Cyclic Fatigue Resistance of Wave One Gold, F6 SkyTaper, One Curve, and AF Blue R3 NiTi Rotary Instrumentation Systems

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Abstract

Objective: This in vitro study is aimed to compare and evaluate the cyclic fatigue of four varying NiTi rotary instrumentation systems.

Method: In this study, four types of rotary files were used in four groups (10 files for each group), namely, Group A: Wave One Gold; Group B: AF Blue R3; Group C: One Curve; Group D: F6 SkyTaper. These groups were evaluated by a cyclic fatigue apparatus to measure cyclic fatigue resistance within the artificial metallic simulating canal that has a 60° angle of curvature, the curvature radius was 5 mm, whereas the inner diameter of the canal was 1.5 mm. All the files were rotated in artificial canals until they fracture. The resistance to cyclic fatigue was determined by counting the number of cycles to fracture, and the time to failure was recorded in seconds then transformed to minutes. In addition to that the fractured fragment length was evaluated.

Results: One-way analysis of variance test showed a significant difference ($P<0.001$) in the average values of cycle number and time needed for file fracture and average fractured portion length among all groups.

The t-test results indicate a significant difference ($P<0.001$) among all groups.

Conclusions: The study concluded that with an apical curvature of an artificial canal with an angle curvature of 60°, AF Blue R3 and F6 SkyTaper instruments exhibit a higher resistance to cyclic fatigue than One Curve and Wave One Gold files most possibly due to surface and alloy feature variation.

Keywords: *Endodontics instrumentation, cyclic fatigue resistant*

Introduction

Rotary instruments for root canal systems made from nickel-titanium (NiTi) alloy exhibit more elasticity than stainless steel instruments, which are rigid and unsuitable for large apical enlargement in thin-curved canals [1]. Specifically, the elastic flexibility of NiTi instruments is approximately 2–3 times greater than that of stainless-steel instruments [2&3].

NiTi instruments feature a risk for fracture owing to cyclic fatigue and torsional shear; this condition is an unexpectedly important disadvantage of rotary files when rotate freely in a curved root canal [4-6]. In order to increase the easiness, simplicity, and speed of root canal preparation procedure for practitioners, a single file Ni Ti rotary systems with either complete rotation or reciprocation motion were introduced [7]. Wave One Gold files manufactured by Dentsply Maillefer in Switzerland are a new version of Wave One files. In this version, the geometry, dimensions, and cross section are modified while maintaining reciprocation motion. The files are made by gold, which is heated at first and then slowly cooled for file production; these files also exhibit two cutting edges with a parallelogram cross section, which may increase file flexibility as claimed by the manufacturer [8].

The F6 SkyTaper manufactured by Komet, Brasseler GmbH & Co. in Germany is a new generation of single-file, one-use NiTi system comprising one available instrument with five diverse sizes (20, 25, 30, 35, and 40) and showing a constant taper of 0.06, which is critical for shaping of the root canal. These files are distinguished by their cross-sectional design, which is a unique double-S cross section. The F6 SkyTaper instrument is produced for use in a continuous clockwise rotation motion [9].

One Curve file manufactured by MICRO MEGA in France is a heat-treated C-wire with a regulated memory of NiTi and a potential to prebending to facilitate access to the root canal. One Curve is also a single-use, single instrument rotary file employed in continuous rotation. The variable cross-section ensures excellent cutting efficiency and debris removal up to the medium and coronal parts of the canal with a perfectly centered trajectory [10&11].

AF Blue R3 manufactured by Fanta Dental Materials Co., Ltd. in Shanghai is a special heat-treated wire used for producing endodontic rotary files. However, NiTi files display a high possibility of unnoticed fracture inside root canals, different from the stainless-steel files, which are most likely to show plastic deformation signs. AFTM-Wire is a developed NiTi alloy and features excellent mechanical strength properties. The flexibility of AFTM-Wire sufficiently avoids canal transportation. Meanwhile, its hardness is large enough to allow for good cutting efficacy. Fanta AFTM-Wire offers three levels of flexibility depending on the crystallographic phases present in the alloy and rectangular cross-section of AF BLUE R3 [12].

The null hypothesis indicates that the tested rotary NiTi instruments show no differences in their cyclic fatigue resistances.

This in vitro study is aimed for comparison and evaluation the cyclic fatigues of Wave One Gold, F6 SkyTaper, One Curve, and AF Blue R3 NiTi rotary instrumentation systems.

Materials and Method

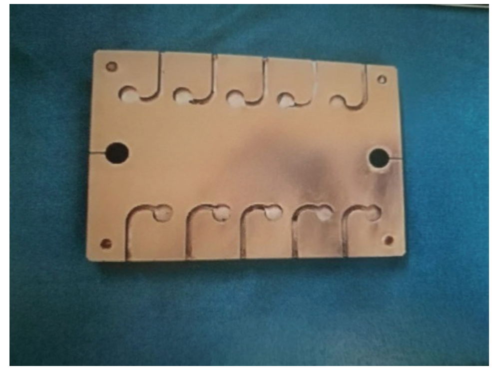

Figure 1: The artificial simulating canal

Figure 2: Cyclic fatigue testing device.

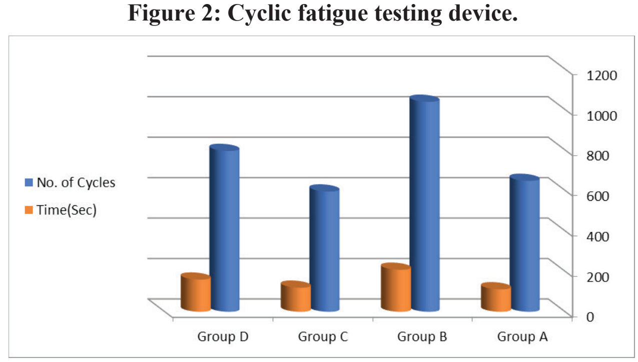

Figure 3: Representation of time in seconds and number of cycles to fracture among groups

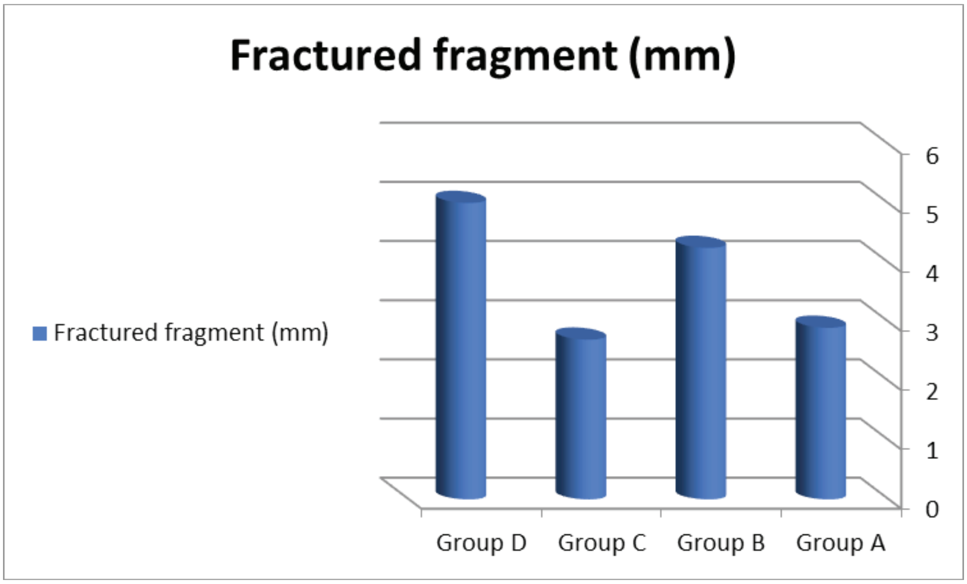

Figure 4: Representation of fractured fragment length in (mm)

In this article, four different rotary instruments were used, and 10 instruments for each type were investigated in the four groups.

Group A: Wave One Gold (primary, #25.07), 25 mm length, and NiTi rotary instruments (350 rpm/5 N cm).

Group B: AF Blue R3 file (#25.06), 25 mm length, and NiTi rotary instruments (300 rpm/2.6 N cm).

Group C: One Curve (#25.06), 25 mm length, and NiTi rotary instruments (300 rpm/2.5 N cm).

Group D: F6 SkyTaper (#25.06), 25 mm length, and NiTi rotary instruments (300 rpm/2.2 N cm).

The instruments were tested within an artificial simulating canal (angle curvature: 60°; Figure 1). The curvature radius was 5 mm, whereas canal width was 1.5 mm. The simulated canal constructed within stainless-steel blocks covered by a swiveling glass allowed for observation of files rotating in the canal and discard of broken instruments after each test [13].

To eliminate binding in the simulating canal, the files were created to be slightly wider than those used in the test (0.3 mm wider than the instruments used), granting a modest lateral movement inside the canal [14&15].

The cyclic fatigue testing apparatus utilized in this study, as shown in Figure 2, was previously illustrated.

The apparatus consists of a wood main frame attached with an electric hand piece and a simulating canal carved in a stainless-steel block. The electric hand piece is supported to a movable apparatus, allowing accurate and repeated placement of each instrument inside the simulating canal [16].

The testing canal was filled with a lubrication medium (3-In-One Multi-Purpose Oil manufactured by WD-40, USA) to minimize the friction produced by the tested file with the canal walls [17]. A glass cover was fixed by the clipper to faciliate file insertion inside the canal and to prevent the instrument from slipping out, thus also providing a clear view of the instruments.

A button on the electric motor was pressed to initiate rotation. Meanwhile, a digital stop watch was also operated. Instrument rotation was monitored by the operator until the file fractured, and the corresponding time was recorded. The electric motor button was pressed again once to stop rotation during fracture of the instrument. The slide was opened, and the fractured file was replaced by a new one.

The time needed for instrument fracture from the begining of the rotation was recorded in seconds then transformed into minutes by dividing over 60. Afterward, time (T) in minutes was multiplied by revolutions per minute (RPM) to conclude the number of cycles or rounds needed for each instrument to fructure (NCF) as shown in the following equation:

NFC = RPM × T

The lengh of fractured fragments for individual instruments was attained by measuring the instrument length after fracturing using a digital Vernier caliper (measured from the end of the handle to the fractured tip). The values were then subtracted from the file length before fracturing (25 mm), as shown in the following equation:

Fractured fragment = File length Before fracture (25 mm) − File length after fracture.

Statistics, including maximum, mean, minimum, and standard deviation (S.D.), calculated for the cycle numbers needed to fracture each file. The data were obtained and noted using SPSS (program version 18) and used in statistical analysis.

One-way analysis of variance (ANOVA) was utilized to determine any statistical difference between the mean cycles needed for fracture occurrence for the different rotary instruments. A separate t-test was performed to assess the significance of variance between a pair of instruments.

In the present test, P values of more than 0.05 were considered statistically non-significant, whereas P values equal or less than 0.05 were regarded as significant. On the other hand, P values less than 0.01 were regarded as highly significant

Results

Table (1): Descriptive Statistical analysis for the time (Seconds) and number of cycles to fracture for groups

Total group	Type of test	Min	Max.	Mean	±SD
Group A Wave One Gold	Time	108.42	113.13	110.94	1.870
	No. of cycles	632.45	659.92	647.18	10.908
Group B Blue R3	Time	190.79	214.89	207.66	10.105
	No. of cycles	953.95	1074.45	1038.31	50.527
Group C One Curve	Time	114.14	121.82	118.91	2.900
	No. of cycles	570.7	609.1	594.59	14.500
Group D F6 SkyTaper	Time	152.13	164.21	159.06	5.189
	No. of cycles	760.65	821.05	795.3	25.946

Table (2): ANOVA test for the time and number of cycles to fracture for groups

Type of test	S. O. V.	SS	Df	MS	F-test	P-value
Time to fracture	Between	47166	3	15722	715.67	0.000 HS
	Within	615	28	21.968		
	Total	47781	31			
Number of cycles to fracture	Between	947894.2	3	315964.7	568.61	0.000 HS
	Within	15558.9	28	555.67		
	Total	963453.1	31			

*P<0.001 Significant

Table (3): t-test for the difference in time and number of cycles to fracture between each two groups

Comparison Groups	t-test time to fracture	p-value	t-test number of cycles	p-value
Group A & Group B	19.240	0.000	15.280	0.000
Group A & Group C	5.165	0.007	6.480	0.003
Group A & Group D	16.821	0.000	9.996	0.001
Group B & Group C	19.884	0.000	19.884	0.000
Group B & Group D	13.546	0.000	13.546	0.000
Group C & Group D	13.616	0.000	13.616	0.000

*P<0.05 significant **P<0.001 High significant ***P>0.05 Non significant

Table (4): Descriptive Statistical analysis for the length of fracture fragment (mm) for each group

Groups	Min	Max	Mean	±SD
Group A Wave One Gold	2.02	3.30	2.90	0.475
Group B Blue R3	3.63	5.30	4.25	0.554
Group C One Curve	2.42	3.04	2.70	0.216
Group D F6 SkyTaper	4.49	5.81	5.01	0.408

Table (5): ANOVA test for the length of fracture fragment among groups

S. O. V.	SS	df	MS	F-test	P-value
Between	29.211	3	9.737	52.349	0.000
Within	5.229	28	0.186		
Total	34.441	31			

*P<0.001 Highly Significant.

Table (6): t-test for the length of fracture fragment between each two groups

Comparison Groups	t-test	p-value
Group A & Group B	8.293	0.000
Group A & Group C	0.854	0.421
Group A & Group D	7.430	0.000
Group B & Group C	6.425	0.000
Group B & Group D	2.885	0.023
Group C & Group D	15.617	0.000

Table 1 summarizes the descriptive statistics for each system. The average cycle-to-fracture values of the AF Blue R3 group were the highest among all groups, whereas the lowest was observed in the Wave One Gold group.

The data inspected by one-way ANOVA demonstrated considerable variation ($P<0.001$) in the NCF mean values among all groups, as shown in (Table 2).

Using t-test, further comparisons among groups were conducted to determine where the significant difference occurred, as shown in (Table 3). The t-test results reveal a considerable variation among all groups ($P<0.01$), except for Group A (Wave One Gold) and Group C (One Curve) ($P< 0.05$), where is not a statistically significant differences in variation were reached ($P=0.05$).

Table 4 lists the mean, minimum, maximum, and S.D. of the fractured fragment length for each rotary instrument tested. The highest mean value of fractured fragment is noted in group D.

From the ANOVA test, as shown in (Table 5), a statistically significant difference was observed in the length of fractured fragments among the instruments.

T-test was utilized to explain the statistically significant difference in the fractured segment length of among the rotary instruments. A considerable difference was found among Wave One Gold, AF Blue R3, and F6 SkyTaper instruments, whereas a nonsignificant difference was observed in the One Curve group. Meanwhile, the AF Blue R3 group showed a significant difference in fracture length when compared with the One Curve and F6 Sky Taper groups. The One Curve group displayed a significant diffence compared with the F6 SkyTaper group (Table 6).

The F6 Sky Taper group revealed the longest fractured segment length, followed by AF Blue R3, Wave One Gold, and One Curve groups.

Discussion

The fracture of rotating NiTi instrument is one of the most critical complications that develop during root canal preparation [18]. Diverse classes of rotary NiTi instruments show variation in resistance to fatigue failure owing to differences in numerous factors, such as their manufacture [19&20].

In this study, the resistance of rotary files to cyclic fatigue was tested under simulating conditions to reduce the effect of other failure mechanisms, e.g., canal diameter and length. Similar to other studies, the test was evaluated using stimulating canals made of stainless steel with a radius of 5 mm and 60° curvature [21&22]. Considering that this study aimed to examine the physical properties of NiTi rotary files, the extracted teeth were unsuitable models as no two root canals are exactly identical [23]. One operator has examined the files, whereas the other operater has operated the stopwatch [24]. The Wave One Gold, AF Blue R3, One Curve, and F6 SkyTaper NiTi rotary instrumentations were selected given their differing cross sections, processing metallurgic altration, and rotation axes. Comparisons were conducted with files of similar curvature and diameter to minimize the *confounding variables*. This study recorded the fractured fragment mean length of the files to ensure exact positioning of the tested files inside the simulated canals and to determine whether stresses were induced at the canal curvature. The Blue R3 files were the most resistant to cyclic fatigue, followed by F6 SkyTaper, One Curve, and Wave One Gold files. The t-test results showed a significant difference among all groups ($P<0.01$). However, the difference between Wave One Gold and One Curve ($P<0.05$) groups showed no statistical significance. In the AF Blue R3 files, the cyclic resistance may be related to a more metal mass and a larger cross-sectional area due to its rectangular cross section in addition to the AF-R Wire Technique, which depend on the crystallographic phases present in the alloy. The files are manufuctured with NiTi, which undergoes an innovative heat treatment, altering its molecular structure, to achieve an increase in cyclic fatigue resistance; surface treatment of the file involves chemical polishing, and additional flexibility and a distinct blue color are also added [12]. However, no data were published until the date of evaluation of the cyclic fatigue resistance of the roots by using AF Blue R3 files. Therefore, comparison of our results with other studies is impossible. The F6 SkyTaper instruments showed more cyclic fatigue resistance compared with the One Curve and Wave One Gold instruments. This observation may be related to the decreased cross-sectional area associated with the unique double S-shaped cross-section design of F6 SkyTaper. Plotino *et al*. noted an inverse relation between cyclic fatigue resistance and cross-section metal mass of NiTi files [25]. This result agrees with that of a study concluding that Wave One Gold shows low resistance to cyclic fatigue [26&27]. This difference in the cross section between files might also contribute to their cyclic fatigue resistance.

Wave One Gold instruments were less resistant to cyclic fatigue and were fractured within a short period possibly due to their cross-section design (parallelogram-shaped cross section), which should be regarded for conclusions of this study. The thermal processing increased the temperature of austenitic transformation of nickel titanium alloy and improved its crystal structure arrangement [28&29]. These factors may improve instrument performance. One Curve files are manufactured with a C-wire by applying controlled heat treatment with the property of regulated memory, thus improving file resistance to cyclic fatigue. Parashos *et al*. noted that small core diameter enhances instrument resistance to cyclic fatigue [30]. One Curve features a low core diameter (approximately 48.327 μm^2). All these findings explain the enhanced fatigue resistance of One Curve files. The instrument morphologies and geometries, such as the cross section design and core diameter, may be considered significant determinants of the position of fractured fragments of files on the curvature of root canal.

Conclusion

Considering the outcomes in this article, we can conclude that AF Blue R3 file exhibits the highest resistance to cyclic fatigue in comparison with F6, One Curve, and Wave One Gold files. Further research is advised to assess the resistance to cyclic fatigue of these files by using different canal lengths and curvatures. The clinical performance of these new files should also be evaluated.

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