Original Article

Clinical and Radiographic Evaluation of Procedural Errors during Preparation of Curved Root Canals with Hand and Rotary Instruments: A Randomized Clinical Study

Abstract

Background: The process of cleaning and shaping the canal is not an easy goal to obtain, as canal curvature played a significant role during the instrumentation of the curved canals. **Aim:** The present *in vivo* study was conducted to evaluate procedural errors during the preparation of curved root canals using hand Nitiflex and rotary K3XF instruments. **Materials and Methods:** Procedural errors such as ledge formation, instrument separation, and perforation (apical, furcal, strip) were determined in sixty patients, divided into two groups. In Group I, thirty teeth in thirty patients were prepared using hand Nitiflex system, and in Group II, thirty teeth in thirty patients were prepared using K3XF rotary system. The evaluation was done clinically as well as radiographically. The results recorded from both groups were compiled and put to statistical analysis. **Statistical Analysis:** Chi-square test was used to compare the procedural errors (instrument separation, ledge formation, and perforation). **Results:** In the present study, both hand Nitiflex and rotary K3XF showed ledge formation and instrument separation. Although ledge formation and instrument separation by rotary K3XF file system was less as compared to hand Nitiflex. No perforation was seen in both the instrument groups. **Conclusion:** Canal curvature played a significant role during the instrumentation of the curved canals. Procedural errors such as ledge formation and instrument separation by rotary K3XF file system were less as compared to hand Nitiflex.

Keywords: *Canal curvature, instrument separation, K3XF, ledge, Nitiflex, perforation, Schneider's method*

Rajesh Khanna, Aashish Handa, Rupam Kaur Virk, Deepika Ghai, Rajni Sharma Handa[1], Asim Goel[2]

Department of Conservative Dentistry and Endodontics, Sri Guru Ram Das Institute of Dental Sciences and Research, Amritsar, [1]Consultant Pedodontist, Private Practice, Amritsar, [2]Department of Periodontology, Genesis Institute of Dental Sciences and Research, Ferozepur, Punjab, India

Introduction

An essential objective of endodontic therapy is total tissue debridement followed by fluid tight obturation of the prepared space as stated by Grossman.[1] This goal can be easily achieved in large and straight canals but becomes difficult in narrow and curved canals.[2] Procedural errors such as apical transportation, elbow formation, ledging, strip perforation, perforation, and instrument fracture do occur.[3] These errors increase when the operator is confronted with curved root canals or when the instruments used are rigid.

Nickel-titanium (Ni-Ti) instruments are used because they have greater flexibility, torsional resistance, and capacity for maintaining the original configuration without creating any iatrogenic events such as ledge formation and perforation.[4] The advent of Ni-Ti rotary file system has revolutionized root canal treatment by reducing operator fatigue, time required to finish preparation, and other procedural errors associated with root canal instrumentation.[5]

Despite these advantages, Ni-Ti instruments can undergo fracture within their elastic limit without any visible sign of previous permanent deformation.[6] To overcome the disadvantages, various improvements are being made in the field of Ni-Ti instruments. Lopes *et al.*[7] compared the flexibility, cyclic fatigue resistance, and torsional load of conventional Ni-Ti instruments (K3 and Revo S) and K3XF (R-phase) instruments. The authors found that the K3XF instruments had the overall best performance in terms of flexibility, cyclic fatigue resistance, and angular deflection at failure.

Several methodologies have been used to evaluate the efficacy of Ni-Ti instruments in remaining centered during preparation.

Address for correspondence:
*Dr. Aashish Handa, No. 6, Lane No. 1, Vijay Nagar, Batala Road, Amritsar, Punjab, India.
E-mail: aashishhanda2000@gmail.com*

Access this article online
Website: www.contempclindent.org
DOI: 10.4103/ccd.ccd_495_17
Quick Response Code:

How to cite this article: Khanna R, Handa A, Virk RK, Ghai D, Handa RS, Goel A. Clinical and radiographic evaluation of procedural errors during preparation of curved root canals with hand and rotary instruments: A randomized clinical study. Contemp Clin Dent 2017;8:411-5.

Radiography is the commonly used method to assess the outcome of endodontic treatment.[8] A preoperative radiograph can provide clinicians with comprehensive information regarding the internal anatomy of the root canal system, risk of possible complications, and treatment prognosis. Furthermore, radiography can be used to assess the quality of work at each phase during the procedure.[9]

Hence, the aim of the present study was to clinically and radiographically evaluate the procedural errors during the preparation of curved root canals using hand (Nitiflex) endodontic files and rotary (K3XF) endodontic instruments.

Materials and Methods

The study was conducted at the Department of Conservative Dentistry and Endodontics, Sri Guru Ram Das Institute of Dental Sciences and Research, Amritsar and approval for the study was granted by the Ethical Committee of the Institute vide letter no. 1995/IDSR/2014. The aim and objectives were to determine the procedural errors such as ledge formation, instrument separation, and perforation (apical, furcal, strip) during the preparation of curved root canals using hand and rotary instruments. A randomized clinical study was carried out on sixty patients in which roots with fully formed apices and curvature more than 20° (according to Schneider's method) at the Department of Conservative Dentistry and Endodontics of the institute. However, teeth with root caries, calcified canals, retreatment cases, and third molars were not selected for the study. Informed written consent was obtained from each patient in accordance with the study protocol. Sixty samples were randomly divided into two groups, namely, Group I and Group II, having thirty teeth each.

Group I: Thirty teeth were prepared with Hand Nitiflex system (Dentsply Maillefer) using # 30/0.04 at the apex.

Group II: Thirty teeth were prepared with K3XF rotary system (Sybron Endo) in a given sequence: # 25/0.10 and # 25/0.08 was taken into canal until resistance, and # 25/0.06 or # 25/0.04 was taken up to working length.

Following local anesthesia, rubber dam isolation was done, and access cavities were prepared with sterilized high-speed airotor handpiece using round carbide, fissure carbide, and Endo Z burs with water as coolant. Patency of root canals was checked using no. 10 K file and preoperative diagnostic radiographs were taken using the standardized technique. These radiographs were used to determine the canal curvature using Schneider's method.

Schneider's method

Radiographs were scanned using a high-resolution transparency scanner. The scanned radiographs and digital images were taken into a computer software program "coral draw." These images were analyzed and measurements were made. An outline in vector form was drawn around the preoperative tooth and the root canal. The presence of file in the canal facilitates the drawing. Tip of the file was taken as the apical end of root canal and subpulpal wall was taken as coronal end. Point "a" was marked at the middle of the file at the level of canal orifice. Point "b" was marked on the file where the instrument made a deviation. Point "c" was marked on the file at the apical end. Two straight lines was drawn first from point "a" to point "b" and second from point "c" to point "b." The internal angle formed by intersection of these two lines was measured and taken as Primary canal curvature. Secondary curvature was measured, if present. Secondary curve is the one that deviates in direction opposite to that of primary curvature. To measure the secondary curve, a fourth point "d" was marked on file at the most apical extension of the primary curve, and a straight line was drawn from this point to apical end point "c." The angle formed by the intersection of these two lines was measured and taken as secondary canal curvature [Figure 1]. Then, working length was determined and biomechanical preparation was done using crown down technique. Before using any Ni-Ti rotary instruments, a glide path up to ISO size 20 with stainless steel K hand files (0.02 taper) was created. Throughout biomechanical preparation, irrigation was done with 5.25% sodium hypochlorite (NaOCl) for 1 min followed by 17% ethylenediaminetetraacetic acid for 1 min, and final rinse was done with 2.5% NaOCl for 30 s followed by saline and 2% chlorhexidine for 5 min. After complete preparation, postoperative radiographs (intraoral periapical radiograph or radiovisiograph) were taken. Pre- and post-operative radiographs were superimposed to check the change in

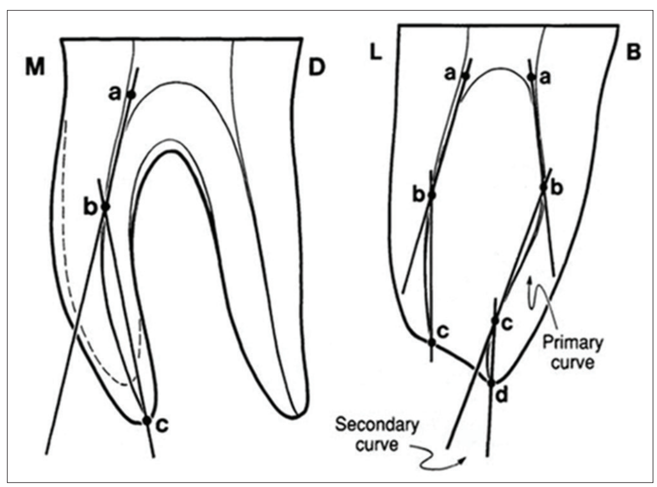

Figure 1: Primary and secondary curvature using Schneider method. Point "a": marked at the middle of the file at the level of canal orifice. Point "b": marked on the file where the instrument made a deviation. Point "c" was marked on the file at the apical end. Primary canal curvature: Two straight lines was drawn first from point "a" to point "b" and second from point "c" to point "b". The internal angle formed by intersection of these two lines was measured. Secondary canal curvature: to measure, a fourth point "d" was marked on the file at the most apical extension of the primary curve and a straight line was drawn from this point to apical end point "c". The angle formed by intersection of these two lines was measured and taken as secondary canal curvature

curvature/ledge formation and were also used to check for the errors during preparation of the canals. After complete biomechanical preparation, canals were dried using air pressure and calcium hydroxide and 2% chlorhexidine dressing was given for 1 week, and pulp chamber was sealed with temporary filling material, i.e., Orafil-G. In the next appointment, temporary filling was removed from the pulp chamber and canals were irrigated and dried with absorbent points, followed by coating the canals with sealer (AH Plus) and obturation with gutta-percha using lateral condensation technique and the tooth was restored with composite.

To determine

Ledge formation/change in canal curvature

Ledge formation and change in canal curvature were determined using Schneider's method. The preoperative angle of curvature of root canal so obtained was noted for each tooth. Thereafter, the scanned postoperative radiographs were also studied. The pre- and post-operative radiographs were superimposed. The change in angle, if any was recorded, compiled, and put to statistical analysis.

Instrument separation

Instrument separation was checked radiographically as well as clinically by measuring the length of the instrument before and after use.

Perforation

Perforation was diagnosed using electronic apex locators, radiographs taken at three different angulations and clinically by direct observation of bleeding or indirect bleeding assessment using a paper point.

Results

Observations of the present *in vivo* study evaluating sixty teeth treated in two groups were tabulated in Tables 1-3. Chi-square test was used to compare the procedural errors (instrument separation, ledge formation, and perforation) and statistical analysis was done.

Table 1 shows the comparative evaluation of ledge formation using hand Nitiflex and rotary K3XF systems. Ledge formation occurred in five (16.7%) out of thirty cases using hand Nitiflex, while with K3XF rotary system ledge formation occurred in two (6.7%) cases. The results were statistically insignificant (*P* = 0.228). Table 2 shows the comparative evaluation of instrument separation using hand Nitiflex and rotary K3XF file system. Instrument separation using hand Nitiflex occurred in seven (23.3%) out of thirty cases, while with rotary K3XF system instrument separation occurred in three (10%) cases. The results were statistically insignificant (*P* = 0.166). Table 3 shows the comparative evaluation of perforation using hand Nitiflex and rotary K3XF. No perforation occurred with any of the two file systems.

Table 1: Comparative evaluation of ledge formation using hand Nitiflex and rotary K3XF endodontic files

Ledge	Nitiflex (%)	K3XF (%)
Present	5 (16.7)	2 (6.7)
Absent	25 (83.3)	28 (93.3)

P=0.228; not significant

Table 2: Comparative evaluation of instrument separation using hand Nitiflex and rotary K3XF endodontic files

Instrument separation	Nitiflex (%)	K3XF (%)
Present	7 (23.3)	3 (10)
Absent	23 (76.7)	27 (90)

P=0.166; not significant

Table 3: Comparative evaluation of perforation using hand Nitiflex and rotary K3XF endodontic files

Perforation	Nitiflex (%)	K3XF (%)
Present	0	0
Absent	30 (100)	30 (100)

Discussion

According to Ingle and Levine, "The primary objective of operative endodontics must be the development of a fluid-tight seal at the apical foramen and total obliteration of the root canal space."[10] When curvatures are present, endodontic preparations becomes more difficult.[11] Schneider was one of the first to describe a reliable method of determining canal curvatures.[12] Bone and Moule[13] modified his method to describe a secondary curvature in the apical region. The process of cleaning and shaping the canal is not an easy goal to obtain, especially in curved canals.[14] In the present clinical study, crown down technique was employed in both hand and rotary instruments as it permits straighter access to the apical region, eliminates coronal interferences, gives better tactile control, removes the bulk of tissue, and microorganisms before apical shaping and allows deeper penetration of irrigants, and the working length is less likely to change.[15]

Unfortunately, a number of procedural errors such as canal transportation, ledges, perforations, and apical zips can occur while shaping curved canals.[16] A ledge is defined as a deviation from the original canal curvature within the apical third which creates or starts to create a new canal at a tangent to the original canal.[3] According to Glossary of endodontic terms (American Association of Endodontists) perforation is defined as "mechanical or pathological communication between the root canal system and external tooth surface."[17] Instrument fracture is a complex, multifactorial event. Reason for instrument fracture is flexural fatigue or torsional loading.[18] Torsional fracture occurs when the tip or any part of the instrument is locked in a canal while the shaft continues to rotate; the instrument exceeds the elastic limit of the metal and shows plastic deformation followed by fracture. The other type of instrument fracture is caused by work hardening and metal fatigue, resulting in flexural fracture (failure).[6]

The introduction of Ni-Ti alloy for hand filing and later the launch of engine driven instruments have significantly altered the canal shaping procedure over the past two decades.[19] Despite their increasing popularity, a concern with the use of Ni-Ti rotary instruments is the possibility of unexpected separation during use.[20] Attempts have been made to increase the flexibility and cutting efficiency of endodontic files by modifying their design.[21] Thermal treatment of Ni-Ti alloys, such as R-phase wire (SybronEndo, Orange, CA, USA) has been used to optimize the mechanical properties of the file.[22] The R-phase is an intermediate phase with a rhombohedral structure that can form during forward transformation from martensite to austenite on heating and reverse transformation from austenite to martensite on cooling. It occurs within a very narrow temperature range. In 2011, K3XF was developed with the R-phase heating and cooling protocol, but instead of being twisted, it was ground like K3.[23]

This study was undertaken to evaluate the procedural errors during the preparation of curved root canals using hand (Nitiflex) and rotary (K3XF) instruments. Bishop and Dummer[21] found ledge formation in five cases with hand Nitiflex and in twenty cases with Flexofiles which was similar to the findings of the present study. However, in contrary Greene and Krell[24] observed 46% ledged canals with hand K-flex files. In a study, Alrahabi[25] found 1.1% ledge formation with Ni-Ti rotary and 14.4% with stainless steel hand endodontic instruments. However, different findings to the current study are reported in the literature according to Rodrigues *et al*.[26] that canal deviation with K3XF was greater as compared to Mtwo and BioRace rotary systems used in the study. Less ledge formation with rotary K3XF system as compared to hand Nitiflex files could be attributed to the U-file design of K3XF which prevent self-threading. K3XF has a variable core diameter and a safe ended tip which decreases the incidence of ledging.

Various authors like Bishop and Dummer[21] observed instrument fracture in seven cases with Nitiflex and in twelve cases with Flexofiles. In another study, Haji-Hassani *et al*.[27] observed that instrument separation occurred in ten cases using hand K files. The findings are similar to the present study. Furthermore, Pérez-Higueras, *et al*.[28] compared the cyclic fatigue resistance of K3, K3XF, and twisted files and showed that the cyclic fatigue resistance was 94% for K3XF. In contrary de Almeida, *et al*.[29] observed that K3XF has shorter cyclic fracture resistance mean time (414.3) as compared to ProTaper Next (1254.7) which has the greatest cyclic fracture resistance mean time. In the present study, less instrument separation occurred with rotary K3XF system as compared to hand Nitiflex files which could be attributed to the improved mechanical and physical properties of the K3XF system due to thermal R-phase heat treatment.

In the present study, no perforation was seen in both hands Nitiflex and rotary K3XF groups. This was in accordance with Bishop and Dummer[21] using Nitiflex and Flexofile groups with apical diameter size 30 and Olivier *et al*.[30] with R-phase K3XF rotary system. Ni-Ti files used in both groups have superelasticity, shape memory, and modified tip designs that reduced the undesirable changes in the curved canals like perforation.

Conclusion

Endodontic mishaps could be avoided with thorough knowledge of the complications and variations in root canal anatomy, good technical skills and training. Canal curvature played a significant role during the instrumentation of the curved canals. In the present study, both hand Nitiflex and rotary K3XF showed ledge formation and instrument separation. Although ledge formation and instrument separation by rotary K3XF file system was less as compared to hand Nitiflex. No perforation was seen in both the instrument groups.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Grossman LI. Root Canal Therapy. 3rd ed. Philadelphia: Lea & Febiger; 1950.
2. Luiten DJ, Morgan LA, Baugartner JC, Marshall JG. A comparison of four instrumentation techniques on apical canal transportation. J Endod 1995;21:26-32.
3. Nagy CD, Bartha K, Bernáth M, Verdes E, Szabó J. The effect of root canal morphology on canal shape following instrumentation using different techniques. Int Endod J 1997;30:133-40.
4. Guelzow A, Stamm O, Martus P, Kielbassa AM. Comparative study of six rotary nickel-titanium systems and hand instrumentation for root canal preparation. Int Endod J 2005;38:743-52.
5. El Batouty KM, Elmallah WE. Comparison of canal transportation and changes in canal curvature of two nickel-titanium rotary instruments. J Endod 2011;37:1290-2.
6. Sattapan B, Palamara JE, Messer HH. Torque during canal instrumentation using rotary nickel-titanium files. J Endod 2000;26:156-60.
7. Lopes HP, Gambarra-Soares T, Elias CN, Siqueira JF Jr, Inojosa IF, Lopes WS, *et al.* Comparison of the mechanical properties of rotary instruments made of conventional nickel-titanium wire, M-wire, or nickel-titanium alloy in R-phase. J Endod 2013;39:516-20.
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;39:867-72.

9. Gutman GL, Dumsha TC, Loudehl PF, Hovaland EJ. Problem solving in endodontics: Prevention, identification and management. 5th ed. Missouri: Elsivier, Mosby; 2011. p. 22.
10. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271-5.
11. Yousuf W, Khan M, Mehdi H. Endodontic procedural errors: Frequency, type of error, and the most frequently treated tooth. Int J Dent 2015;2015:673914.
12. Cunningham CJ, Senia ES. A three-dimensional study of canal curvatures in the mesial roots of mandibular molars. J Endod 1992;18:294-300.
13. Bone J, Moule AJ. The nature of curvature of palatal canals in maxillary molar teeth. Int Endod J 1986;19:178-86.
14. Pettiette MT, Metzger Z, Phillips C, Trope M. Endodontic complications of root canal therapy performed by dental students with stainless-steel K-files and nickel-titanium hand files. J Endod 1999;25:230-34.
15. Morgan LF, Montgomery S. An evaluation of the crown-down pressureless technique. J Endod 1984;10:491-8.
16. Hülsmann M, Stryga F. Comparison of root canal preparation using different automated devices and hand instrumentation. J Endod 1993;19:141-5.
17. Alhadainy HA. Root perforations. A review of literature. Oral Surg Oral Med Oral Pathol 1994;78:368-74
18. Parashos P, Gordon I, Messer HH. Factors influencing defects of rotary nickel-titanium endodontic instruments after clinical use. J Endod 2004;30:722-5.
19. Nagaraja S, Sreenivasa Murthy BV. CT evaluation of canal preparation using rotary and hand NI-TI instruments: An *in vitro* study. J Conserv Dent 2010;13:16-22.
20. Shen Y, Coil JM, Haapasalo M. Defects in nickel-titanium instruments after clinical use. Part 3: A 4-year retrospective study from an undergraduate clinic. J Endod 2009;35:193-6.
21. Bishop K, Dummer PM. A comparison of stainless steel flexofiles and nickel-titanium niTiFlex files during the shaping of simulated canals. Int Endod J 1997;30:25-34.
22. Shen Y, Zhou HM, Wang Z, Campbell L, Zheng YF, Haapasalo M, *et al.* Phase transformation behavior and mechanical properties of thermomechanically treated K3XF nickel-titanium instruments. J Endod 2013;39:919-23.
23. Plotino G, Costanzo A, Grande NM, Petrovic R, Testarelli L, Gambarini G, *et al.* Experimental evaluation on the influence of autoclave sterilization on the cyclic fatigue of new nickel-titanium rotary instruments. J Endod 2012;38:222-5.
24. Greene KJ, Krell KV. Clinical factors associated with ledged canals in maxillary and mandibular molars. Oral Surg Oral Med Oral Pathol 1990;70:490-7.
25. Alrahabi M. Comparative study of root-canal shaping with stainless steel and rotary NiTi files performed by preclinical dental students. Technol Health Care 2015;23:257-65.
26. Rodrigues RC, Soares RG, Gonçalves LS, Armada L, Siqueira JF Jr. Comparison of canal preparation using K3XF, Mtwo and BioRaCe rotary instruments in simulated curved canals. ENDO (Lond Engl) 2015;9:129-35.
27. Haji-Hassani N, Bakhshi M, Shahabi S. Frequency of iatrogenic errors through root canal treatment procedure in 1335 charts of dental patients. J Int Oral Health 2015;7:14-7.
28. Pérez-Higueras JJ, Arias A, de la Macorra JC. Cyclic fatigue resistance of K3, K3XF, and twisted file nickel-titanium files under continuous rotation or reciprocating motion. J Endod 2013;39:1585-8.
29. de Almeida BC, Ormiga F, de Araújo MC, Lopes RT, Lima IC, dos Santos BC, *et al.* Influence of heat treatment of nickel-titanium rotary endodontic instruments on apical preparation: A micro-computed tomographic study. J Endod 2015;41:2031-5.
30. Olivier JG, García-Font M, Gonzalez-Sanchez JA, Roig-Cayon M, Durán-Sindreu F. Danger zone analysis using cone beam computed tomography after apical enlargement with K3 and K3XF in a manikin model. J Clin Exp Dent 2016;8:E361-7.