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COMPARISON OF SURFACE CHARACTERISTICS OF APICAL THIRD OF ROTARY NiTi FILES MANUFACTURED FROM DIFFERENT PHASES OF NiTi BEFORE AND AFTER USE : AN SEM ANALYSIS

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ABSTRACT

Clinically, there is a real potential for rotary NiTi instruments to separate in the canal; hence increasing the resistance to fracture has been a focus in the designing of new NiTi rotary systems. NiTi alloys go through various transitional phases and these have been utilized by manufacturers in different file systems. Aim : To evaluate and compare the surface changes of rotary nickel-titanium instruments manufactured from the Austenite phase, M-wire technology and R- phase before and after multiple uses. Materials and Methodology : 60 freshly extracted human mandibular premolars with a single, straight canal were selected. They were divided into 3 groups of 20 teeth each. Cleaning and Shaping was carried out using the crown down technique. All instruments were evaluated for defects under Scanning Electron Microscope (SEM) before and after multiple uses and scored for the defects. Results were statistically analyzed using Kruskal Wallis and Mann Whitney U test. Results : The p-value was <0.0001, indicating a statistically significant difference between the three groups in terms of resistance to surface defects. Conclusion : R-phase technology had superior resistance to surface defects, followed by M-wire and the austenitic phase.

Key words : NiTi instruments, Surface Defects, Transitional Phases

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Traditionally, endodontic instruments were made from carbon steel, which was prone to corrosion. This led to advent of the stainless steel alloy. Although stainless steel had some advantages like better cutting action and superior corrosion resistance, its modulus of elasticity was found to be high, resulting in lack of flexibility.[1] This led to introduction of a new alloy called the nickel-titanium alloy, developed in early 1960s by W.F. Buehler at the Naval Ordinance Laboratory in Silver Springs, Maryland, USA. In comparison to conventional stainless steel files, NiTi instruments offer superior flexibility and shape memory. The super elasticity of NiTi instruments allows preservation of the root canal anatomy, thus reducing procedural errors.[2,3] However, one of the major drawbacks of NiTi instruments is their vulnerability to fracture. Hence constant endeavours are being made to overcome the drawbacks and yet harness the uniqueness of this material.

The crystalline structure of NiTi alloy at a high temperatures (i.e. around 100°C) is a stable, body-centered cubic lattice called as austenite or parent phase. Nitinol has a uniquecharacteristic of undergoing a change in the crystalline structure when it is cooled through a critical Transformation Temperature Range (TTR). It forms a closely packed hexagonal lattice which is referred to as martensitic or daughter phase.[2] In alloys with excess of Nickel, an intermediate martensitic phase, called the R-phase, can form prior to transformation of austenite phase to martensite phase. This phase change is responsible for the super elasticity of the alloy.

Endodontic instruments are conventionally manufactured from a particular form of the conventional austenitic NiTi alloy which is commercially available i.e. Nitinol 508.[4,5] Protaper Universal (Dentsply Maillefer, Tulsa

Dental, OK, USA) was one such system representing the conventional alloy. Manufacturers have researched new manufacturing techniques and utilized various transitional phases of NiTi alloy to improve the physical and mechanical properties of the instruments. One modification was R-phase heat treatment resulting in a transformed crystalline structure. The Twisted Files (Sybron Endo, Orange County, CA, USA) represented this group. Another such material was developed to include both R-phase and B19' martensitic phase and was termed as the M-wire technology.[4,6] Protaper Next (Dentsply Maillefer, Tulsa Dental, OK, USA) utilizes this technology.

The fracture of these NiTi instruments occurs without any macroscopically visible defects. Therefore, the microscopic evaluation of the surface quality of the cutting surfaces is of clinical interest to the clinicians.[7] The purpose of this study was to evaluate and compare surface changes of the apical third of the rotary NiTi instruments manufactured from the conventional austenite phase, R-phase and the M-wire technology before and after multiple uses.

MATERIALS AND METHODS

60 freshly extracted human mandibular premolars with a single, straight canal were selected. They were checked to ensure that no restorative or endodontic treatment had been carried out on them. Defective teeth were replaced. Radiographs were taken from buccolingual and mesiodistal angles. The width of the canal on both angles was measured at 9 mm from the apex. Also in all the teeth, the canal width near the apex was compatible with a size 10 K-file (Mani, Japan). They were stored in containers filled with normal saline at room temperature to avoid any effect of the fixative on dissolution of organic tissue. Teeth with open apices, developmental defects, abnormalities in the root canal shape and calcified canals were excluded from the study.

All teeth were decoronated using diamond discs under a water coolant. A small amount of wax was placed at each root tip to prevent escape of the irrigating solution. Next, the apical patency was established using a no. 10 K file (Mani, Japan). This was followed by working length determination by inserting a no. 10 K file into the canal until its tip was visible at the apical foramen and then subtracting 0.5mm. Hand filing was carried out sequentially upto no. 25 K file (i.e. no. 15, 20 and 25) (Mani, Japan), in combination with irrigation using 3% NaOCl and 5% EDTA (RC Help, Prime Dental Products Pvt. Ltd., Mumbai, India). Canal orifices of all the specimens were enlarged using S_X Protaper file (Dentsply Maillefer, Tulsa, OK, USA).

The 60 samples were divided into three groups of 20 samples each.

Group I: Specimens in this group were instrumented with the Protaper Universal System (Dentsply Maillefer, Tulsa Dental, OK, USA) representing the conventional austenitic NiTi alloy. In this system the full sequence of files upto file F_2, driven by an X-Smart motor (Dentsply Maillefer, Tulsa Dental, OK, USA) at a speed of 300 rpm was used following which the F_2 file was subjected to SEM examination.

Group II: Specimens in this group were instrumented with the Twisted File System (Sybron Endo, Orange County, CA, USA) representing the R-phase NiTi alloy. In this system the full sequence of files upto file 25, 0.06 taper was used, driven by an X-Smart motor (Dentsply Maillefer, Tulsa Dental, OK, USA) at a speed of 500-600 rpm following which the 25, 0.06 taper file was subjected to SEM examination.

Group III: Specimens in this group were instrumented with the Protaper Next System (Dentsply Maillefer, Tulsa Dental, OK, USA) representing the M-wire technology. In this system the full sequence of files upto file X_2, driven by an X-Smart motor (Dentsply Maillefer, Tulsa Dental, OK, USA) at a speed of 300 rpm was used following which the file X_2 was subjected to the SEM examination.

SEM Examination :

Files from all the three groups were examined under the Scanning Electron Microscope, using a customized file holder (Figure 1) before use to check

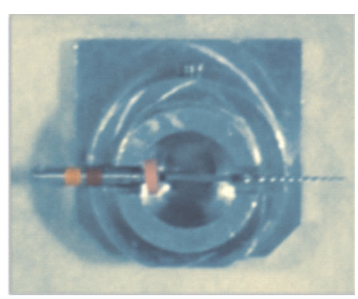

Figure 1: Files were placed in a customized file holder and then placed in the Scanning Electron Microscope

for any manufacturing defects. Photomicrographs of the surface defects in apical third of the files were taken at 90° and 360° with the aid of a custom-made holder and observed at 100X and 250X. Then, the files were subjected to six uses under simulated clinical conditions and cleaned with acetone between each use. They were then again examined under Scanning Electron Microscope in similar manner as before. Surface defects on the used and unused instruments were then evaluated and compared on the recorded photomicrographs and final data was recorded.[1,8]

Scoring Criteria :

Scoring criteria examined in new and used instruments was given by Christine Eggert, Ove peters et al-1999.[1]

Surface defects

Score 1 – No visible defect
Score 2 – Pitting
Score 3 – Fretting
Score 4 – Micro fractures
Score 5 – Complete fracture
Score 6 – Metal flash
Score 7 – Metal strips
Score 8 – Blunt cutting edges
Score 9 – Disruption of cutting edge
Score 10 – Corrosion
Score 11 – Debris

The surface defects of all instruments in each group before and after use were recorded and the results were subjected to statistical analysis tests.[9] All the statistical analysis were performed using SPSS 16.0 software (SPSS Inc., Chicago, IL, USA).

RESULTS

The results were analyzed statistically using Kruskal Wallis Test and Mann Whitney 'U' Test.

A significant difference was found when Group I was compared to Group II and Group III while the experimental results showed no significant difference when Group II and Group III were compared amongst themselves. Maximum surface defects were seen in Group I (Protaper Universal) followed by Group II (Protaper Next) and least in Group III (Twisted Files).

When the scoring of individual groups was cross tabulated, following inferences could be drawn (Table 1).

Table 1: Showing the percentage of different surface defects on the different rotary files

Type of Defect	Protaper Universal	Protaper Next	Twisted File
No visible defect	15%	30%	60%
Pitting		35%	30%
Fretting	-	35%	10%
Micro fractures	-	-	-
Complete fracture	-	-	-
Metal flash	-	-	-
Metal strips	-	-	-
Blunt cutting edges	55%	-	-
Disruption of the cutting edge	30%	-	-
Corrosion	-	-	-

Surface defects were observed in 85% of the instruments in Group I (Protaper Universal), 70% in Group II (Protaper Next) and 40% in Group III (Twisted Files).

Defects in form of blunt cutting edges were seen in 55% of the instruments in Group I (Protaper Universal) and were absent in instruments belonging to Group II (Protaper Next) and Group III (Twisted Files). Similarly surface defects in form of disrupted cutting edges were seen only in 30% of the instruments in Group I (Protaper Universal) and were absent in Group II (Protaper Next) and Group III (Twisted Files).

Fretting (Figure 2A and 2B) was observed in 35% of Group II (Protaper Next) instruments. 10% of the Group III (Twisted Files) instruments also showed similar defects.

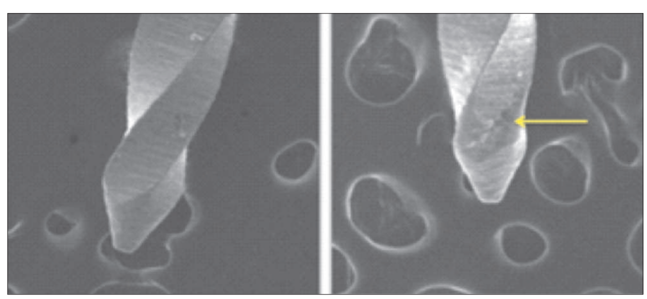

Figure 2(A) Figure 2(B)

Figure 2(A): SEM image at 100X of Protaper Next before use
Figure 2(B): SEM image at 100X of Protaper Next after use with the arrow pointing towards the surface defect i.e. fretting

Similarly, overall pitting defects were seen only in Group II (35%) (Protaper Next) and Group III (30%) (Twisted Files) and were absent in Group I.

None of the study groups exhibited surface defects in form of microfractures, complete fractures, metal flash and strips or corrosion.

DISCUSSION

Endodontic therapy encompasses treating vital and necrotic teeth, hence restoring their function and esthetics. Several factors affect the successful outcome of this procedure, canal preparation being one of the most important factor. This is because it lays down the foundation for efficacy of all the subsequent procedures.[1]

Over the years different materials were used to manufacture root canal instruments but since their inception in 1988, NiTi instruments have gradually evolved to occupy a significant position in today's world of endodontics.

Various NiTi rotary systems should be used according to condition of the root canal in clinical situation. Hence, NiTi files with high flexibility and superior cyclic fatigue resistance should be used for curved canals, whereas stiffer files should be restricted to prepare constricted and/or straight portion of the root canal. Care should be taken especially during cleaning and shaping of the curved canals as they are prone to various iatrogenic errors such as canal transportation.[10,11]

Despite increased strength and flexibility of NiTi instruments, a major drawback with their use is their tendency to fracture,[10,12,13] moreover they fracture without any warning signs.

Based on etiology, the fracture of NiTi files can be divided into two categories, cyclic flexural fatigue and torsional fatigue. Cyclic flexural fatigue is caused by work hardening and metal fatigue. Torsional fatigue is the stress build up in a file during its rotation in the canal. It is further categorized into 2 types.[1,8,14,15,16,17]

a. Dynamic torsional fatigue which occurs from frictional forces caused by resistance of dentin to cutting by the file.
b. Static torsional fracture which occurs by continuous rotation of the file at one end while the other end stops spinning when a section of file is locked in place while the handpiece continues to rotate.

NiTi files are exposed to irrigating solutions, especially NaOCl during cleaning and shaping protocol and this affects the surface of files. Hence normal saline was used for irrigation in this study to eliminate the effect of NaOCl.[18]

The results of this study confirmed previous reports that manufacturing process of NiTi instruments is often subjected to errors resulting in irregular surfaces.[9]

The NiTi alloy M-wire demonstrates increased resistance to cyclic fatigue.[4,19,20] The Protaper Next represents this technology. But it was found that Protaper Next showed more irregularities than Twisted file, which is manufactured from R-phase NiTi alloy. Hence it could be concluded that R-phase showed superior resistance to surface defects as compared to the M-wire technology.[15,20,21]

Magnification is an indispensable aid in visualizing the features leading to failure process as well as gaining insight into the mechanism of failure which is not possible with the naked eye. Hence in the present study the files were viewed under the Scanning Electron Microscope at 100X and 250X.

In a study conducted by Sattapan et al it was observed that files that broke due to torsion exhibited signs of deterioration above the point of fracture whereas files that broke due to fatigue through flexure did not exhibit defects linked to their subsequent fracture. Instrument failure depends on number of factors like complexity of root canal system, curvature, size of the instrument, action and method of instrumentation. In curved canals, the files undergo both torsional and flexural fatigue, whereas in straight canals only torsional fatigue is observed. So in this study, files used exclusively in mandibular premolars with straight canals, were evaluated for defects caused by fatigue after each use.[10]

Apical one-third of the files were evaluated in this study in accordance with Sattapan et al who stated that clinically, files were found to fracture close to the tip generally.[10] Also in this study, file F_2 was tested in the Protaper Universal Group, file X_2 was tested in the Protaper Next group and file number 250.06 taper was tested in the Twisted Files group to ensure uniformity of size amongst all the groups.

Of all the instruments that were tested, Group I was found to be most susceptible to surface defects, followed by group II and least number of defects were seen in Group III. None of the groups showed micro fracture, complete fracture and corrosion, this is in similarity to the study conducted by Eggert et al.[9]

A study conducted by Kuhn et al showed that fatigue crack growth rate was less in Ni-Ti when compared to conventional metals or alloys.[22]

CONCLUSION

Within the limitations of this in-vitro study it can be concluded that files made from conventional austenitic NiTi alloy have least resistance to surface defects, followed by files made from the M-wire technology (R-phase and B19' martensitic phase) whereas files made from R-phase NiTi alloy showed superior resistance to surface defects.

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