Original Research Article

Evaluation of canal preparation with rotary and hand Niti files in curved root canals using Cone Beam Computed Tomography: An In Vitro Study

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Abstract

Background: Cleaning and shaping the root canal is an important phase in endodontic therapy. A prepared root canal should have a shape that flares from apical to coronal regions, maintaining the apical foramen and not changing the original canal curvature.

Aim: To compare canal transportation, canal centring ability and remaining dentin thickness, in curved root canals using Twisted Files, PathFiles-ProTaper System, RaCe files, WaveOne reciprocating files and hand NiTi K-files with Cone Beam Computed Tomography.

Materials and methods: 125 canals with completely formed apices and angle of curvatures ranging from 10 degrees to 60 degrees were used. The teeth were divided in five experimental groups of 25 each. Instrumentation was performed in Group I with Twisted files, Group II with PathFile-ProTaper, Group III with Hand NiTi files, Group IV with RaCe files and Group V with WaveOne reciprocating files. CBCT images were obtained before and after instrumentation with Kodak CS9300 equipment

(CS3D Imaging Software 3.1.9). The amount of canal transportation, centering ability and remaining dentin thickness was calculated at nine levels. Results were analysed using ANOVA test and Post-hoc Bonferroni Multiple Comparison test.

Results: Statistically significant difference was noted among the groups at the middle and apical third level with WaveOne files showing the least and hand NiTi files showing the highest transportation. The mean centering ratio was statistically highest with WaveOne and smallest with hand NiTi files at the middle third level. At the apical level ($p < 0.05$) the mean remaining dentin thickness was highest with WaveOne and smallest with PathFile-ProTaper.

Conclusion: WaveOne and Twisted files were similar in terms of canal transportation, centring ability and remaining dentin thickness. Hand NiTi files and Pathfile-ProTaper systems produced maximum amount of canal aberrations.

Key words

Canal transportation, Centering ability, Remaining dentin thickness, Curved root canals, Cone Beam Computed Tomography.

Introduction

Cleaning and shaping the root canal is an important phase in endodontic therapy. A prepared root canal should have a shape that flares from apical to coronal regions, maintaining the apical foramen and not changing the original canal curvature [1]. When curvatures are present endodontic preparation becomes more difficult, and there is a tendency for all preparation techniques to divert the prepared canal away from the original axis leading to procedural errors such as transportation, creation of zips, elbows, ledges, loss of working length, perforation and separation of instruments [2]. As reported by Cimis, et al. (2009)**,** 46% of curved canals exhibit various degrees of apical transportation following instrumentation [3].

The introduction of NiTi alloy for hand filling and later the launch of rotary instruments allowed a safer and easier preparation of canals with complex anatomies [4].The super-elasticity of NiTi rotary files allow less lateral forces to be exerted against the canal walls, especially in severely curved canals, reducing the risk of canal aberrations while maintaining the original canal shape [5, 6].

According to William G. Kuhn, et al. (1997) [7], the factors governing the centricity of canal preparation are the type of alloy used for making the instrument, the tip design, the instrument design and the instrumentation technique **.** Hence a number of rotary NiTi file systems have been developed with different instrument and tip design features like the PathFiles(Dentsply, Maillefer, Ballaigues, Switzerland) which are used in combination with ProTaper (Dentsply, Maillefer) system, have a constant taper with a square cross section, to reduce the risk of canal transportation [2]. ProTaper files have a convex triangular cross section with sharp cutting edges, no radial lands, and a non cutting safety tip, which provides flexibility. Similar to ProTaper, an instrument with sharp cutting edges and triangular cross section are RaCe files (FKG Dentaire Switzerland). They have round, non cutting tips with alternating cutting edges, to avoid the screwing in effect [8].

Despite these improvements in instrument design, instrument separation is still a major concern when using NiTi rotary files, mainly because of flexural and torsional stresses, with canal curvature being a predominant risk factor. Numerous methods have been developed to overcome this, like thermal processing of NiTi alloy and its twisting during phase transformation into the “R phase” of NiTi. Twisted Files (Sybron Endo) are manufactured using this process. The R-phase heat treatment and special surface conditioning of these files,

significantly increases the resistance to cyclic fatigue, and maintains the original canal centre [2, 9].

In 2007, a new NiTi alloy termed the M-Wire (Dentsply Tulsa-Dental Specialties, Tulsa, OK) was developed. The manufacturer states that a proprietary new thermal process is used to produce the alloy that increases flexibility and resistance to cyclic fatigue compared with files constructed from traditional NiTi alloy [10]. It is currently used for the manufacture of GTseries X instruments (Dentsply Tulsa-Dental Specialties), Reciproc (VDW, Munich, Germany), Wave One (Denstply Mailifier, Ballaigues, Switzerland), and Protaper Next files (Dentsply Tulsa-Dental Specialties)

Along with these new instrument designs, newer preparation techniques have also been introduced like the reciprocating motion of the NiTi instruments. The motion consists of counter clockwise and a clockwise rotation. With this technique, although the instrument frequently engages dentin at its tip, the counter-clockwise rotation immediately disengages the instrument, reducing the torsional stress [6]. A number of reciprocating single file systems are available like Wave One, Reciproc and Wave One Gold.

Hence, in achieving Schilder's [11] objective of maintaining the root canal curvature, avoiding eccentricity and transportation, which file system should be used- recipropocating files like Wave One, the files manufactured using new R phase treatment-Twisted files, or the files with special design characteristics like RaCe or Pathfile ProTaper.

Aim and objectives

- To compare canal transportation.
- To compare canal centring ability.
- To compare remaining dentin thickness.

in curved root canals with Twisted Files, PathFiles-ProTaper System, RaCe files, WaveOne reciprocating files and hand NiTi K-files in curved root canals using Cone Beam Computed Tomography.

Materials and methods

In total, 125 canals with completely formed apices and angle of curvatures ranging from 10 degrees to 60 degrees, according to the criteria described by Pruett John P, et al. (1997) [12] were used in the study. Canals that were larger than ISO size 15 were excluded. Access cavities were prepared using round diamond burs (Mani Inc, Tochigi-Ken, Japan). A size 10 K-flexofile (Dentsply, Maillefer) was placed into the canal until it was visible at the apical foramen, and the working length (WL) was established 0.5mm short of this length. The teeth were divided in five experimental groups of 25 each. Experimental groups were as per **Table – 1**.

Table - 1: Experimental groups.

GROUPS	FILES
Group 1	Twisted file
Group 2	Pathfile-Protaper
Group 3	Hand NiTi K file
Group 4	RaCe file
Group 5	WaveOne Primary file

Canal instrumentation

In group 1, the shaping procedure commenced with Twisted file size 25 taper .08. It was used to prepare the coronal one third. TF size 25 taper .06 was inserted and used until 2 mm short of WL. Shaping was continued with TF size 25 taper .04 and completed with size 25 taper .06 file to the working length.

In group 2, the shaping procedure commenced with PathFile #1 followed by #2 and then by #3 to WL. This was followed by ProTaper S1 and then S2 to WL used with a brushing motion. Shaping continued with F1 finishing instrument followed by F2 to working length. Group 3 of 25 teeth were shaped by using "watch-winding'' manipulation of hand NiTi K-flex files (20-40) with a step-back technique. Final apical preparation was done till size 25 file.

In group 4, coronal preparation was started with RaCe file size 35 taper 0.08 followed by file of size 25 taper 0.06. Apical preparation was completed by using file of size 25 taper 0.02 followed by size 25 taper 0.04. File of size 25 taper 0.06 was used to the full working length.

Group 5 of 25 teeth were prepared using WaveOne Primary file, having a size 25 and a taper of 0.08, according to manufacturer's recommendation. The shaping procedure commenced with PathFile #1 followed by #2 and then by #3 to working length. This was followed by WaveOne Primary reciprocating files used in pecking motion to working length.

For all groups, canals were irrigated with 3 mL of 3% NaOCl solution. 17% EDTA was used as a lubricant. Each instrument was changed after 5 canals, except WaveOne which was changed after each canal. Summary of features of four experimental groups were as per **Table – 2**.

Table - 2: Summary of features of the four experimental groups.

Features	Twisted Files	Pathfile-ProTaper	RaCe	WaveOne
1. Cross-section	Triangular	Convex Triangular	Triangular	2 different cross section(modified triangular and convex triangular)
2. Tip	Safe ended non cutting pilot tip	Guiding	Safe cutting tip	Non-cutting modified guided tip
3. Radial Lands	Absence	Absence	Absence	Presence (D1-D8)
4. Rake angle	Negative	Negative	Negative	Neutral(D9-D16)
5. Manufacturing process	R-phase treatment	NiTi grinding	NiTi grinding	M-Wire

Scanning and imaging

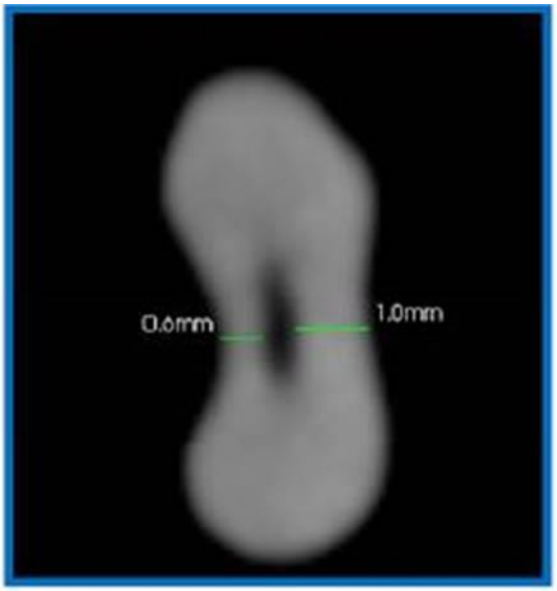
CBCT images for all prepared teeth were obtained before and after instrumentation, with Kodak CS9300 equipment (CS3D Imaging Software 3.1.9) in high resolution dental mode at 84 kV, 5 mA and a single scout image. Image assessment was performed by a calibrated endodontic post-graduate student and a maxillofacial radiologist using the CBCT software tools.

Assessment included evaluation of residual dentin thickness in the axial plane; starting 0.5 mm coronal to the anatomical apex and measuring at successive 1mm intervals. Nine levels were chosen for evaluation .To calculate the remaining dentin thickness for all the groups, the shortest distance from the canal outline to the closest adjacent root surface was measured at each level. The amount of canal transportation, centering ability and remaining dentin thickness was calculated at all the levels.

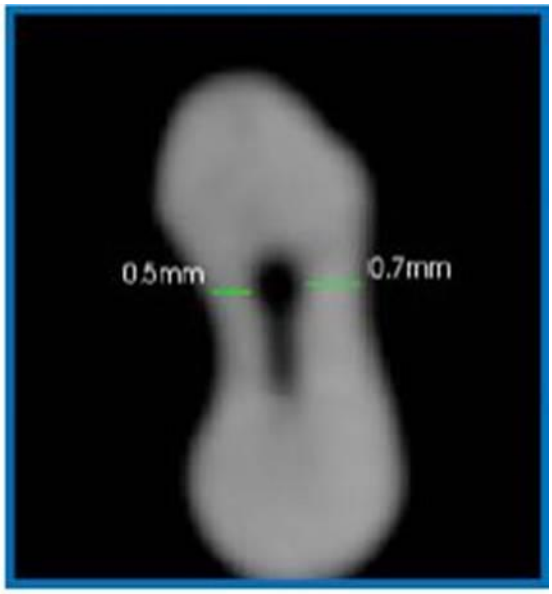
Results were analysed using ANOVA Test. Intergroup comparisons was done using the Post-hoc Bonferroni Multiple Comparison Test. The

level of significance was set at p-value <0.05. CBCT image showing measurements was as per **Figure – 1**. CBCT images at nine levels were as per **Figure – 2**.

Figure - 1: CBCT image showing measurements.



PRE INSTRUMENTATION



POST INSTRUMENTATION

Results

Canal transportation

There was no significant difference among the five groups with respect to transportation at levels 3, 5, 6, 7, 8, 9 ($p > 0.05$). At levels 1, 2, 4 ($p < 0.05$) significant differences were noted among the groups.

At level 1 and 2, the mean degree of canal transportation was statistically smallest with WaveOne files and highest with hand NiTi files (**Graph - 1, 2**).

At level 4, the mean degree of canal transportation was statistically smallest with WaveOne files and highest with hand NiTi files (**Graph - 3**).

Statistically significant difference ($p < 0.05$) was noted between
a. Hand NiTi files >Twisted files
b. Hand NiTi files > RaCe files
c. Hand NiTi files > WaveOne
d. Pathfile-ProTaper > RaCe files
e. Pathfile-ProTaper > WaveOne

Canal centering ability

There was no significant difference between the five groups with respect to centering ratio at levels 1, 2, 4, 5, 7, 8, 9 ($p > 0.05$).

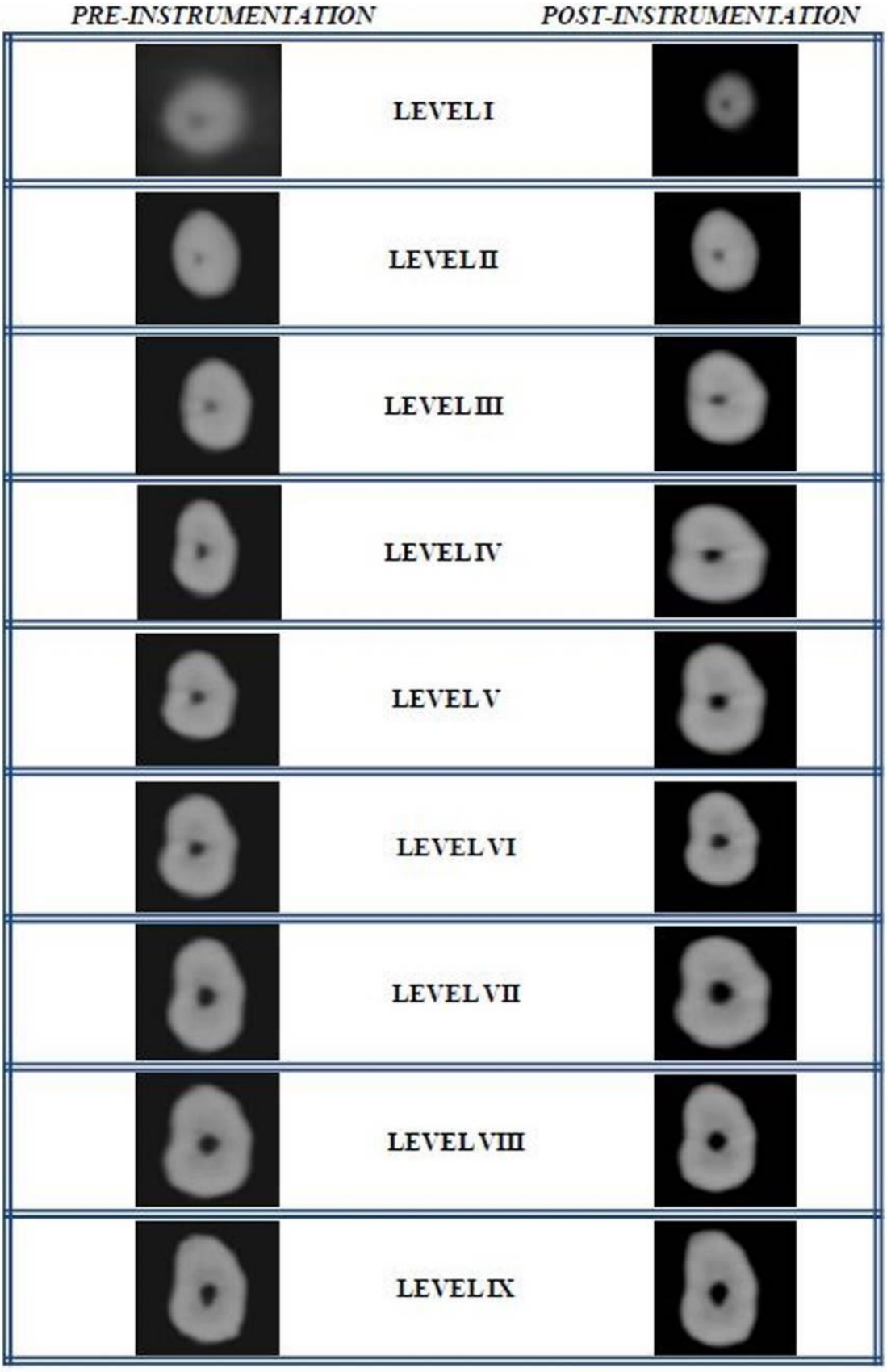
At **level 3 and 6,** the mean centering ratio was statistically the highest with WaveOne and smallest with hand NiTi files (**Graph - 4, 5**).

At level 6, statistically significant difference ($p < 0.05$) was noted between
a. WaveOne files > Pathfiles - ProTaper
b. WaveOne files > Hand NiTi files.

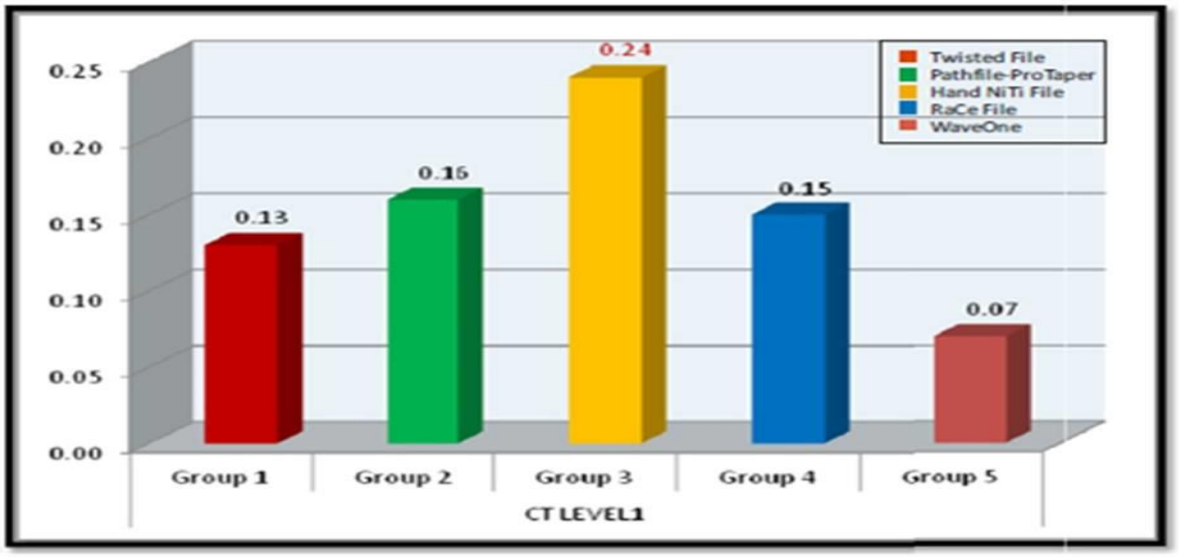
Remaining dentin thickness

There was no significant difference between the five groups with respect to remaining dentin thickness at levels 2, 3, 4, 5, 6, 7, 8, 9 ($p > 0.05$).
At level 1, the mean remaining dentin thickness was highest with WaveOne and smallest with PathFile-ProTaper (**Graph - 6**).

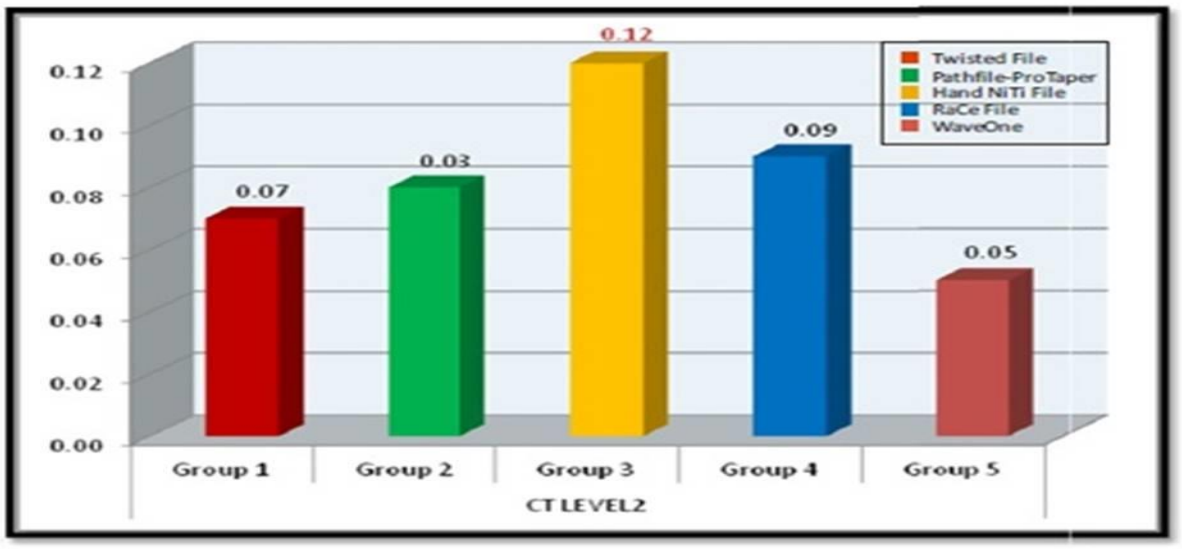
Figure - 2: CBCT images at nine levels.



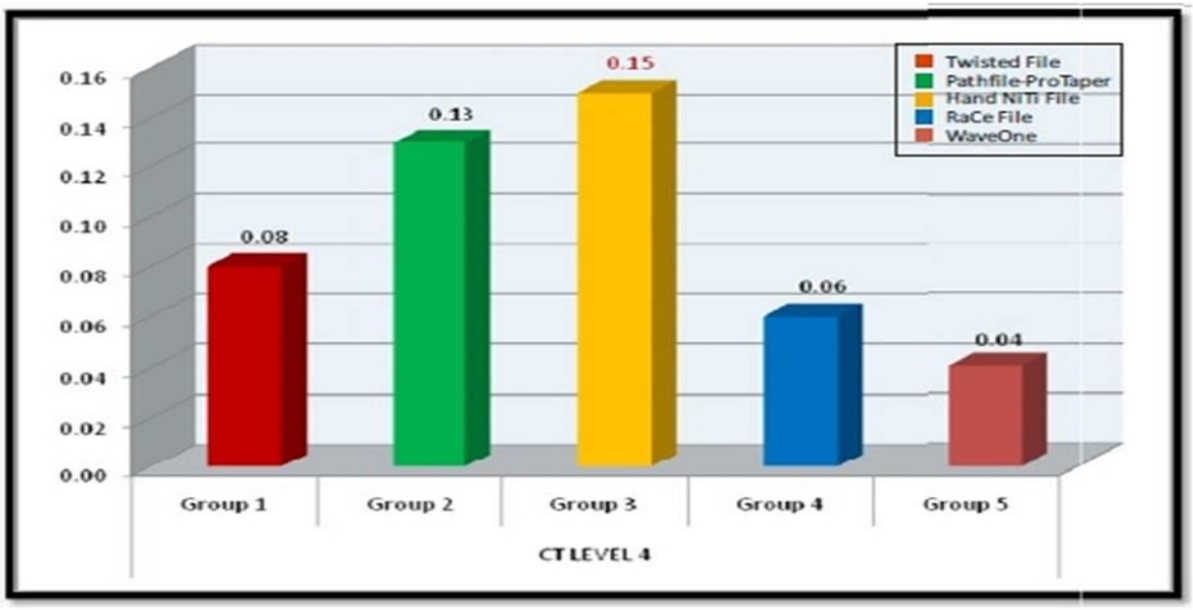
Graph - 1: Mean Canal Transportation at Level 1 for five groups.



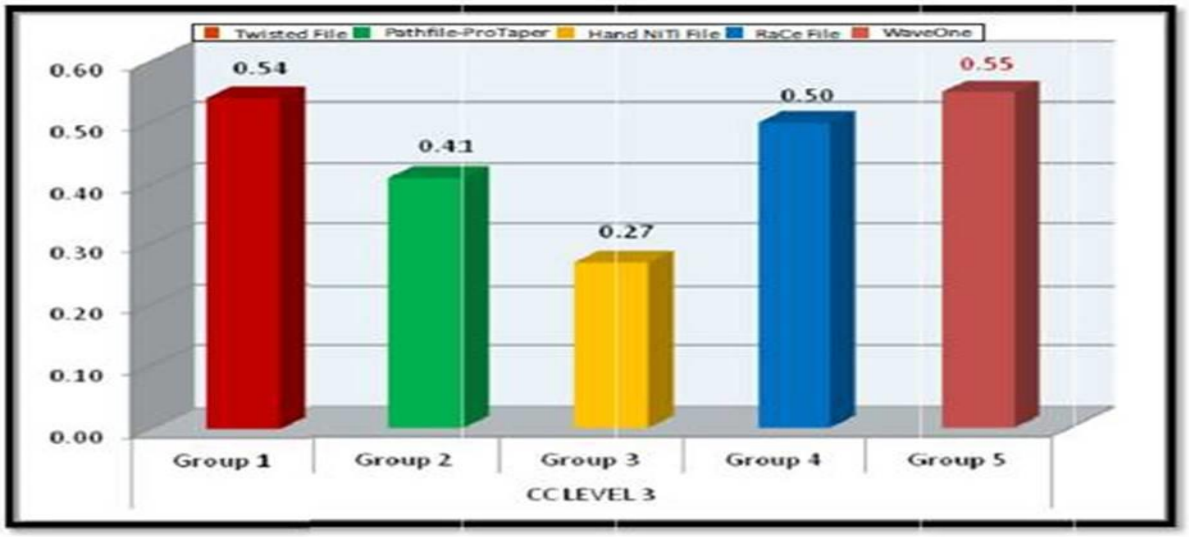
Graph - 2: Mean canal transportation at Level 2 for five groups.



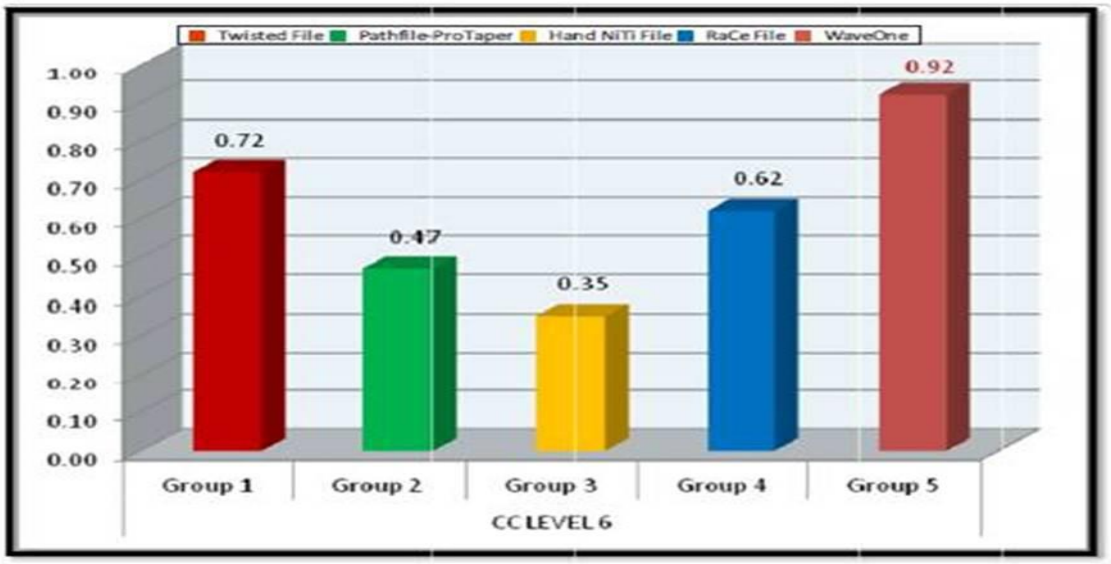
Graph - 3: Mean canal transportation at Level 4 for five groups.



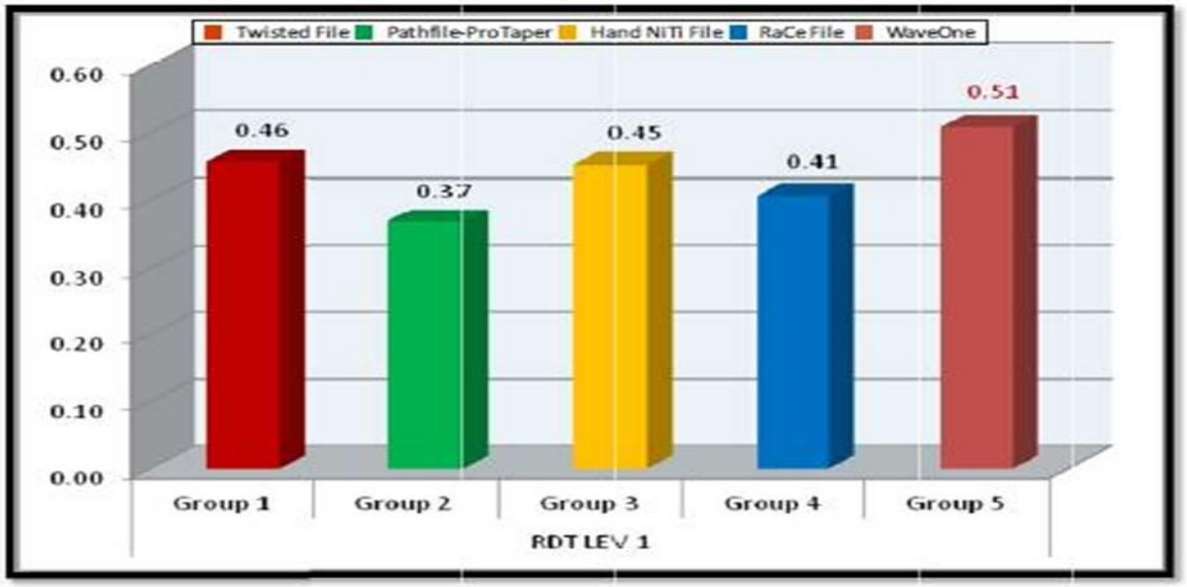
Graph - 4: Mean canal centering ability at Level 3 for five groups.



Graph - 5: Mean canal centering ability at Level 6 for five groups.



Graph - 6: Mean remaining dentin thickness at Level 1 for five groups.



Discussion

The goal of instrumentation is to produce a continuously tapered preparation that maintains the canal anatomy, without any deviation from the original canal curvature. The root canal anatomy, dictates the choice of instruments and instrumentation system to be used. Over the recent years, a number of instrument designs, advanced preparation concepts have been developed to avoid undesirable aberrations such as canal transportation, elbows, zips and ledges [11].

The main parameters used to evaluate a technique or an instrument should be maintenance of the original canal curvature and adequate cleaning of the root canal walls [13]. In this study, Cone Beam Computed Tomography was used to evaluate the canal preparation using hand NiTi K-files, PathFile-ProTaper, RaCe, Twisted Files and WaveOne files in curved canals.

The first parameter evaluated was Canal transportation

Excessive and inappropriate dentin removal in a single direction rather than in all direction equidistantly from the main tooth axis is known as "*Canal transportation*". In a curved canal, apical pressure leads to transportation towards the outer curvature, at the same time, the reactionary force builds up in straightening the instrument against the dentin coronal to the curvature and leads to transportation towards the inner curvature. Studies by Hulsmann et al (2001) [5], Short et al (1997) [14], Javaheri and Javaheri (2007) [15], Glossen, et al. (1995) [16] and Tasdemir, et al. (2005) [13] have shown that rotary NiTi instruments produced less canal transportation than stainless steel or NiTi hand files. Similar results were found in our study. At levels 1, 2 and 4, lowest transportation was noted with WaveOne files followed by Twisted Files, RaCe Files, Path-File ProTaper and hand NiTi files. Statistically significant difference was noted only between WaveOne and hand NiTi files at the apical level. The reason can be because hand NiTi files have a cutting tip while RaCe, ProTaper and Twisted files that have non cutting tips.

WaveOne primary file used in reciprocating motion showed minimum apical transportation. This could be attributed to its reciprocating movement. The reciprocating motion is an evolution of the balanced force technique that allows shaping of severely curved canals with hand instruments to larger apical diameters. The motion consists of counter clockwise (cutting direction) and a clockwise motion (release of the instrument). The movement is more symmetrical, thus shaping the preparation in a more uniform manner, increasing the centring ability [6]. Another reason could be the presence of radial lands from D1-D8 in WaveOne primary files which may help the instrument to stay centred in the canal [17]. The radial lands help to distribute the pressure of the blades more uniformly around the circumference of a curved canal. This is in accordance to studies by Berutti Elio, et al. (2012) [6] and Franco et al (2011) [18] who have compared rotary and reciprocating motion. However, Burklein, et al. (2012) [19] compared the shaping ability and cleaning effectiveness of Reciproc, WaveOne, Mtwo and ProTaper in severely curved root canals of extracted teeth and found no significant difference between the files.

In this study, among the instruments used in continuous motion, maximum canal transportation was noted with Pathfile-ProTaper files, as compared to RaCe and Twisted files. This result was statistically significant between Pathfile-ProTaper and RaCe files at the middle third. 6% constant taper and alternating cutting edges of RaCe file could be responsible for the lower transportation. When compared to Twisted files, Pathfile-ProTaper showed more canal transportation but the result was not statistically significant. This could be attributed to the way they are manufactured, by twisting of NiTi wire in the R-phase. This new process respects the grain structure for maximum strength and does not introduce milling marks or other surface irregularities, which maximizes flexibility and

resistance to breakage. Similar results were obtained in studies by Yoshmine, et al. (2005) [20], Javaheri and Javaheri (2007) [15] Miglani Revathi, et al. (2008) [21].

The second parameter evaluated was Canal centring ability

The mean degree of centring ratio at Level 3 was highest with WaveOne files followed by Twisted files, RaCe, Pathfile-ProTaper and least with hand NiTi files. This could again be attributed to the presence of radial lands from D1-D8 as well as the reciprocating movement of the WaveOne files [6].

The third parameter evaluated was the Remaining dentin thickness

An ideal instrumentation outcome would have equal dentin removal from the canal walls, providing successful debridement, yet avoiding excessive thinning of root structure [21]. In our study, the mean remaining dentin thickness at level 1 was highest with WaveOne followed by Twisted Files, Hand NiTi files, RaCe Files and Pathfile-ProTaper.

Pathfile- ProTaper were most aggressive at level 1, in our study. The 8 percent taper, triangular cross section of ProTaper instrument results in greater restoring forces being applied in the apical part of the canal, leading to greater canal transportation and higher dentin removal in this region [22].

This is in accordance with results of Franco et al (2011) [18], where largest canal enlargement at the apical third of the canal was produced by the continuous group as compared to the reciprocating group. In continuous movement, a greater enlargement of the canal is seen as, when the instrument makes a 360 degree turn in continuous movement, in the same time span instruments in reciprocating movement do a 20 degree turn [18].

Among all the parameters evaluated reciprocating motion of WaveOne files showed the best results.

Conclusion

In our study, WaveOne and Twisted Files were similar in terms of canal transportation, centering ability and remaining dentin thickness. Hand NiTi files and Pathfile-ProTaper systems produced maximum amount of canal aberrations. Reciprocating motion of WaveOne primary file maintained the original canal anatomy with less modification of canal curvature. Therefore, reciprocating motions may hold the key to future canal preparations.

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