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A comparative evaluation of cyclic fatigue resistance for different endodontic NiTi rotary files: An *in-vitro* study☆

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ABSTRACT

Aim: This in-vitro study evaluated and compared the flexural fatigue resistance for Hero Shapers, Hyflex CM, One Shape, Profile Vortex and Protaper Next rotary NiTi files.

Method and materials: Total 25 rotary NiTi files allocated to each experimental group were tested in a simulated constructed apparatus with an angle of curvature 60° & radius of curvature 5 mm. Each experimental file was coated with EDTA gel and was placed in endodomotor handpiece with rubber stopper at support steel cylinder and its end between two shaping steel cylinders on the simulated apparatus. File was then rotated at 400 rpm, 2.5 N/cm torque and simultaneously digital stop watch was started. Time taken (in seconds) until the file got fractured was recorded.

Results: Time taken to fracture ranged from 7 to 58 s in different groups. Analysis of variance show a statistically significant intergroup difference ($p < 0.001$). Tukey HSD test showed the significant differences. The Weibull modulus values ranged from 7.31 to 24.19.

Conclusion: Cyclic flexural fatigue resistance was observed highest for Grp IV (Hyflex CM) and lowest for Grp I (Hero Shapers).

Clinical significance: Hyflex CM rotary NiTi files can be used in curved root canals as they had superior resistance and long survival time which will be helpful in eliminating one of the reasons for file fracture (due to cyclic flexural fatigue) during the root canal treatment clinically where root canal possesses a sharp bend or curve.

1. Introduction

Endodontics has evolved and changed over the years like many other dental and medical specialties. It primarily comprises of root canal treatment involving access cavity preparation followed by cleaning and shaping of root canal and finally a three dimensional seal of that prepared pulp space. The endodontic instruments plays a major role in contributing to reach success. Earlier, the root canal instrumentation was by performed by carbon steel alloy instruments which were replaced by stainless steel instruments due to their disadvantage of being corroded and rusted. Stainless steel instruments in clinical use also showed disadvantages in form of procedural errors like perforations, zips or ledges that altered natural canal anatomy. These errors potentially decreased the success of the root canal treatment. To overcome, root canal instruments made up of Nickel Titanium alloy were introduced in 1960's by Sir William Buehler & Frederick Wang at Naval Ordinance Laboratory, Maryland. NiTiNOL occurs in two forms NiTiNOL 60 and NiTiNOL 55.NiTi alloys exhibits two characteristic properties of Shape memory and superelasticity. Due to these properties endodontic NiTi files have shown 2–3 times more flexibility while bending as well as torsion while working in a curved root canal.[1] No doubt about it that root canal treatment benefitted from introduction of NiTi files but clinician only concern remained the same about its breakage while in use in a curved canal. According to Spanaki et al. fracture of instrument is the most common procedural error that occurs during clinical use of rotary NiTi instruments.[2] Sattapan et al. Parashos et al., Peng et al. Shen et al. reported that clinically working in a curved canal file got fractured due to shear or flexural fatigue.[3–7] Flexural fatigue arises when a endodontic file rotating in a curved canal without any obstruction experiences repeated cycles of compression and tension

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at the maximum curved part of the canal.This induces stress which finally leads to file fracture in the canal. The aim of the present in-vitro study was to evaluate and compare cyclic flexural resistance of total 125 rotary Hero Shapers, Protaper Next, Profile Vortex, Hyflex CM and One Shape NiTi files manufactured from M wire Technology, CM wire technology and Conventional NiTi alloy.

2. Method

Total 125 experimental rotary NiTi files were divided in 5 groups namely Group I (Hero Shapers, MicroMega), Group II (Protaper Next, Dentsply) and Group III (Profile Vortex, Dentsply Tulsa Dental) manufactured from M wire alloy, Group IV(Hyflex CM,Coltene Whaledent) manufactured from CM wire technology and Group V(One Shape, MicroMega) manufactured from conventional NiTi alloy. Each group comprised of 25 experimental rotary files were kept standardized of 21 mm length, 6% taper and ISO size 25. All these files were tested in a simulated constructed apparatus with angle of curvature 60° and radius of curvature 5 mm. Each file was coated with EDTA Gel (Glyde, Dentsply) and was placed in TriautoMini endomotor handpiece with the file stoppers at support steel cylinder and file tip between two shaping steel cylinders on the simulated constructed apparatus. Each file was then allowed to rotate at 400 rpm and 2.5 N/cm torque preset in triauto Mini endomotor and simultaneously a digital stopwatch was started. Time taken (inseconds) until file fractured was recorded. Number of cycles performed by a file until fracture was calculated by the following formula: No. of cycles performed by experimental file until fracture = 400/60 x Time taken till fracture (in sec.).Observations were laid down (Table 1 and Table 2) and were statistically analysed using Annova, Tukey HSD test and Weibull's analysis.

3. Results

The results obtained showed that mean time taken until fracture of rotary NiTi file ranged from 7 to 58 s in different tested groups. Group IV showed maximum mean time taken until fracture and least in case of Group I. Analysis of Variance showed a statistically significant intergroup difference ($p < 0.001$). Tukey HSD test found maximum group difference between Group I and Group IV and Mimimum group difference between Group I and Group III. Weibull's modulus ranged from 7.31 (Group I) to 24.19 (Group IV). Characteristic survival time was maximum for group IV (58 s) and minimum in Group I (7 s).Overall, while testing the cyclic flexural fracture resistance in the selected experimental rotary NiTi files, Hyflex CM files showed superior cyclic flexural fracture resistance with maximum survival time followed by One Shape files, ProTaper Next files, Profile Vortex files and minimum cyclic flexural fracture resistance was observed by Hero Shapers files.

Table 1
Time taken (in seconds) by experimental files in each group until fracture.

S. no.	Group I (n = 25)	Group II (n = 25)	Group III (n = 25)	Group IV (n = 25)	Group V (n = 25)
1	12	24	14	52	40
2	8	22	10	50	38
3	10	18	12	58	32
4	8	18	10	54	30
5	12	26	14	56	34
6	10	18	12	58	30
7	10	22	14	57	34
8	9	24	10	58	36
9	8	24	10	55	38
10	7	20	12	56	38
11	10	18	12	58	30
12	10	22	14	57	34
13	9	24	10	58	36
14	8	24	10	55	38
15	7	20	12	56	38
16	12	26	14	56	34
17	8	18	10	54	30
18	10	18	12	58	32
19	8	22	10	50	38
20	12	24	14	52	40
21	9	22	14	50	36
22	8	18	12	54	34
23	10	24	10	52	30
24	8	18	10	54	38
25	12	24	10	50	40

Table 2
No. of cycles performed by Experimental files until file fractured.

S.No.	Group I (n = 25)	Group II (n = 25)	Group III (n = 25)	Group IV (n = 25)	Group V (n = 25)
1	80.04	160.08	93.38	346.84	266.8
2	53.36	146.74	66.7	333.5	253.46
3	66.70	120.06	80.04	386.86	213.44
4	53.36	120.06	66.7	360.18	200.1
5	80.04	173.42	93.38	373.52	226.78
6	66.7	120.06	80.04	386.86	200.1
7	66.7	146.74	93.38	380.19	226.78
8	60.03	160.08	66.7	386.86	240.12
9	53.36	160.08	66.7	366.85	253.46
10	46.69	133.4	80.04	373.52	253.46
11	66.7	120.06	80.04	386.86	200.1
12	66.7	146.74	93.38	380.19	226.78
13	60.03	160.08	66.7	386.86	240.12
14	53.36	160.08	66.7	366.85	253.46
15	46.69	133.40	80.04	373.52	253.46
16	80.04	173.42	93.38	373.52	226.78
17	53.36	120.06	66.7	360.18	200.1
18	66.7	120.06	80.04	386.86	213.44
19	53.36	146.74	66.7	333.5	253.46
20	80.04	160.08	93.38	346.84	266.8
21	60.03	146.74	93.38	333.5	240.12
22	53.36	120.06	80.04	360.18	226.78
23	66.07	160.08	66.7	346.84	200.1
24	53.36	120.06	66.7	360.18	253.46
25	80.04	160.08	66.7	333.5	266.8

4. Discussion

The present in-vitro study comprised of direct comparison of cyclic fatigue resistance among the selected NiTi rotary files being tested, therefore a separate control group was not required. Various apparatus designs have been constructed evaluating cyclic fracture resistance of endodontic files.[8–10] They used artificial canals constructed by bending glass or metal into cylindrical tubes with different inner diameters having different radii and angles of curvature. Because of the inner diameter of the tubes made up of glass or metal was greater than that of the instruments, an instrument rotated in the tube followed a trajectory that was not predictable and without the parameters of radius and angle of curvature and point of maximum curvature that were established when constructing the artificial canals. Another drawback with loose-fitting canal was that the file may walk or vibrate in that space, leading to a change in the magnitude of stress and possibly leading to variations in the results. Moreover, if the files of the same dimensions followed different trajectories in the test apparatus, a direct comparison between instruments of different brands was difficult to establish and the results obtained were unreliable and not consistent. Other apparatus design showed resting of the endodontic file against an inclined grooved that produced root canal curvature.[11] This method also had a significant shortcoming that it ignored the radius of curvature. The present study used three pin/cylinders customized apparatus for a precise trajectory as mentioned by Cheung et al. to evaluate cyclic fatigue resistance.[12] This apparatus design provided standardization of assay conditions and minimized other mechanisms of file fracture other than cyclic fatigue. The simulated root canals with an angle of curvature of 60° and radius

of curvature of 5 mm in the present study were based on the study done by Pruett J.P et al. that stated that the stress levels induced by curvatures smaller than 5 mm of radius and 30° angle did not result in instrument separation.[8]

In the present study, Total 125 experimental rotary NiTi files were divided in 5 groups namely Group I (Hero Shapers, MicroMega), Group II (Protaper Next, Dentsply) and Group III (Profile Vortex, Dentsply Tulsa Dental) manufactured from M wire alloy, Group IV(Hyflex CM,Coltene Whaledent) manufactured from CM wire technology and Group V(One Shape, MicroMega) manufactured from conventional NiTi alloy. Each group comprised of 25 experimental rotary files were kept standardized of 21 mm length, 6% taper and ISO size 25. All these files were tested in a simulated constructed apparatus with angle of curvature 60° and radius of curvature 5 mm. Each file was coated with EDTA Gel (Glyde, Dentsply) and was placed in TriautoMini endomotor handpiece with the file stoppers at support steel cylinder and file tip between two shaping steel cylinders on the simulated constructed apparatus. Each file was then allowed to rotate at 400 rpm and 2.5 N/cm torque preset in triauto Mini endomotor and simultaneously a digital stopwatch was started. Time taken (inseconds) until file fractured was recorded. Upon Statistical analysis, results obtained showed that Group IV rotary file (Hyflex CM) had longest survival time and minimal survival time was shown by Group I NiTi rotary file (Hero Shapers). Cyclic fatigue resistance of tested rotary niti files in descending order was Group IV Hyflex CM$^{>}$ Group V One Shape $^{>}$ Group II Protaper Next $^{>}$ Group III Profile Vortex $^{>}$ Group I Hero Shapers. The reasons attributed for Hyflex CM greater cyclic fatigue resistance were due to the composition of Hyflex CM files that has low % weight of nickel, Stable Martensitic active structure, Greater Austenite finish (A_f) temperature which had mixture of both Austenite and Martensitic structures at room temperature and Proprietary Processing.[13–16] Hero Shapers file (Group I) showed the least cyclic flexural fracture resistance as these files possessed a relatively narrow range of elasticity due to alteration in grain structure caused by grinding process.[17] Also asymmetrical triangular cross section design and manufacturing from conventional NiTi alloy added to low fracture resistance in Hero Shapers files.[18] The grinding across the grain structure during manufacturing process created microfracture points and defects along the length of the entire instrument. These defects acted as stress concentration points that weakened the instruments and finally led to fracture of file. Increased fracture resistance of Hyflex CM files can also be due to the crack propagation mechanism. It presents a large number of highly branched cracks that propagates very slowly in contrary to superelastic NiTi form where only a few fatigue cracks nucleates and propagates at faster speed. One possible source of error in the cyclic fatigue experiments comes from the observer being required to manually use a digital stopwatch to record the time when a rotary file fractures during rotation. All known cyclic fatigue studies employ this method. However, in the present study there were no instances noted where the observer missed the breakage of the instrument during rotation.

5. Conclusion

On testing cyclic flexural fracture resistance among the experimental groups the cyclic fatigue resistance was observed in descending order Group IV (Hyflex CM) $^{>}$ Group V (One Shape) $^{>}$ Group II (Protaper Next) $^{>}$ Group III (Profile Vortex) $^{>}$ Group I (Hero Shapers).

Hyflex CM files had longest survival time while minimal survival time was shown by Hero Shapers files. The clinical significance obtained from this in-vitro study is that Hyflex CM rotary NiTi files which have superior resistance and long survival time will be helpful in reducing or eliminating one of the reasons for file fracture (due to cyclic flexural fatigue) during the root canal treatment clinically where root canal possesses a sharp bend or has a severe curvature.

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Conflicting interest (If present, give more details)

None.

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