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Cyclic Fatigue Resistance of 2-Shape Endodontic System

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Abstract

Aims: This study aimed to evaluate the effect of different tapers (4% and 6%) on the cyclic fatigue resistance of the 2Shape endodontic system using three types of canal curvature 45°,60°, and 90°. **Materials and Methods:** This research used Sixty (60) NiTi rotary files. Two sets of these files were created. (n = 30 for each group), group one TS1 (0.25) taper 4%, group two TS2 (0.25) taper 6%. Then, each group was subdivided into three subgroups (n = 10 for each subgroup) each subgroup was tested in 45°, 60° and 90° canal curvature respectively in a stainless-steel metal block containing an artificial canal with a radius of curvature of 3mm and diameter of 1.5 mm. Each file was rotated continuously at 300 rpm and 1.2 N.cm torque for TS1, 300 rpm, and 2.5 N.cm for TS2 until it fractured. The time it took to separate the files was noted. Each file's number of cycles to failure (NCF) was computed. Kolmogorov-Smirnova normality test was done for all instruments and One-way ANOVA was used to examine the data statistically. **Results:** At 45º canal curvature there is a highly significant difference between 2Shape taper 4% and 2Shape taper 6% ($p \leq 0.01$). Regarding canal curvature of 60º there is a highly significant difference between 2Shape taper 4% and 2Shape taper 6% ($p \leq 0.01$). For canal curvature of 90 º there is a highly significant difference between 2Shape taper 4% and 2Shape taper 6% ($p \leq 0.01$). **Conclusions:** This study concluded that the 2Shape system resists cyclic fatigue better at canal curvature of 45° followed by 60° and 90°. Regarding the taper used 4% is better than 6%. To limit the possibility of separation, it is advised that these files be used just once.

مقاومة القوة المسلطة المتكررة على ثنائي الابعاد للنظام المستخدم في الحشوات اللبية

الملخص

الأهداف: هدفت هذه الدراسة إلى تقييم تأثير Taper المختلف (4٪ و 6٪) على مقاومة الإجهاد الدوري لنظام 2Shape system باستخدام ثلاثة أنواع من انحناء القناة 45 درجة و 60 درجة و 90 درجة. **المواد وطرائق العمل:** استخدم هذا البحث ستين (60) ملفًا من ملفات NiTi الدوارة. تم إنشاء مجموعتين من هذه الملفات. (ن = 30 لكل مجموعة) ، المجموعة الأولى TS1 (0.25) Taper 4% ، المجموعة الثانية TS2 (0.25) Taper 6% بعد ذلك ، تم تقسيم كل مجموعة إلى ثلاث مجموعات فرعية (ن = 10 لكل مجموعة فرعية) تم اختبار كل مجموعة فرعية في 45 درجة و 60 درجة و 90 درجة من انحناء القناة على التوالي في كتلة معدنية من الفولاذ المقاوم للصدأ تحتوي على قناة صناعية بنصف قطر انحناء 3 مم وقطرها 1.5 مم. تم تدوير كل ملف بحركة دوران مستمرة 300 دورة في الدقيقة وعزم دوران 1.2 نيوتن سم لـ TS1 و 300 دورة في الدقيقة و 2.5 نيوتن سم لـ TS2 حتى تكسر. تم تدوين الوقت المستغرق لفصل الملفات. تم حساب عدد دورات الكسر لكل ملف. (NCF) تم استخدام ANOVA لفحص البيانات إحصائيًا. **النتائج:** عند انحناء القناة 45 درجة يوجد فرق إحصائي عالي بين 2Shape Taper 4% و 2Shape Taper 6% ($p \leq 0.01$).فيما يتعلق بانحناء القناة بمقدار 60 درجة يوجد فرق إحصائي عالي بين 2Shape Taper 4% و 2Shape Taper 6% ($p \leq 0.01$). بالنسبة لانحناء القناة بمقدار 90 درجة يوجد فرق إحصائي عالي بين 2Shape Taper 4 % و 2Shape Taper 6% ($p \leq 0.01$). **الاستنتاجات:** خلصت هذه الدراسة إلى أن نظام 2Shape يقاوم الاجهاد الدوري بشكل أفضل عند انحناء القناة 45 درجة متبوعًا بـ 60 درجة و 90 درجة. فيما يتعلق Taper المستخدم 4٪ أفضل من 6٪. للحد من إمكانية الفصل ، يُنصح باستخدام هذه الملفات مرة واحدة فقط.

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INTRODUCTION

The primary goals of endodontic therapy are to properly root canal apparatus preparation and cleaning while retaining the original design and avoiding iatrogenic occurrences. Manual root canal preparation has traditionally been done with burs, reamers, and files. Most hand preparation procedures, including ledging, zipping, apical blocking, and canal transit, is time intensive and prone to iatrogenic mistakes. NiTi rotary devices have lately gained popularity [1].

NiTi endodontic rotary instruments may fracture as a result of severe torsion or cyclic fatigue [2 & 3]. Cyclic fatigue being the most prevalent reason[4]. Cyclic failure is brought on by the instrument's continuous tension and compression load on the area of greatest root canal curvature. Torsional failure happens when the instrument shank continues to rotate while the file tip binds into the canal, increasing the torque and exceeding the metal's plastic limit. During the production of files, supplementary components like the degree of rotation, cross-sectional layout, metallurgical characteristics, and thermomechanical techniques are all variables that can be considered [5].

NiTi endodontic rotary files' cyclic fatigue resistance is influenced by a number of variables for example: canal radius and angle of curvature [6], operator competence [7 & 8], root canal system anatomical configuration [9], irrigation solutions [10], number of sterilization cycles [11] and the alloy of NiTi [12 & 13].

However, the effect of NiTi endodontic rotary file taper on cyclic fatigue resistance has not been reported, despite the fact that a research has shown that the fracture incidence of NiTi endodontic rotary files increased in curved root canal systems, possibly due to taper of the NiTi endodontic rotary files [14].

Several thermally treated NiTi alloys have been developed by manufacturers to improve the resistance to cyclic fatigue [15]. Furthermore, several investigations have shown that the root canal morphology has concealed curvature; this type of curvature increases the bending stresses in NiTi rotary files [16].

2 Shape (Micro-Mega, Besancon, France) are rotated continuously in a sequence which has been heat treated using T Wire technology, the company claims that the flexibility of the instruments promotes user comfort and makes it easier to negotiate great curves with the instruments, which recover their original shape after each usage. The asymmetrical cross-section of the file, which has two primary and one secondary cutting edges, provides greater cleaning of the root canal walls, these edges increase the cutting efficiency of the file and improve debris removal [17].

Aim of the study

This study aims to evaluate the effect of different tapers (4% and 6%) on the cyclic fatigue resistance of 2Shape micromega endodontic system using three types of canal curvature 45°,60° and 90°.

Study hypothesis

The null hypothesis (H0) states that the number of cycles to failure would not be affected by the different tapers (4% and 6%) and types of canal curvature. And the alternative hypothesis was there a significant difference between taper 4 and taper 6 at types of canal curvature used.

MATERIALS AND METHODS

This study involved 60 new instruments from 2Shape system (TS1 0.25 tip size, 0.04 taper and TS2 0.25 tip size, 0.06 taper) (TS; Micro-Mega, Besancon, France) divided into two groups each group consisting of 30 instruments in each group three types of canal curvature used 10 instruments for each canal curvature was tested Figure (1).

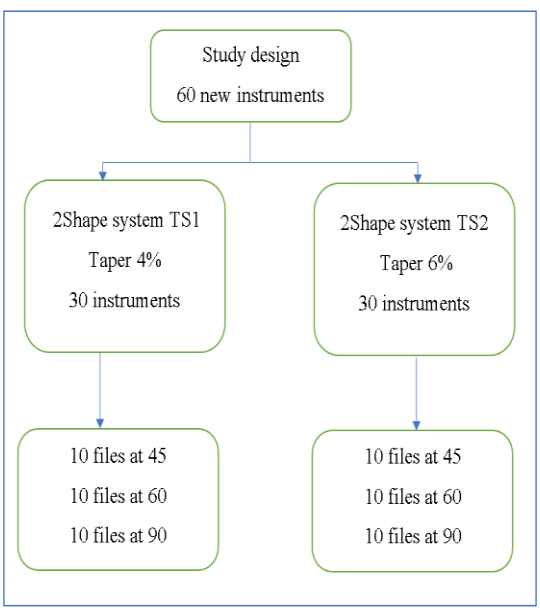

Figure (1): Samples Grouping.

Canal curvature drawing criteria:

Pruett's approach from 1997 uses two factors to define the geometry of any root canal curvature: angle of curvature (a1) and radius of curvature (r1) [18] (Figure 2). To describe these measurements, a straight line is established along the coronal portion of the canal's long axis. The lengthy axis of the apical portion of the channel is traced by a second line. Each of these lines has a beginning position (point a) and a finishing point (point b) for the canal curvature (point b). A circle with tangents at positions a and b represents the curved section of the canal at these locations. The angle of curvature is determined by drawing a circle around these two spots and measuring the angle that the circle's arcs generate points (a and b). The radius of this circle is equal to the radius of curvature [19].

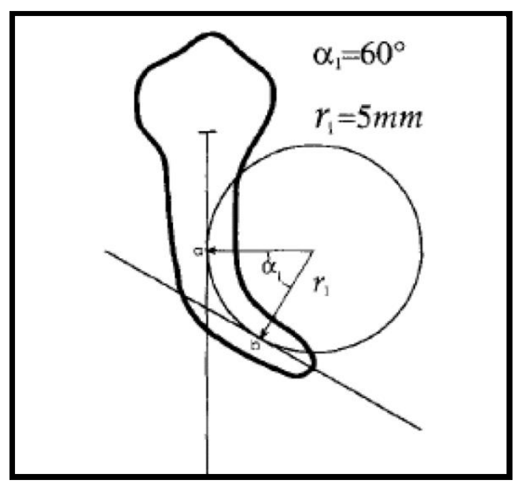

Figure (2): Pruett method.

Preparation of artificial canals.

The artificial canals are prepared on a stainless-steel metal block with dimensions

50mm x 30mm x 5mm by a computer numerically controlled milling machine (CNC machine, Taiwan) with three types of canal curvature: 45°, 60° and 90°, as shown in (Figures 3 A and B); to investigate how canal curvature affects the cyclic fatigue resistance of the instruments.

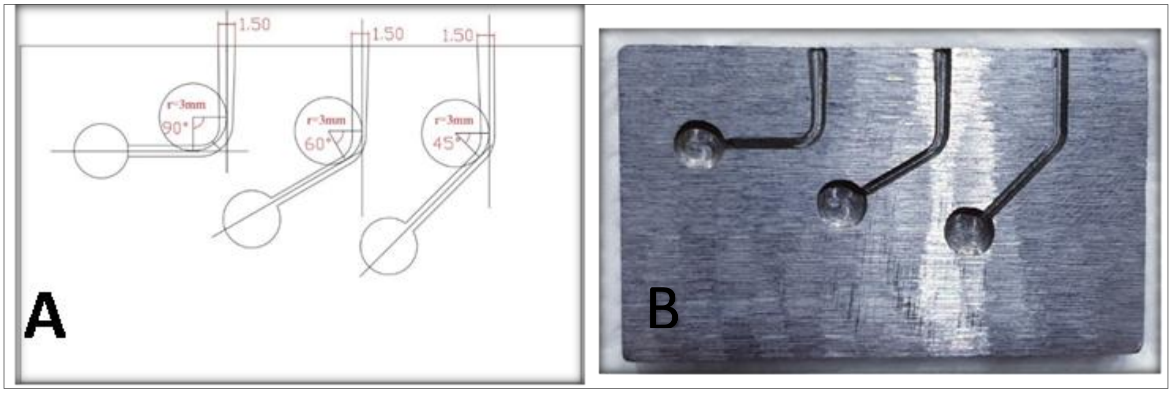

Figure (3): A- Schematic drawing of types of canal curvature drawn by AutoCAD 2006 program according to the method proposed by [19]; B- Artificial canals.

Cyclic Fatigue Resistance Test

For this study, a total of 60 new instruments were chosen, thirty instruments from TS1 (0.25/ 4%) and thirty instruments from TS2 (25/ 6%). Ten instruments (n=10) from each group were tested in 45°, 60° and 90° canals respectively. The cyclic fatigue test was carried out in a custom-made device consisting of an endo-motor handpiece attached to a table vice vertically (as shown in Figure 4). and stainless-steel metal block containing artificial canal with a radius of curvature of 3mm, a diameter of 1.5 mm [20]. It simulates a root canal with three curvatures of 45°, 60° and 90° angle.

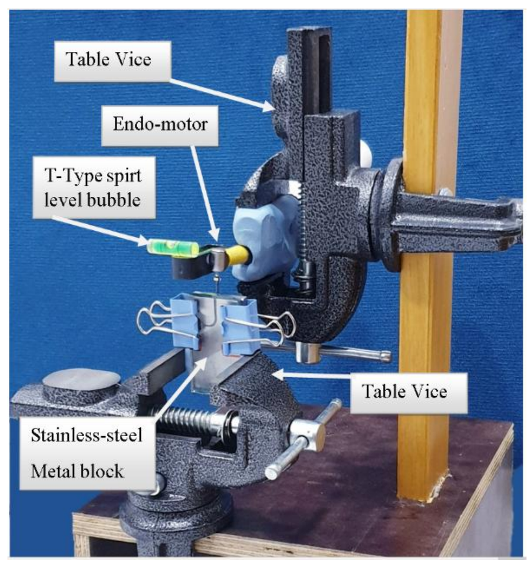

Figure (4): Custom-made device of cyclic fatigue test.

Capar, Ertas [20] used 45° and 60° angles, while Azim, Tarrosh [21] used a 90° angle. The curved segment of the canal was 3.5 mm in length. The stainless-steel artificial canal was fixed to a table vice horizontally.

Each instrument was introduced into the canal until the tip of the instrument was 5 mm away from the curve according to the article [21].

To standardize the instrument penetration depth and a red line was painted for all canals, this red line will keep the tip of the file at the same distance from the canal curvature for all canals and prevent the over penetration of the files inside the canals so this will affect the results of the test.

T-type spirit level bubble was glued to the head of the handpiece by Fix all 808 universal fast adhesive glue, in order to ensure the centralization of the file inside the artificial canal, prevent titling to any unwanted direction and deliver the rotation of the file inside the canal without pressure (Figure 5). as did Altaay and Shukri [22] when they connect it with the metal block.

Figure (5): T-type spirit level bubble.

To stop the instruments from slipping out of the artificial canal, see the instrument when it breaks, remove the broken instrument with ease, and prevent the loss of the shattered pieces, the artificial canal was protected with a glass plate [23].

Counting the Number of cycles to failure

Instruments rotated freely without pressure according to speed and torque that determined by the manufacturer as 2Shape TS1 used at 300 rpm and 1.2N.cm [24] and 2Shape TS2 used at 300rpm and 2.5N.cm [25]. Using an electric endomotor E-Connect until a fracture occurred, at which point the time to fracture was recorded in seconds and video recording was established. synthetic oil (WD-40 Company, Milton Keynes, UK) was utilized as a lubricant to lessen friction as the file made contact with the artificial canal walls [26]. The number of cycles to failure (NCF) was calculated using the method below: NCF = revolutions per minute (rpm) × time to fracture (s) / 60 [27].

Statistical Analysis

Using the SPSS 26(IBM-SPSS Inc., Chicago, IL, USA) program, Kolmogorov-Smirnova test is used to examin whether the data are normaly distributed. The results of the number of cycles to failure (NCF) for each group were examined In order to determine whether there were any statistically significant variations between the various canal curvatures, the data were then analyzed using a one-way analysis of variance (ANOVA).

RESULTS

Test of Normality of all Instruments:

At the start of the statistical analysis, the NCF results for all instruments were assessed using the generally used normality test (Kolmogorov-Smirnova test) to determine if the data were normally distributed, as shown in table below this test revealed that the data are normally distributed. For all of the files, the Kolmogorov-Smirnova test value is bigger than the alpha value ($p > 0.05$), Table (1).

Table (1): Kolmogorov-Smirnova test for all instruments:

		Kolmogorov-Smirnova		
Canal curvature	**system**	**Statistic**	**df**	**Sig.**
45º	2Shape taper 4%	0.185	10	0.200
	2Shape taper 6%	0.131	10	0.200
60º	2Shape taper 4%	0.214	10	0.200
	2Shape taper 6%	0.264	10	0.051
90º	2Shape taper 4%	0.158	10	0.200
	2Shape taper 6%	0.189	10	0.200

***p* > 0.05 normally distributed**

Mean and St. Deviation of NCF for each group at each canal curvature:

In the table below, shows the mean and Std. Deviation of NCF for each group it is obvious that each statistical mean at one column of canal curvature take the same letter of other mean of the same column that means there is no statistical difference between them, if the statistical mean at one column took different letter that means there is statistical difference between them, Table (2).

Table (2): Mean and St. Deviation of NCF for each group:

Systems		45 º	60 º	90 º
2Shape system 4%	Mean	2517.00 a	536.00 a	107.50 a
	N	10	10	10
	S.D.	509.66	196.19	17.19
2Shape system 6%	Mean	547.00 b	213.00 b	50.50 b
	N	10	10	10
	S.D.	83.03	17.51	6.85
Total	Mean	3064.00	749.00	158.00
	N	20	20	20
	S.D.	592.69	213.70	24.04

S.D.: Stander Deviation.

Regarding the canal curvature of 45º there is statistical difference between 2Shape taper 4% and 2Shape taper 6% so they took different letters (a and b).

For the canal curvature of 60º there is statistical difference between 2Shape taper 4% and 2Shape taper 6% so they took different letters (a and b). At canal curvature of 90 º there is statistical difference between 2Shape taper 4% and 2Shape taper 6% so they took different letters (a and b), Figure (6).

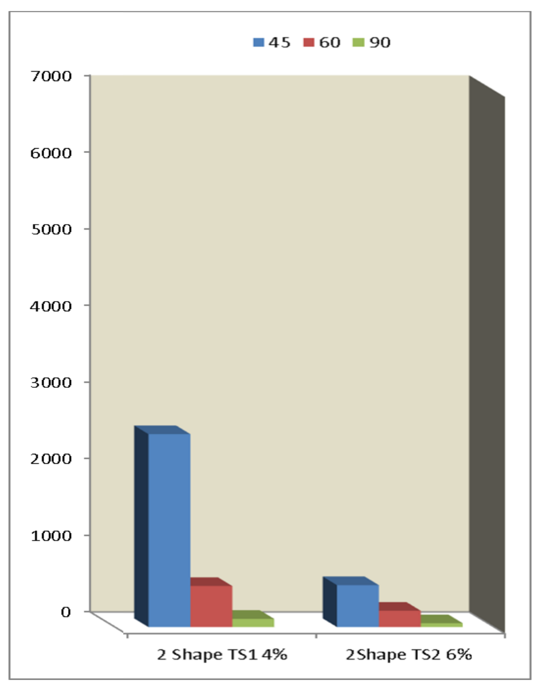

Figure (6): Bar chart (NCF) at each canal curvature.

DISCUSSION

The block was made of stainless steel, and the canals were milled inside to prevent canal wear from occurring after continuous usage and maintain the same trajectory for all files. Furthermore, the artificial canals' depth was machined to 2 mm in order to accommodate the numerous diameters and tapers of all files and permit them to easily rotate inside the canals [28].

A glass top cover was placed over the stainless-steel testing block to make it possible to see how the file moved through the waterway and when it finally snapped. Additionally, it assisted in preserving the oil inside the canal for a longer length of time, stopping the file from straying outside of the canal's confines and avoiding the loss of the broken pieces [23]. According to Azim, Tarrosh [21] all instruments were used inside the artificial canal until the tip of the instrument was 5 mm away from the curve and a red line was painted at all canals.

T-type spirit level bubble was connected to the head of the handpiece in order to ensure the centralization of the file inside the artificial canal, prevent titling to any unwanted direction and deliver the rotation of the file inside the canal without pressure, as did Altaay and Shukri [22] when they connected it with the metal block.

The metallurgical characteristics and heat processes of the NiTi alloy also had an effect on the crystal structures, taper, flexibility, and cyclic fatigue resilience of NiTi endodontic files [29 & 30]. Gambarini, Gerosa [31] discovered that 25.04 NiTi endodontic rotary files had much greater cyclic fatigue resistance in comparison between 20.06 and 25.06. These findings support those of the current investigation and emphasize the importance of the taper above the apical diameter.

The following is a summary of these results: The instrument's resilience to cycle fatigue was adversely impacted by increasing the mass based on a taper and/or apical width, which also decreased the instrument's elasticity and led to extra root canal dentine removal, apical transport, root perforations, and fractures [32, 33]. Faus-Llácer, Kharrat [34] showed that increasing the apical diameter and taper of NiTi endodontic rotary files reduced their cyclic fatigue resistance.

In terms of how the angle of canal curvature affected NCF, 2Shape system tools significantly decreased NCF as the angle of canal curvature increased. The instruments experienced greater compressive and tensile loads as channel curvature grew, which led to earlier failure [35]**.** This result was consistent with other studies [36 & 37]. The cyclic fatigue resistance of NiTi instruments was evaluated using various angles of curvature at 45°, 60°, and 90° [35]. In order to calculate the NCF under various stresses, this study employed 45°, 60°, and 90° angles of curvature.

According to previous research [38], the radius of curvature has a considerable impact on the fatigue life of NiTi rotary instruments. That is, when the radius of curvature grows, NCF increases dramatically. The multivariate linear regression model revealed that increasing the radius of curvature from 2 to 8 mm improves cycle fatigue resistance.

When compared the taper 4% with taper 6% of the 2Shape system taper 4% at 45° canal curvature shows higher NCF at all canal curvature. This is due to the fact that the large instrument tapers acquire more internal tension during stress-compression cycles when bent to suit the curvature of the root canal system (39). It has been stated that the tiny core diameter increases the instrument's cyclic fatigue resistance (31 & 40).

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication and/or funding of this manuscript.

CONCLUSIONS

Within the limitation of this study, it is concluded that the 2Shape system is resistant to cyclic fatigue better at 45 canal curvature followed by 60 and 90 canal curvature, regarding the taper used 4% is better than 6%.

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