference in outcome is probably due to lack of proper supervision and training offered to the interns to build their capacity to undertake molar endodontics. A study by Ali *et al.* found file separation as the most common procedural error by interns using NiTi instruments.[31] These differences can be attributed to possible overuse of files by study participants, however an audit of potential reasons may reveal the true cause.

Present study results suggested only a marginal improvement in endodontic outcome for NiTi instruments. While NiTi was able to reduce the iatrogenic errors (Table-4) the overall effect of this reduction was only minimal due to a large sample size. These results agree with those of Haug *et al* as discussed earlier.[22] Majority of studies have

demonstrated the superiority of NiTi over SS and disagree with our overall findings. One reason maybe that hand instruments were compared to the engine driven instruments in these studies. The engine driven instruments are easier to use and have been demonstrated to perform better in various studies.[2,32] Therefore, the conditions of our study may not be comparable to those studies and comparisons drawn may not be valid. In spite of these results the benefits of NiTi overweigh its shortcomings. For instance, a recent study found better quality of life experience in patients treated with manual NiTi as compared to SS.[33]

The present study is distinct from previous studies due to its large sample size. We couldn't find any study with a sample size of over 1200. Most of the previous studies also did not calculate a sample size.

Current study results were limited by the fact that it was a retrospective study. The success criteria were based on the radiographic appearance. Also, no follow up data was available to observe the effect of instrument type on long term success. Another limitation was the fact that effect of operator skill and instrument fatigue on the results could not be studied. We recommend future studies that are based on audit of corrective measures taken by the respective department in order to enhance the performance of interns. This may include but not limited to follow-up studies.

CONCLUSION

Within the limitations of the current study we conclude that the endodontic performance of interns was not improved with progressive taper NiTi manual instruments. While overall percentage of failure was similar, both groups differed in type of failure.

Conflict of Interest:

The author AH has received honorarium and free material from Dentsply. He was also their key opinion leader.

AUTHORS' CONTRIBUTION

AH: Concept, data collection, data evaluation, statistics and write up. JAK: Data evaluation, write up and reviewing. AA: Data collection. FRK: Write up and reviewing. FN: Reviewing.

REFERENCES

1. Burke FM, Lynch CD, Ní RíOrdáIn R, Hannigan A. Technical quality of root canal fillings performed in a dental school and the associated retention of root-filled teeth: a clinical follow-up study over a 5-year period. J Oral Rehabil 2009;36(7):508–15.
2. Schafer E, Schulzbongert U, Tulus G. Comparison of Hand Stainless Steel and Nickel Titanium Rotary Instrumentation: A Clinical Study. J Endod 2004;30(6):432–5.
3. Rafeek RN, Smith WA, Mankee MS, Coldero LG. Radiographic evaluation of the technical quality of root canal fillings performed by dental students. Aust Endod J 2012;38(2):64–9.
4. Vadhera N, Makkar S, Kumar R, Aggarwal A, Pasricha S. Practice profile among endodontists in India: A nationwide questionnaire survey. Ind J Oral Sci 2012;3(2):90.
5. Gupta R, Rai R. The adoption of new endodontic technology by Indian dental practitioners: a questionnaire survey. J Clin Diagn Res 2013;7(11):2610–4.
6. Hasan A, Ali SA, Syed S. Quality of Endodontic Treatment Performed by House Officers. In Lahore: International Association for Dental Research; [Internet]. 2011 [cited 2018 Sep 20]. Available from: https://iadr.abstractarchives.com/abstract/pakistan11-151828/quality-of-endodontic-treatment-performed-by-house-officers
7. Hayes SJ, Gibson M, Hammond M, Bryant ST, Dummer PM. An audit of root canal treatment performed by undergraduate students. Int Endod J 2001;34(7):501–5.
8. Er O, Sagsen B, Maden M, Cinar S, Kahraman Y. Radiographic technical quality of root fillings performed by dental students in Turkey. Int Endod J 2006;39(11):867–72.
9. Pettigrew LK, Jauhar S, Lynch CD, Savarrio L, Carrotte P, Hannigan A. An audit of the quality of root canal treatments performed by undergraduate dental students on single-rooted teeth in Glasgow dental hospital and School. Eur J Prosthodont Restor Dent 2007;15(2):72–6.
10. Ilgüy D, Ilgüy M, Fisekçioglu E, Ersan N, Tanalp J, Dölekoglu S. Assessment of root canal treatment outcomes performed by Turkish dental students: results after two years. J Dent Educ 2013;77(4):502–9.
11. Cheung GSP, Liu CSY. A Retrospective Study of Endodontic Treatment Outcome between Nickel-Titanium Rotary and Stainless Steel Hand Filing Techniques. J Endod 2009;35(7):938–43.
12. Abu-Tahun I, Al-Rabab'ah MA, Hammad M, Khraisat A. 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(3):123–30.
13. Alrahabi M. Comparative study of root-canal shaping with stainless steel and rotary NiTi files performed by preclinical dental students. Technol Health Care 2015;23(3):257–65.
14. Jungnickel L, Kruse C, Vaeth M, Kirkevang LL. Quality aspects of ex vivo root canal treatments done by undergraduate dental students using four different endodontic treatment systems. Acta Odontol Scand 2018;76(3):169–74.
15. Gluskin AH, Brown DC, Buchanan LS. A reconstructed computerized tomographic comparison of Ni-Ti rotary GT files versus traditional instruments in canals shaped by novice operators. Int Endod J 2001;34(6):476–84.
16. Cohen S, Burns RC, editors. Pathways of the pulp. 8th ed. St. Louis: Mosby, 2002; p.1031.
17. Cohen S. Cohen's pathways of the pulp. Eleventh edition. Hargreaves KM, Berman LH, Rotstein I, editors. St. Louis, Missouri: Elsevier, 2016; p.907.
18. Kirkevang LL, Ørstavik D, Hörsted-Bindslev P, Wenzel A. Periapical status and quality of root fillings and coronal restorations in a Danish population. Int Endod J 2000;33(6):509–15.
19. Eleftheriadis GI, Lambrianidis TP. Technical quality of root canal treatment and detection of iatrogenic errors in an undergraduate dental clinic. Int Endod J 2005;38(10):725–34.
20. Khabbaz MG, Protogerou E, Douka E. Radiographic quality of root fillings performed by undergraduate students: Quality of root fillings. Int Endod J 2010;43(6):499–508.
21. Ribeiro DM, Réus JC, Felippe WT, Pacheco-Pereira C, Dutra KL, Santos JN, *et al*. Technical quality of root canal treatment performed by undergraduate students using hand

instrumentation: a meta-analysis. Int Endod J 2018;51(3):269–83.
22. Haug SR, Solfjeld AF, Ranheim LE, Bårdsen A. Impact of Case Difficulty on Endodontic Mishaps in an Undergraduate Student Clinic. J Endod 2018;44(7):1088–95.
23. Kerekes K, Tronstad L. Long-term results of endodontic treatment performed with a standardized technique. J Endod 1979;5(3):83–90.
24. Benenati F, Khajotia S. A Radiographic Recall Evaluation of 894 Endodontic Cases Treated in a Dental School Setting. J Endod 2002;28(5):391–5.
25. Elsayed RO, Abu-bakr NH, Ibrahim YE. Quality of root canal treatment performed by undergraduate dental students at the University of Khartoum, Sudan: Root Canal Treatment Quality. Aust Endod J 2011;37(2):56–60.
26. Elemam RF, Abdul Majid ZS, Groesbeck M, Azevedo ÁF. Quality of Root Canals Performed by the Inaugural Class of Dental Students at Libyan International Medical University. Int J Dent 2015;2015:135120.
27. Sheikh A, Rashid S, Ali FM, Abdullah F. Radiographic Quality of Root Canal Filling Performed by House Officers at A Teaching Institute in Karachi, Pakistan. J Pak Dent Assoc 2019;28(02):56–62.
28. Hendi SS, Karkehabadi H, Eskandarloo A. Iatrogenic Errors during Root Canal Instrumentation Performed by Dental Students. Iran Endod J 2018;13(1):126–31.
29. Donnelly A, Coffey D, Duncan HF. A re-audit of the technical quality of undergraduate root canal treatment after the introduction of new technology and teaching practices. Int Endod J 2017;50(10):941–50.
30. Fong JYM, Tan VJH, Lee JR, Tong ZGM, Foong YK, Tan JME, et al. Clinical audit training improves undergraduates' performance in root canal therapy. Eur J Dent Educ 2018;22(3):160–6.
31. Ali SA, Hussain M, Shahzad M, Nafees H. Frequency of Procedural Errors during Root Canal Treatment Performed by House Officers in Private Teaching Dental Hospital. J Liaquat Univ Med Health Sci 2019;18(01):55–9.
32. Gergi R, Rjeily JA, Sader J, Naaman A. Comparison of Canal Transportation and Centering Ability of Twisted Files, Pathfile-ProTaper System, and Stainless Steel Hand K-Files by Using Computed Tomography. J Endod 2010;36(5):904–7.
33. Abrar E, Baig QA, Afaq A, Anzar W. Efficacy of different endodontic procedure with post-operative pain and Quality of Life (QoL) using (OHIP-4). Prof Med J 2021;28(02):218–23.

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