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Comparative evaluation of efficacy of hand, reciprocating and continuous rotary file systems in relation to centering ability, cracks and apical transportation – An In-vitro Micro Computed Tomography Study

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Abstract

Background: Many variables are associated with the resistance of rotary instruments to torsional loads, including those linked to clinical use and those connected to the manufacturing process, in addition to the influence of flexural stresses. Features of the files itself are related to the manufacturing process such as type of alloy, heat treatment, surface treatment, cross sectional design, shaft length, tip size, pitch and taper. These variables may affect performance of the files during cleaning and shaping of canals.

To date, there is limited information about the effectiveness of current instrumentation techniques and studies comparing the efficacy of different techniques in relation to centering ability, cracks and apical transportation. Hence this study aims to evaluate the in vitro efficacy of hand filing, reciprocating filing and continuous rotary filing systems using micro – computed Tomo graphy.

Methods: 40 extracted human permanent mandibular first molars. Samples were randomly divided into four groups based on the instruments used for Cleaning and shaping of the mesio- lingual canal of permanent mandibular first molar. Group 1: Hand Universal Pro-taper file, group 2: Neo lix rotary file, group 3: Protaper Universal rotary file, group 4: Wave one gold file system.

The data on categorical variables is shown as n (% of cases) and the data continuous variables are presented as mean and standard deviation (SD). The inter-group statistical comparison of distribution of categorical variables is tested using Chi-Square test or Fisher‘s exact probability test if more than 20% cells have expected frequency less than 5. The inter-group statistical comparison of means of normally distributed continuous variables is done using analysis of variance (ANOVA) with Post - hoc Bonferroni‘s test for multiple group comparisons.

The intra- group statistical comparison of means of continuous variables is done using paired t test. The underlying normality assumption was tested before subjecting the study variables to ANOVA and t test. All results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly.

Results: Mean canal centering ability of Group I was 0.42 ± 0.24, in Group II was 0.49±0.18. In Group III and IV the centering ability was 0.14±0.03 and 0.14±0.04 respectively. ANOVA for between group comparison of centering ability showed statistically high significant difference in the Centering ability between Group I, II, III and IV respectively. Pairwise comparison was done using Tukey's post hoc test showed statistically high significant difference when Group I was compared with Group III and IV respectively. ($p<0.001$) A statistically high significant difference in centering ability was observed when Group II was compared with Group III and IV respectively. ($p<0.001$). Apical transportation was seen maximum in Group II (0.38±0.11) Mean apical migration in Group I was 0.13±0.09, in group III the apical migration was found to be 0.21±0.05 and in Group IV was 0.15±0.02 respectively.

Conclusion: The centering ability of universal pro-taper files was observed to be better than hand pro-taper, neo lix and wave one gold files. Apical transportation of hand pro-taper files was found to be minimum when compared with neo lix, universal pro- taper and wave one gold prot-aper files. The microcracks formed were maximum in wave one gold files while hand pro-taper files showed no cracks formation. The difference in the crack formation was found to be statistically significant.

Keywords: apical transportation, centering ability, cone beam computed tomography, cracks, rotary.

Introduction

The reduction in intracanal micro-organisms is the major goal of root canal treatment. This can be achieved using a proper chemo-mechanical preparation and is thus essential for successful endo dontic treatment [1]. For years such preparation was performed with stain less steel hand instruments, which had a number of limitations mainly in curved and flat canals, leading to deviations, zip formations, and perforations [2].

Such limitations led to the development of nickel-titanium instruments with increased flexibility and cutting efficiency, favouring the treatment of curved canals and making the clinical procedure faster and safe [3].

Canal shaping is a critical aspect of endodontic treatment because it influences the outcome of the sub sequent phases of canal irrigation and filling and the success of the treatment itself.

Apical transportation is often caused by mechanical instrumentation with large files that are more effective in removing infected tooth structure than small files [4-5]. During endodontic treatment, bacterial reduction or elimination may be achieved by both chemo-mechanical preparation and intracanal dressings using antibacterial irrigants which significantly help to remove bacterial cells from root canal. Although it seems unreasonable to place particular emphasis on any endodontic procedure, chemo-mechanical preparation may be considered an essential step in root canal disinfection [5].

This is especially critical near the DCEJ, as well as near the furcation region of multi rooted teeth, because these are regions with decreased thicknesses of surrounding dentin. However, the use of rotary nickel-titanium (NiTi) instruments has enhanced the overall shaping quality and reduced the frequency of procedural errors such as ledges, zips, perforations, and canal transportation [5]. Enlarging the root canal to a larger diameter removes more debris and promotes better cleaning of the apical third, while allowing maximal contact of the irrigants with the apical debris [6-7]. Therefore, mechanical preparation of curved root canals remains challenging [8].

Several brands and designs of file sare manufactured from a nickel – titanium (NiTi) alloy, which has a very low modulus of elasticity, superior flexibility in bending, and great resistance to torsional fracture [9]. Nickel-titanium (NiTi) endo dontich and instruments were introduced in 1988, and soon after NiTi rotary instru mentation became popularized. The super elastic property of NiTi, coupled with advanced file design, allowed safe and effective instru mentation using hand piece- driven file so perated at slow speed Sina crown to apex direction [10].

They have excellent flexibility compared to stain less steel files which allows for quick preparation and maintenance of original canal shape with fewer clinical errors.

Thus, NiTi instrumentation has been proven effective for maintaining the original canal shape [11]. Third – and fourth -generation files include Neo niti ™ (Neo lix, Chatres La - Foret, France) and One Shape™ (Micro-Mega, Besancon, France), respectively. These both employ a single file used in continuous rotating motion to clean and shape the whole root canal system [12].

Despite the ease of use and clinical efficiency of NiTi files, this type of instrumentation system can result in complications and accidents. Unexpected fracture of instruments in the absence of visible signs of cutting blade deformation has been reported. Fracture of NiTi instruments used in continuous rotary motion can be caused by torsion or cyclic fatigue [6].

Recently, Protaper Gold (PG) (PG; Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) NiTi rotary system was introduced. The Protaper System is also available in the form of hand-operated instruments with identical design to the rotary instruments. They are recommended for use in reaming or “modified balanced forces” motion. The mechanical stresses acting on a hand-operated instru ment might differ from those on engine-driven instru ments [13].

Fatigue fracture is caused by crack initiation at the surface and trans – granular crack growth, which are likely to occur when the instrument is rotating within a curvature. Shear failure is the result of an applied shear moment exceeding the elastic limit of the material, producing plastic deformation and, ultimately, fracture.

This may occur when the tip of the instrument is forced into an arrow canal lumen, generating high torsional loads [14].

There have been many techniques used to compare instru mentation of different file systems, which include plastic models, histologic sections, scanning electron microscopy, serial sectioning, radio graphic comparisons, silicone impressions of instru mented canals, computed Tomo graphy (CT), and micro - CT [14].

Many variables are associated with the resistance of rotary instruments to torsional loads, including those linked to clinical use and those connected to the Manu facturing process, in addition to the influence of flexural stresses. Features of the files itself are related to the manufacturing process such as type of alloy, heat treatment, surface treatment, cross sectional design, shaft length, tip size, pitch and taper [15].

These variables may affect performance of the files during cleaning and shaping of canals. To date, there is limited information about the effectiveness of current instrumentation techniques and studies comparing the efficacy of different techniques in relation centering ability, cracks and apical transportation.

Hence this study aims to evaluate the in vitro efficacy of hand filing, reciprocating filing and continuous rotary filing systems using micro-computed tomography.

Methodology

Sample Size estimation

The sample size was calculated from a previously published scientific article at 95% confidence interval and 80% power to the study.

The total sample size calculated was 40. Formula of calculating sample size (Sample size calculation formula for clinical trial outcome variable on ratio scale) & objective: Estimating mean difference between inter vention (M1) and control group (M2).

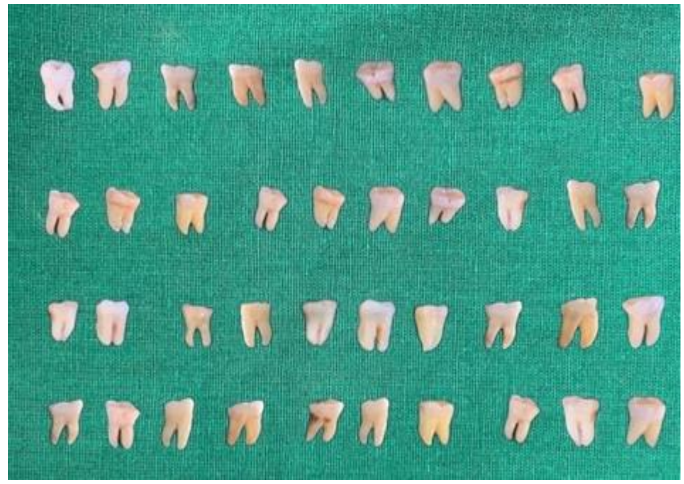

Figure 1: 40 extracted human permanent mandibular 1st molars

Sampling and Allocation

Samples were randomly divided into 4 groups based on the instruments used for Cleaning and shaping of the mesio- lingual canal of permanent mandibular first molar.

Group 1: Hand Universal Pro-taper file

Group 2: Neo lix rotary file

Group 3: Protaper Universal rotary file

Group 4: Wave one gold file system

Procedure

a) Specimen Selection and Preparation

In the present study a total of 40 freshly extracted human mandibular molar teeth with completely formed apices were collected and stored in 0.9% normal saline. Pre-scans of the samples were taken by Micro-CT.

Access cavities were prepared using a high-speed round carbide bur (Mani) in high – speed hand piece with water spray size 10 K – file (Mani). # 15 K file was used to establish a glide path after establishing working length to prevent locking of the file during instrumentation.

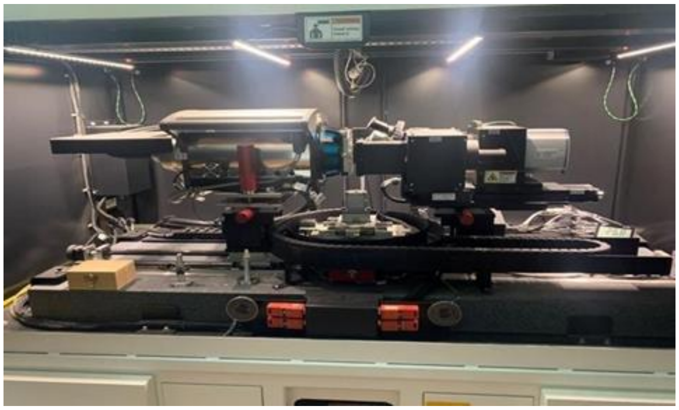

Figure 2: Micro Computed Tomography Device (Zeiss X Radia Versa)

b) Canal Instrumentation

All the teeth were scanned by Micro CT and images were captured in a field of view) voxel size to determine the root canal shape before instrumentation. The samples were randomly divided into 4 groups according to the file system being used for bio mechanical pre paration. Bio mechanical preparation was then done. Orifices were enlarged using orifice opener. Post- operative scans after biomechanical preparation were taken by Micro CT.

Group 1: Cleaning and shaping with Universal Hand Protaper (till F2)

Group 2: Cleaning and shaping with Neo lix files (till 25.06%)

Group 3: Cleaning and shaping with Protaper Gold files (till F2)

Group 4: Cleaning and shaping with Wave One Gold files. (Till 25.07%)

c) Evaluation of Canal Transportation

The amount of canal transportation was determined by superimposing the pre and post scan images on each other, the difference between the two was used to evaluate the amount of canal transportation.

d) Evaluation of Centering bility

Centering ability was evaluated by superimposing the pre and post Micro CT scans on each other.

e) Evaluation of cracks

Cracks were evaluated after biomechanical preparation on the instrumented surface by Micro CT scans.

Statistical Analysis

The data on categorical variables is shown as n (% of cases) and the data continuous variables are presented as mean and standard deviation (SD). The inter-group statistical comparison of distribution of categorical variables is teste dusing Chi-Square test or Fisher‘s exact probability test if more than 20% cells have expected frequency less than 5. The inter-group statistical comparison of means of normally distributed continuous variables is done using analysis of variance (ANOVA) with Post - hoc Bonferroni ‘s test for multiple group comparisons. The intra- group statistical comparison of means of continuous variables is done using paired t test. The underlying normality assumption was tested before subjecting the study variables to ANOVA and t test. All results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly.

In the entire study, the p-values less than 0.05 are considered to be statistically significant.

All hypo theses were formulated using two tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data is statistically analyzed using Statistical Package for Social Sciences (SPSS ver 24.0, IBM Corporation, USA) for MS Windows.

Results

In the entire study, the p-values less than 0.05 are considered to be statistically significant. All hypo theses were formulated using two tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data is statistically analyzed using Statistical Package for Social Sciences (SPSS ver 24.0, IBM Corporation, USA) for MS Windows.

Mean canal centering ability of Group I was 0.42 ± 0.24, in Group II was 0.49±0.18. In Group III and IV the centering ability was 0.14 ± 0.03 and 0.14 ± 0.04 respectively.

Table 1: Mean Canal centering Ability of Group I, II, III and IV

Centring Ability			
	N	Mean	Std. Deviation
Group I	10	0.4275	0.24383
Group II	10	0.4900	0.18035
Group III	10	0.1405	0.03605
Group IV	10	0.1413	0.04548

ANOVA for between group comparison of centering ability showed statistically high significant difference in the Centering ability between Group I, II, III and IV respectively.

Table 2: Comparison of Centering Ability between Group I, II, III and IV

ANOVA		
Centring Ability		
	F	p value
Between Groups	28.807	<0.001

Pair wise comparison was done using Tukey's post hoc test showed statistically high significant difference when Group I was compared with Group III and IV respectively. (p <0.001) A statistically high significant difference in centering ability was observed when Group II was compared with Group III and IV respectively. (p < 0.001)

Table 3: Pairwise comparison of Centering ability between Group I, II, III and IV.

(I) Group	(J) Group	Mean Difference (I-J)	p value	95% Confidence Interval	
				Lower Bound	Upper Bound
Group I	Group II	-.06250	.578	-.1907	.0657
	Group III	.28700*	<0.001*	.1588	.4152
	Group IV	.28625*	<0.001*	.1580	.4145
Group II	Group I	.06250	.578	-.0657	.1907
	Group III	.34950*	<0.001*	.2213	.4777
	Group IV	.34875*	<0.001*	.2205	.4770
Group III	Group I	-.28700*	<0.001*	-.4152	-.1588
	Group II	-.34950*	<0.001*	-.4777	-.2213
	Group IV	-<0.00175	1	-.1290	.1275
Group IV	Group I	-.28625*	<0.001*	-.4145	-.1580
	Group II	-.34875*	<0.001*	-.4770	-.2205
	Group III	<0.00175	1	-.1275	.1290

*. The mean difference is significant at the 0.05 level.

There was no statistically significant difference between I and II and in between Group III and IV in the centering ability. (p>)

Table 4: Mean Apical Transportation in Group I, II, III and IV.

z	N	Mean	Std. Deviation
Group I	10	0.1310	0.09233
Group II	10	0.3850	0.11367
Group III	10	0.2110	0.05108
Group IV	10	0.1515	0.02852

Apical transportation was seen maximum in Group II (0.38±0.11) Mean apical migration in Group I was 0.13±0.09, in group III the apical migration was found to be 0.21±0.05 and in Group IV was 0.15±0.02 respectively.

Table 5: Pairwise comparison of Apical transportation between Group I, II, III and IV.

Tukey HSD					
(I) Group	(J) Group	Mean Difference (I-J)	p value	95% Confidence Interval	
				Lower Bound	Upper Bound
Group I	Group II	-.25400*	<0.001*	-.3195	-.1885
	Group III	-.08000*	.010*	-.1455	-.0145
	Group IV	-.02050	.844	-.0860	.0450
Group II	Group I	.25400*	<0.001*	.1885	.3195
	Group III	.17400*	<0.001*	.1085	.2395
	Group IV	.23350*	<0.001*	.1680	.2990
Group III	Group I	.08000*	.010*	.0145	.1455
	Group II	-.17400*	<0.001*	-.2395	-.1085
	Group IV	.05950	.088	-.0060	.1250
Group IV	Group I	.02050	.844	-.0450	.0860
	Group II	-.23350*	<0.001*	-.2990	-.1680
	Group III	-.05950	.088	-.1250	.0060
*. The mean difference is significant at the 0.05 level.					

Pair wise comparison showed statistically high significant difference between Group I and II (p < 0.001). Difference in Apical migration between Group I and III was found to be statistically significant (p=0.01). There was statistically high significant difference in apical migration when group II was compared with Group III and IV respectively. (p<0.001)

There was no statistically significant difference in the apical migration between Group I and IV and between Group III and IV respectively. (p>0.05)

Table 6: Comparison of frequency of dentinal micro-cracks among specimens of different study groups.

Group	Dentinal micro-cracks present		Dentinal micro-cracks absent	
	Number of specimens	Percentage	Number of specimens	Percentage
Group 1	0	0	10	100
Group 2	2	20	8	80
Group 3	2	20	8	80
Group 4	4	40	6	60
p- value	0.001 (Significant)			

It was observed that in Group 1 no cracks were present. In group 2 and 3 cracks were observed in 20 % samples. In Group 4 cracks were found in 40% samples. The maximum cracks formation was seen in Group 4 while in Group 2 and 3 cracks were present in only 2 samples respectively. This difference in the cracks formation was found to be statistically significant ($p<0.001$).

Discussion

Endo dontic cleaning and shaping is a challenging procedure in the root canal treatment due to the variations in root canal Ana to my. Root canal shaping influences the quality of the next steps of root canal irrigation and filling. Ideally, root canal shaping should create a continuous tapered preparation from crown to apex while maintaining the original path of the canal and keeping the foramen size as small as possible [16].

Endo dontic treatment of root canals with accentuated curvature can result in accidents, such as ledge formation, perforations, canal trans portation, zip for mation; demanding longer clinical chair time, patience and operator skills [16]. These accidents make it difficult for clinicians to obtain a properly cleaned and filled root canal and might lead to endodontic treatment failure. Any new instrument has to ful fill the objectives proposed by Schilder [17].

These instruments present great flexibility, excellent cutting efficacy, and they maintain a constant, central position in the main canal, thus reducing the possibility of apical transportation.

Curved canals have been commonly used as specimens in research studies because these canals present with a greater challenge to instrumentation. Thus, evaluation of the performance of different instrument systems has been correlated to their ability for shaping curved canals and their ability to maintain the original anatomy of the canal to verify its curvatures [17].

The changes caused in the process of glide path preparation are further aggravated in the process of root canal shaping because the long itudinal axis of the curved canals changes in this process, the degree of curvature decreases, and the original curvature of the canal becomes rather straight [18]. Glide path is a smooth radicular patency from the root canal orifice to the apical construction. Files with a small taper (.02) and sizes of 0.15 or 0.20 are recommended to prevent taper lock and file fracture. Stainless steel K-files have been recom mended for manual glide path preparation to reduce the fracture rate of NiTi instruments. Thus, in this study glide path was done by size # 10 K file [19-20]. The Wave one Gold instru ments can completely prepare a canal with single instrument by slow in and out pecking motion following minimal glide path preparation. In single file reciprocation, stresses on the instru ments are expected to be higher during the canal preparation. Hence these files are intended for single use [21-22]

The Pro Taper endo dontic instruments are designed with varying taper over the length of the cutting blades; supposedly allowing each instrument to prepare a specific region of the canal. The Manu facturer states that one of the benefits of a progressively tapered instrument is that it engages a smallerz one of dentin, thus reducing torsional stress and the potential for instrument breakage [23]. The Protaper system is also available as hand – operated instruments. The Protaper instruments consist of three shaping (S1, S2and S3) and three finishing (F1, F2 and F3) instruments. In present study bio mechanical preparation was done till F1 using Universal and hand Protaper files [23].

The current study was conducted with the aim to evaluate and compare the efficacy of Hand Protaper, Neo lix files, Universal Protaper and Wave one rotary file system in relation to cracks, apical trans portation and centering ability in mandibular first molars. The mandibular roots of first molar show an accentuated curvature and it is highly recommended to follow glidepath in these teeth. Therefore, mandibular first molar sare selected in the present study.

In the present study canal centering ability and apical transportation was assessed by using micro computed Tomo graphy. By, recent technological advances, use of non - invasive techniques such as microcomputed Tomo graphy (micro-CT) may provide precise information about the results of root canal instrumentation [24].

Cross-sectioning of the canals is another technique that enables direct observation of the root canal shape. However, the original canal path prior to instrumentation cannot be studied in this technique [25-26]. Micro-CT is increasingly used for the assessment of the efficacy of new endo dontic instruments due to its non-invasiveness. In this technique, the root canal morphology is studied preoperatively and prior to probing of the canal with small hand files. The results showed that canal centering ability of Rotary Universal Protaper file was better when compared with hand Protaper, Neo lix files and wave one files. It was observed that there was statistically high significant difference between these files. These differences can be explained due to different cross-sectional design features and cutting tip of the files.

The findings from the current study revealed Hand Protaper files showed minimum apical transportation but more of canal centering ability when compared with neo lix, rotary Universal and Wave one Gold files respectively. This might be due to larger taper at coronal portion than apical one that causes less flexible coronally as a result minimizes canal transportation and increase in the centering ability.

In Current study cracks formation was also evaluated which showed that Hand Protaper showed no cracks formation while Wave one gold showed more cracks when compared with Hand Protaper, neo lix and Protaper Universal. This might be due to the fact that Active rotating movement results in a high level of stress concentrations in root canal walls that may result in crack formation. The reason for micro crack for mation is due to the tipped sign of rotary instruments, cross - sectional geo metry, constant or variable pitch and taper, and flute form. This study was conducted under in vitro conditions, and high standard deviation values due to the use of natural teeth were the limitation of this study. Therefore, the results should be generalized to the clinical setting with caution. Future clinical trials are required to confirm the current findings.

Conclusion

The results from the present study revealed that there was statistically significant difference in the centering ability and apical transportation between hand pro-taper, neo lix, universal and wave one gold pro-taper files. The centering ability of universal pro - taper files was observed to be better than hand pro-taper, neo lix and wave one gold files. Apical transportation of hand pro-taper files was found to be minimum when compared with neo lix, universal pro-taper and wave one gold Protaper files. The microcracks formed were maximum in wave one gold files while hand pro – taper files showed no cracks formation. The difference in the crack formation was found to be statistically significant.

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