Scanning electron microscopic evaluation of root canal surfaces prepared with three rotary endodontic systems: Lightspeed, ProTaper and EndoWave

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Abstract

Background and Objectives: The purpose of this *in vitro* study was to evaluate and compare the cleaning efficiency, preparation time, instrument deformation and fracture with LightSpeed (LS), ProTaper (PT) and EndoWave (Ew) rotary instruments.

Materials and Methods: A total of 45 freshly extracted human mandibular premolars were subjected for the study. They were divided into three groups, each group consisting of 15 teeth. Group 1: The canals were prepared with LS system; Group 2: PT rotary system, Group 3: Ew rotary system. All the groups were prepared according to manufacturer's recommendation, using 5.25% sodium hypochlorite and 17% ethylenediaminetetraacetic acid (dent wash, prime dent) alternately as an irrigants. Crowns of each tooth were removed with diamond disks at the level of cemento enamel junction. Canal length was determined by placing a size 10 K-file. The working length was 0.5 mm short of canal length. Two longitudinal grooves were prepared on the lingual and buccal surfaces of each root to facilitate vertical splitting with a chisel after canal instrumentation. The sections were then observed under scanning electron microscope for presence or absence of debris and smear layer and the photographs were taken at coronal, middle and apical 1/3 with a magnification of ×200 and ×1000 respectively. The time taken to enlarge each canal was recorded in minutes and seconds. The instruments were examined after every use for deformation. The scores recorded were statistically analyzed using one-way analysis of variance and Mann–Whitney test.

Results: There was statistically significant difference with regard to removal of debris and smear layer at coronal, middle and apical third for LS versus PT and LS versus Ew ($P < 0.01$). There was no significant difference between PT and Ew. The mean preparation time for LS, PT and Ew was 1.76, 2.50 and 2.75 respectively.

Interpretation and Conclusion: The study demonstrated that, LS instrumentation removed debris and smear layer effectively with shorter preparation time and Ew instrument showed deformation.

Key words: Debris, EndoWave, instrument deformation, LightSpeed, nickel-titanium instruments, preparation time, ProTaper, scanning electron microscope analysis, smear layer

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Introduction

Thorough debridement of root canal system is essential for the successful outcome of root canal therapy. "The quality guideline of the European society of Endodontology (1994) states that the elimination of residual pulp tissue, the removal of debris and maintenance of the original canal

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curvature during enlargement are the main objectives of root canal instrumentation."[1] The removal of debris is often neglected or overlooked and the influence of smear layer on the outcome of endodontic treatment is still controversial. Mechanically well prepared canals harbored areas that were never contacted by endodontic instruments. These findings prompted other investigators to look at the effect of mechanical preparation under scanning electron microscope (SEM).[2] Use of irrigating solutions are ineffective in completely removing hard and soft tissue debris, especially in the apical portion of the canal.[3]

Many of our currently accepted methods of chemo mechanical preparations being inadequate in producing debris free canal. Therefore, the emphasis has been placed on improving the endodontic instruments and developing more effective cleaning and shaping procedures.

A new generation of rotary endodontic instruments developed from nickel-titanium (Ni-Ti) alloys has brought a path breaking change in endodontics. They potentially allow shaping of canals, procedure being noticeably easier, faster than hand preparation. They are effective in removing debris and smear layer in apical third of the canal compared to hand instrumentation.[4-6]

Nickel-titanium instruments have 2–3 times more elastic flexibility and appear to be more fracture resistant than stainless steels. Concern has been expressed about comparatively high incidence of fracture of rotary Ni-Ti instruments.[7]

An advanced instrument design includes noncutting tips, radial lands and varying tapers have been developed to improve working safety, and shorten the working time.[8] Use of rotary Ni-Ti instruments with various tapers lead to good instrumentation of the canal. However, little is known about their cleaning effectiveness.

The purpose of this study was to determine the efficacy of LightSpeed (LS), ProTaper (PT), and EndoWave (Ew) rotary instruments in removing debris and smear layer from the canal surface. The efficacy of instruments in terms of preparation time and instrument failure was also determined.

Materials and Methods

Forty-five freshly extracted human mandibular premolars with fully formed apices, free of apical root resorption and caries were collected and were stored in 10% formalin.

Methods

The collected samples were randomly divided into 3 groups of 15 each. A small piece of modeling compound was placed at the root tip of each tooth to prevent the flow of irrigants through apical foramen.

An ideal access cavity was prepared for each tooth to obtain a straight-line access to the root canal. Teeth were decoronated at cemento enamel junction using diamond disc in order to obtain root segment for the preparation. The working length was obtained by measuring the length of initial instrument no. 10 visible at apical foramen − 0.5 mm for all the groups.

Root canal preparation for all the teeth was carried out with 3 different types of rotary instruments.

- The canals were prepared with LS instrument
- The canals were prepared with PT rotary instrument
- The canals were prepared with Ew instrument.

Crown down preparation technique was carried out in all the teeth according to manufacturer's recommendation, using alternate 5.25% sodium hypochlorite and 17% ethylenediaminetetraacetic acid (EDTA) (dent wash, Prime Dent) (Dent Wash, Prime Detnal Products Pvt, Ltd.India) as irrigants.

Procedure for root canal preparation

LightSpeed recommended method

Instrumentation was performed at constant speed of 1300 rpm. Straight-line access was obtained, and coronal flaring was done with Gates Glidden drill. Preparation involved five steps as described below:

- Determining the LS size that was used to begin rotary instrumentation (sizing or gauging the apical canal diameter). A LS instrument can reach working length, if its cutting head is smaller than the canal's diameter from orifice to working length. Sizing apical 3rd by hand was continued with smaller to sequential larger sizes, until the instrument did not reach the working length. This is known as first LightSpeed size to bind (FLSB). FLSB was chosen to begin instrumentation
- Determining the apical preparation size: Instrumentation with FLSB was started with slow-continuous movement until it engaged the canal walls. At this point, the instrument progressed apically in advance and withdrawal motion (pecking). This pecking movement was continued until FLSB reached the working length. Sequential larger instruments were used with pecking movement to enlarge the apical 3rd. The instrument that takes at least 12 pecks to reach working length is known as master apical rotary (MAR). This is called 12 pecks rule
- Completing apical instrumentation: After determining MAR, the next LS size which is short by 4 mm to working length was used. This enables the 5 mm long simplifill plug to closely match the size and shape of canal preparation

- Mid root instrumentation: The middle 3rd of root canal was prepared with sequential larger instruments with 4–8 light pecks, which means stopping after 4 pecks if LS did not advance, but continuing with 8 pecks if light speed advanced. This was continued until to reach the size of the instrument, which did not advance easily past the apical extend
- Recapitulation: Recapitulation to working length of each canal was done with respective MAR.[9]

ProTaper recommended method

Instrumentation was performed at speed of 200–300 rpm. Straight-line access was obtained. Glide path was established in coronal two-third of the canal with no. 10 and no. 15 hand file, until they are smooth and loose in the canal.

The depth of insertion of no. 15 hand file was measured, and the length was transferred to shaping file S1 and S2. The coronal third of the canal was enlarged sequentially with S1 and S2 using brushing motion. The auxiliary file Sx was used to relocate the coronal aspect of the canals to produce more shape as desired in any canal. Sx was inserted, if light resistance was felt on the instrument, file was withdrawn and worked in brushing the motion against the dentin wall, which enabled removal of overlapping dentin walls.

After completing the preparation of the coronal third of the canal, the apical extent of the canal wall was fully negotiated, working length confirmed, patency established and foramen enlarged to the size of no. 15 hand file. A smooth reproducible glide path to terminus was verified. Then shaping files S1 and S2 were carried to full working length. After Instrumenting with S2, working length was reconfirmed with a hand file. The finishing file F1 was carried to the working length. Size of the apical foramen was confirmed by gauging with no. 20 hand file. A snugly fitting no. 20 hand file indicated the completion of apical preparation.

If the file was loose in the canal, preparation was proceeded sequentially with F2 and F3. Gauging was performed after instrumenting with each finishing file with no. 25 and no. 30 hand files respectively to confirm the completion of apical preparation.[10]

EndoWave recommended method

Crown down preparation technique was employed to enlarge the canal by using file series from large to small size. A speed of 280 ± 50 rpm was maintained. Enlargement by using files from large to small resulted in smooth coronal flaring without creating steps on the canal wall.

No. 35/08 file was used to prepare the coronal half of the canal with back and forth motion. This was followed by no. 30/06, then no. 25/06, which was 2–3 mm short of the estimated working length. No. 20/06 instrument was used to prepare the canal to the full working length. If resistance occurred with no. 20/06, a smaller instrument no. 15/02 was used. Then apical preparation was completed with no. 25/06 instrument.

The teeth were embedded in the alginate mold, which was used as the conducting medium for the electronics apex locator and lip clip electrode of the Tri Auto Zx (J Morita, Kyoto, Japan) was inserted into the alginate to complete the circuit. This model was used for the preparation of the canal with Ew instrument.[11,12]

Since manufacturer recommended, Ew instrument to be used with Tri Auto Zx hand piece which has in built apex locator.

Preparation for scanning electron microscopic study

After completion of the instrumentation, each canal was flushed with sodium hypochlorite solution and dried with absorbent points. Longitudinal grooves were made on the buccal and lingual root surfaces with a diamond disk without penetrating the canal. The chisel and hammer was used to complete the fracture of the specimen. The specimens were stored in 2.0% glutaraldehyde aqueous solution till the SEM was carried out. The specimens were dehydrated using aqueous ethanol solution and were dried in a desiccator for 48 h. They were mounted on aluminum stubs, sputter coated with gold. Sections were mounted on the SEM (JSM-840A SEM, JEOL-Japan) to evaluate the presence of debris and smear layer at coronal 1/3rd, middle 1/3rd and apical 1/3rd using × 200 and × 1000 magnification respectively.

Scanning electron microscope photomicrographs for each specimen were taken, and cleanliness of the canal was evaluated in three areas by means of numerical evaluation scale.

Hulssman (1997) has given 5-step scale rating the debris and smear layer depending upon the amount of clumps present on the canal walls. Debris was defined as dentine chips, pulp remnants and particles loosely attached to the root canal wall.

- Score 1: Clean canal wall, only a few small debris particles
- Score 2: A few small agglomeration of debris
- Score 3: Many agglomeration of debris covering < 50% of root canal wall
- Score 4: More than 50% of root canal wall covered by debris
- Score 5: Complete or near complete root canal wall covered by debris.

Smear layer was defined as a surface film of debris retained on dentine or other surfaces after instrumentation with either rotary instrument or endodontic files, consisting of dentine particles, remnants of vital or necrotic pulp tissue, bacterial components and retained irrigants.

- Score 1: No smear layer, dentinal tubules open
- Score 2: Small amount of smear layer, some dentinal tubule open
- Score 3: Homogeneous smear layer covering the root canal wall, only few dentinal tubules open
- Score 4: Complete root canal wall covered by homogeneous smear layer, no open dentinal tubules
- Score 5: Heavy, inhomogeneous smear layer covering the complete root canal wall.[13]

Preparation time

The time is taken to enlarge each canal was recorded in minutes and seconds. It included only active instrumentation and not irrigation time or the changing of files.

The time required for individual tooth preparation in each group was noted, and mean time required for individual tooth preparation among three groups was calculated and compared.

Instrument failure

The instruments were examined after every use visually, and record was kept of those permanently deformed or fractured. The defects of instruments were observed based on the classification given by Sotokawa as follows.[14]

- Type I: Bent instrument
- Type II: Stretching or straightening of twist contour without bending
- Type III: Peeling or tearing off metal at edges of the instrument without bending or straightening of twist contour
- Type IV: Partial reverse twisting of the instrument
- Type V: Cracking along the file axis
- Type VI: Fracture of the instrument.

Deformed or fractured instruments were observed under stereomicroscope and photographs were taken. The number of instrument failures was recorded and compared among three groups.

All measurements and reading were noted and statistically analyzed and compared among three groups.

Result

Debris and smear layer

The score for debris and smear layer at coronal, middle and apical third were subjected to statistical analysis [Tables 1 and 2]. One-way analysis of variance

Table 1: Comparison of scores for debris removal

Score	Coronal			Middle			Apical		
	LS	PT	Ew	LS	PT	Ew	LS	PT	Ew
Mean (SD)	1.7 (1.0)	3.5 (1.2)	3.9 (0.7)	2.9 (0.8)	3.8 (0.9)	3.9 (0.6)	3.4 (0.8)	4.5 (0.5)	4.4 (0.8)
Median	1	4	4	3	4	4	3	5	5
ANOVA *F*, *P*		20.2, $P<0.01$			7.6, $P<0.01$, S			12.1, $P<0.01$	
LS versus PT*		$P<0.01$, S			$P<0.05$, S			$P<0.01$, S	
LS versus Ew		$P<0.01$, S			$P<0.01$, S			$P<0.01$, S	
PT versus Ew		$P=0.050$, NS			$P=0.29$, NS			$P=1.00$, NS	

LS=LightSpeed; PT=ProTaper; Ew=EndoWave; ANOVA=Analysis of varience; NS=Not significant; S=Significant; SD=Standard deviation, * Mann-Whiteny test, $P<0.05$, $P<0.01$ S=Significant, $P>0.05$, NS=Not Significant

Table 2: Comparison of scores for smear layer removal

Score	Coronal			Middle			Apical		
	LS	PT	Ew	LS	PT	Ew	LS	PT	Ew
Mean (SD)	1.5 (0.9)	2.7 (1.0)	3.0 (0.5)	2.5 (0.5)	3.4 (1.9)	3.4 (0.6)	2.8 (0.6)	4.2 (1.0)	4.2 (0.8)
Median	1	3	3	3	3	3	3	5	4
ANOVA *F*, *P*		14.1, $P<0.01$			6.9, $P<0.01$, S			15.1, $P<0.01$	
LS versus PT*		$P<0.01$, S			$P<0.05$, S			$P<0.01$, S	
LS versus Ew		$P<0.01$, S			$P<0.01$, S			$P<0.01$, S	
PT versus Ew		$P=0.19$, NS			$P=0.96$, NS			$P=0.86$, NS	

LS=LightSpeed; PT=ProTaper; Ew=EndoWave; ANOVA=Analysis of varience; NS=Not significant; S=Significant; SD=Standard deviation, * Mann-Whiteny test, $P<0.05$, $P<0.01$ S=Significant, $P>0.05$, NS=Not Significant

Table 3: Preparation time

Group	Number of specimens	Preparation time (min)			Difference between groups		
		Range	Mean (SD)	Median	Groups compared	Mean difference	*P* value*
LS	15	1.00-2.59	1.76 (0.51)	1.83	LS-PT	0.74	<0.01, S
PT	15	1.25-3.16	2.50 (0.55)	2.52	LS-Ew	0.99	<0.01, S
Ew	15	1.59-4.17	2.75 (0.57)	2.77	PT-Ew	0.25	0.23, NS

LS=LightSpeed; PT=ProTaper; Ew=EndoWave; NS=Not significant; S=Significant; SD=Standard deviation, *Mann-Whiteny Test, $P<0.05$, $P<0.01$ S=Significant, $P>0.05$, NS=Not Significant

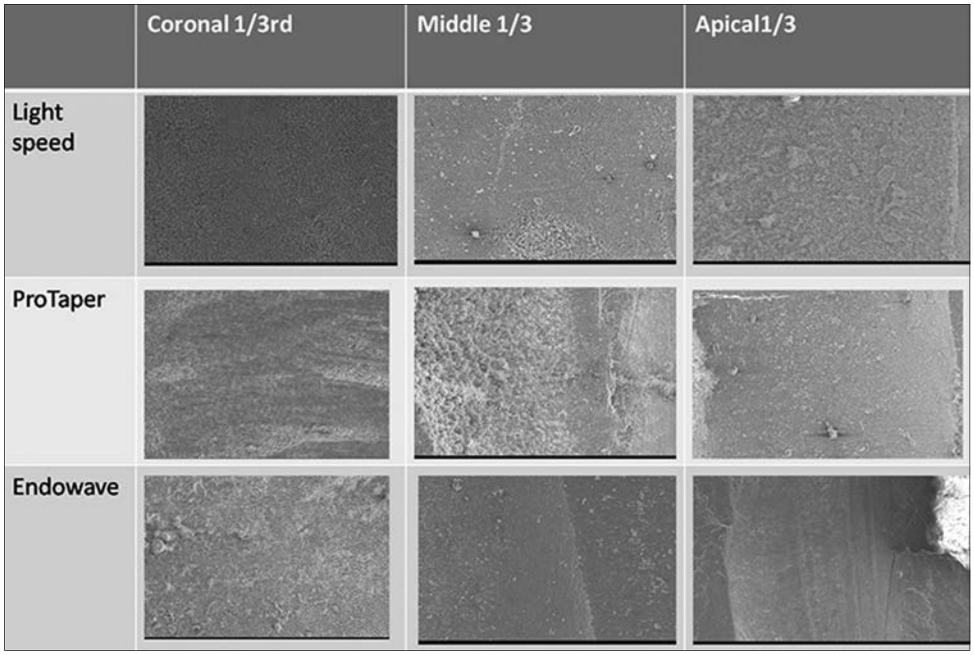

Figure 1: Scanning electron microscope comparison of debris

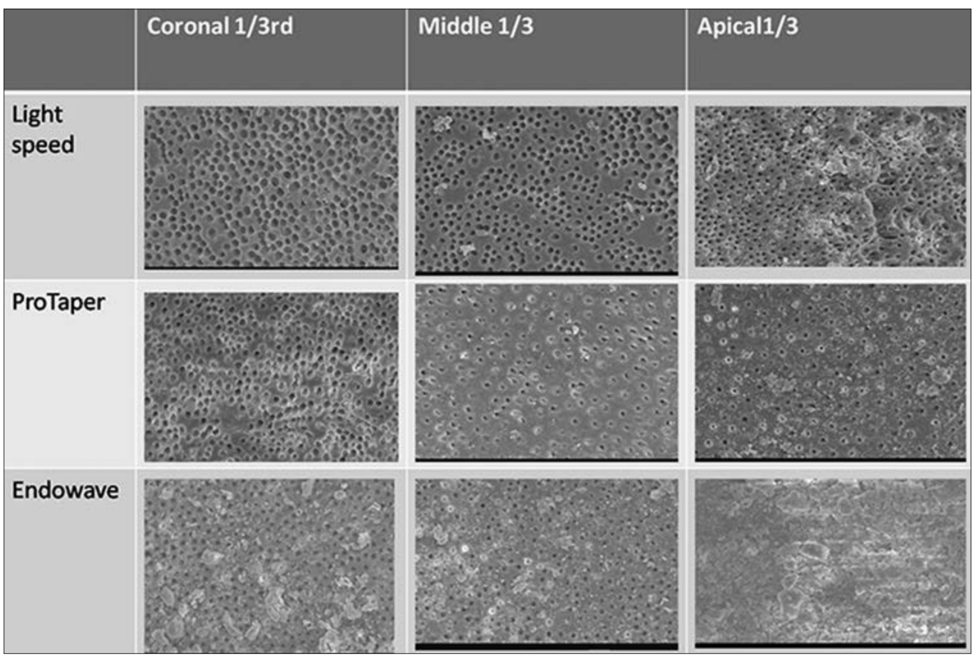

Figure 2: Scanning electron microscope comparison of smear layer

indicated that there was significant variation when compared between Group I, II and III ($P < 0.05$). Mann–Whitney test was performed for group wise comparison. There was a significant difference for removal of debris and smear layer at coronal, middle and apical third for LS versus PT and LS versus Ew ($P < 0.01$). There was no significant difference was observed between PT and Ew ($P > 0.01$).

The entire group showed higher removal of debris and smear layer in coronal third followed by middle third and lower scores in apical third [Figures 1 and 2]. Overall, LS instrumentation was significantly more efficient in removing of debris and smear layer than compared to PT and Ew.

Preparation time

Time taken to complete the preparation of canals with various instruments is shown in Table 3. The mean preparation time for LS, PT and Ew was 1.76, 2.50 and 2.75 respectively. Comparisons between LS and PT and LS and Ew showed statistically significant difference. However, difference between PT and Ew was not statistically significant [Table 3].

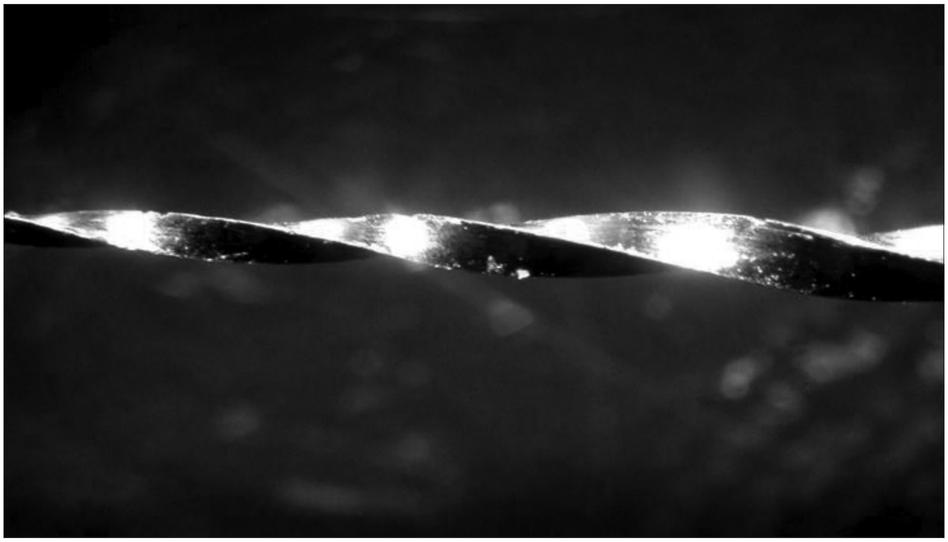

Figure 3: Deformation of EndoWave

Overall, the average time taken to prepare the canal was shortest for LS followed by PT and Ew Ni-Ti rotary instruments.

Instrument failure

None of the instruments showed visible deformation or fracture, but no. 25/06 taper Ew instrument showed tearing off metal at edges, when observed under stereomicroscope [Figure 3].

Discussion

The present study was conducted to evaluate the efficacy of LS, PT, and Ew rotary instrumentation to remove debris and smear layer from the root canal surface. The preparation time and instrument deformation of the three systems were also compared.

In the present study, results indicated statistically significant differences for LS versus PT and LS versus Ew for debris and smear layer removal. There was no significant difference between PT and Ew. This observation was in accordance with previous studies.[15,16]

The Cleaning efficiency of instruments in coronal and middle third was better because,

- Large preparation obtained with LS, PT, and Ew was no. 45–55, no. 30 (F3 file), no. 25/06 taper file respectively allows a larger volume of irrigants to be in contact with canal wall
- Use of irrigants such as 5.25% Naocl and 17% EDTA solution
- File designs such as the presence of radial land and U shape may prevent the risk of debris jamming in the canal
- Positive rake angle of PT instrument works like curette and may help to eliminate dentinal shaving during instrumentation.[17,10]

Cleaning ability of all the instruments in the apical third of the canal was less than middle and coronal third regardless of instrument used. This could be due to, with torque control hand piece reduced the cutting efficiency of instrument and progression of the file into apical third becomes more difficult.[18]

In general LS, instrument was more efficient in removing debris and smear layer. This may be attributed to the following factors:

- LightSpeed instrumented canal had larger apical stops, which enabled large volume of irrigating solution to react in the apical area.

However, their spade design would allow movement of debris coronally in an irrigant flooded canal.

- Manufacturer has recommended irrigation of canal with 5.25% Naocl and 17% EDTA
- Instrument was used in advance and withdrawal motion. Cutting occurs with advancement and withdrawal removes debris.

The current study indicated that none of the rotary instrumentation produced completely clean canal. But LS demonstrated better results compared to other systems.

Mean preparation time to instrument with LS was 1.76 min as compared with 2.50 and 2.75 min with PT and Ew. This difference was significant, and instrumentation was completed with a shorter period of time with LS that was in accordance with the previous studies.[19,8] The preparation time for LS was shorter due to the reduced contact zone between instrument and canal wall. The difference might be explained by the fact that the time an operator keeps the instrument working inside the root canal and the speed for up and down movement of the file is not clearly defined and will vary individually.[19]

The LS and PT instrument has not reported any fracture or deformation during the study. This finding is consistent with the results of previous studies. A no. 25/06 taper Ew file showed deformation. This could be attributed to the use of auto torque reversing with a hand piece and instrument tip tight in the canal, caused chipping of the flutes.The difference between the results reflects difference in design between three systems, especially about length of cutting shaft engaging the canal wall. The incidence of fracture increased with increasing size of files.[20] The reason for the deformation of rotary instrument was nonconstant speed of rotation, high torque, overuse of instrument and too much pressure.[21]

Conclusions

This *in vitro* comparison study of root canal preparation using LS, PT and Ew rotary instruments on their effect on cleaning ability, preparation time, instrument deformation and fracture has drawn the following conclusions:

- LightSpeed instrument was more efficient in removing debris and smear layer than other groups
- LightSpeed instrument took less time for root canal preparation than other groups, which was statistically significant
- The instrument deformation or separation was not seen in LS and PT but Ew instrument no. 25/06 showed deformation.

Under the conditions of this study, LS proved to perform better than other two groups with respect to the parameters under taken.

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