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RESEARCH ARTICLE

EVALUATION OF RADICULAR DENTINAL DEFECT FORMATION USING DIFFERENT INSTRUMENTATION TECHNIQUES BY CONE BEAM COMPUTED TOMOGRAPHY (AN IN VITRO STUDY)

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ABSTRACT

Introduction: Root canal instrumentation achieves chemical and mechanical preparation before obturation. However instrumentation may result in dentinal defects, decreasing the strength of endodontically treated teeth.

Objectives: This study was designed to evaluate dentinal defects formed after root canal instrumentation by two single file systems using reciprocating and rotation motion versus manual instrumentation.

Methodology: This study was conducted on 45 mesial roots of mandibular first molars. Teeth were divided into three groups of 15 specimens each. Pre-instrumentation cone beam computed tomography images were taken to identify defects possibly present in the specimens, to have an objective comparison with post-instrumentation images. Root canals were instrumented as follows; Group (1): reciprocating primary Wave One instrument, Group (2): rotary One Shape instrument, Group (3): manual instrumentation with K-Flexofiles. Post-instrumentation cone beam computed tomography images were used to assess dentinal defects formed.

Results: The three groups showed dentinal defects formation after instrumentation, with the highest number of defects found in group (2) (One Shape group), however no statistically significant difference was found between the three groups.

Conclusions: Dentinal defects formed as a result of instrumentation weren't affected by the instrumentation technique used.

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INTRODUCTION

Vertical root fracture is one of the frustrating complications of root canal treatment, which often results in tooth extraction (Walton *et al*. 1984, Tamse 2006). It is probably caused by propagation of smaller defects and not by the force practiced during preparation or obturation (Shemesh *et al*., 2008; Soros et al., 2008). Rotary Ni-Ti instrumentation could potentially cause dentinal defects in the walls of the canal which may act as areas of stress concentration and crack initiation. These Ni-Ti instruments increase the risk of dentinal damage to root in the form of complete cracks, incomplete cracks, craze lines or fractures (Garg *et al*., 2008). Recently, a new generation of Ni-Ti files has been introduced with a variable cross-sectional design and different working motions, achieving canal preparation with only 1 instrument (Liu *et al*., 2013).

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The use of a single file for shaping root canals simplifies instrumentation and reduces the contact with canal dentin (Yared 2008; Berutti *et al*., 2012). Wave One (Dentsply Maillefer, Ballaigues, Switzerland) is a single-file reciprocating root canal preparation system that alternates counter-clockwise and clockwise rotation movements, allowing the file to rotate 360° after performing three reciprocating movements (Silva *et al*., 2015). These files are made of a special nickel-titanium alloy called M-wire (Gutmann and Gao 2012). This M-wire alloy provides increased flexibility and improved resistance to cyclic fatigue of the instruments (Alapati *et al*., 2009, Al-Hadlaq *et al*., 2010). One Shape file (Micro-Mega, Besançon Cedex, France) is another single file system One Shape file (Micro-Mega, Besançon Cedex, France) is another single file system with a different instrumentation technique, in which it uses a traditional continuous rotation motion (Liu *et al*. 2013). The file is made of conventional Ni-Ti alloy. Cone beam computed tomography (CBCT) is a radiological imaging system which overcomes the limitations of conventional radiography by producing undistorted, three-dimensional images of the area under examination. These properties make this form of imaging particularly suitable for use in endodontics (Durack and Patel, 2012).

The dilemma of diagnosing dentinal cracks continues to present a challenge in endodontics (Henry *et al*., 2004). Dentinal defects identification is usually performed by sectioning the tooth at multiple levels and examining the sections, however the heat and stress generated from the sectioning procedure may lead to defects affecting the accuracy of the results. The use of CBCT in diagnosing dentinal defects eliminates the need to section the tooth, a problem associated with the previous methods used in diagnosing dentinal defects. The aim of this study was to evaluate dentinal defects formed using two single file systems (reciprocating and rotation) versus manual instrumentation using CBCT.

MATERIALS AND METHODS

Forty five mesial roots of mandibular first extracted molars were used in this study, with moderate curvature (10-25°) according to Schneider's classification Schneider's classification. Access opening was done and the distal roots of all teeth were resected. The removal of coronal constraints was accomplished by the use of Endoflare (Micro Mega, Besancon, France). To establish apical patency, size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted through the canal 1mm beyond the apical foramen. The working length (WL) was established by subtracting 2mm of the recorded length. The mesial root surface of each tooth was lined with wax to be later replaced by silicone impression material to simulate the periodontal ligament space. The mesial root specimens were mounted in acrylic resin blocks with each block containing 4 teeth.

The mesial root specimens were randomly divided into three groups of 15 teeth each, according to the type of instrument used.

Group 1: WaveOne primary file. (Dentsply Maillefer, Ballaigues, Switzerland)
Group 2: One Shape file. (Micro Mega, Besancon, France)
Group 3: K-Flexofiles. (Dentsply Maillefer, Ballaigues, Switzerland)

Pre-instrumentation CBCT imaging

Evaluation of the incidence and size of dentinal defects originally present in the specimens was done for the full length of the root by CBCT using J. Morita R100 cone beam 3D imaging system with high resolution (125 µm voxel), standard exposure time (20 seconds), tube voltage 90kVp and 8mA, and field of view 100mm× H80mm.

Instrumentation

In Group (1), the canals were irrigated with 3ml NaOCl 2.5% using a 27 gauge needle. Wave One primary file was introduced into the canal, activated by X-Smart Plus electric motor (Dentsply Maillefer, Ballaigues, Switzerland) and applied in reciprocating motion (according to the pre-saved program on the motor) in an in and out movement without pressure. Shaping procedure was performed until the file met resistance or reached the full working length. After three pecking motions, the instrument was removed from the canal, cleaned with sterile gauze and the canals were irrigated with 3ml NaOCl 2.5% using a 27 gauge needle. This procedure was repeated until the instrument reached the original working length. Recapitulation with #10 K-file was performed if necessary. Glyde (Dentsply Maillefer, Ballaigues, Switzerland) was used to aid in the lubrication of the root canals.

In Group (2), the canals were irrigated with 3ml NaOCl 2.5% using a 27 gauge needle. One Shape file was activated by X-Smart Plus electric motor and applied in continuous rotation motion in a rotation speed of 350 rpm, and a torque of 2.5 N.cm. The file was placed down to the 2/3 of the WL using an in and out movement without pressure. An upward circumferential filing movement was performed in order to pre-enlarge the canal. After three pecking motions, the instrument was removed from the canal, cleaned with sterile gauze and the canal was irrigated with 3ml NaOCl 2.5% using a 27 gauge needle. Canal patency was checked with a #10 K file. One Shape file was re-introduced canal and placed down to 3 mm from working length using an in and out movement without pressure. The file was withdrawn from the canal and cleaned. Irrigation and re-checking of the canal patency was done with a #10 K file. One Shape was re-introduced into the root canal and taken down to the full working length by performing the in and out movement. Glyde was used to aid in the lubrication of the root canals.

In Group (3), the canals were irrigated with 3ml NaOCl 2.5% using a 27 gauge needle. Step back instrumentation technique was carried out using K-Flexofiles. Initial file used was file #15, with master file #30. Step back was carried out till file #45. Irrigation with 3ml NaOCl 2.5% using a 27 gauge needle was done after the use of each file. Glyde was used to aid in the negotiation of the root canals.

According to manufacturers' instructions of both, WaveOne and One Shape files, each file is to be used in a single tooth, which means that it can be used for a tooth with four canals. So in our study, each file was used in preparing four canals (2 specimens). The same was carried out with K-flexo files to ensure standardization.

Post-instrumentation CBCT imaging

Evaluation of the incidence and size of dentinal defects formed after instrumentation was done for the full length of the root by Cone beam computed tomography using J. Morita R100 cone beam 3D imaging system with the same specifications mentioned before.

Dentinal defects were classified as follows according to Burklein:

1. No defect: Root dentin without any lines or cracks on the external or the internal surface of the root.
2. Incomplete crack: A line extending from the canal wall into the dentin without reaching the outer surface.
3. Complete crack: A line extending from the root canal wall to the outer surface of the root.

4. Craze lines: All other lines that did not reach any surface of the root or extend from the outer surface into the dentin but did not reach the canal wall.

RESULTS

Comparison between the number and type of defects before and after instrumentation is shown in Table (1), showing an increase in the number of defects when comparing the specimens before to after instrumentation in the three studied groups.

In Groups (1) and (3), two teeth showed new defects not originally present in the specimens, however in group (2), three teeth showed new defects. However there was no significant difference between the three studied groups regarding the number of defects, the number of incomplete, and the number of complete cracks at $P<0.05$. No craze lines were detected before or after instrumentation in the three studied groups. A comparison between the direction of defects (bucco-lingual or mesio-distal) before and after instrumentation is shown in table (2), showing no significant difference between the three studied groups at $P<0.05$. Figure (1) illustrates the comparison between the size of defects before and after instrumentation.

Table 1. Comparison between the number of defects before and after instrumentation in the three studied groups

	Before Instrumentation		After Instrumentation		Change in defects	P
	No.	%	No.	%		
Number of defects						
Group I	4	26.7	6	40.0	2	0.438
Group II	2	13.3	5	33.3	3	0.396
Group III	0	0.0	2	13.3	2	0.14
Incomplete cracks						
Group I	1	6.7	2	13.3	1	0.542
Group II	0	0.0	2	13.3	2	0.14
Group III	0	0.0	2	13.3	2	0.14
Complete cracks						
Group I	3	20.0	5	33.3	2	0.408
Group II	2	13.3	3	20.0	1	0.624
Group III	0	0.0	1	6.7	1	0.309

Chi square test

Table 2. Comparison between the direction of defects before and after instrumentation in the three studied groups

	Before Instrumentation		After Instrumentation		P
	No.	%	No.	%	
Number of defects					
Group I	4	26.7	6	40.0	0.438
Group II	2	13.3	5	33.3	0.396
Group III	0	0.0	2	13.3	0.14
Mesio-distal cracks					
Group I	2	13.3	4	26.7	0.36
Group II	0	0.0	1	6.7	0.309
Group III	0	0.0	1	6.7	0.309
Bucco-lingual cracks					
Group I	2	13.3	2	13.3	1.0
Group II	2	13.3	4	26.7	0.36
Group III	0	0.0	1	6.7	0.309

Chi square test

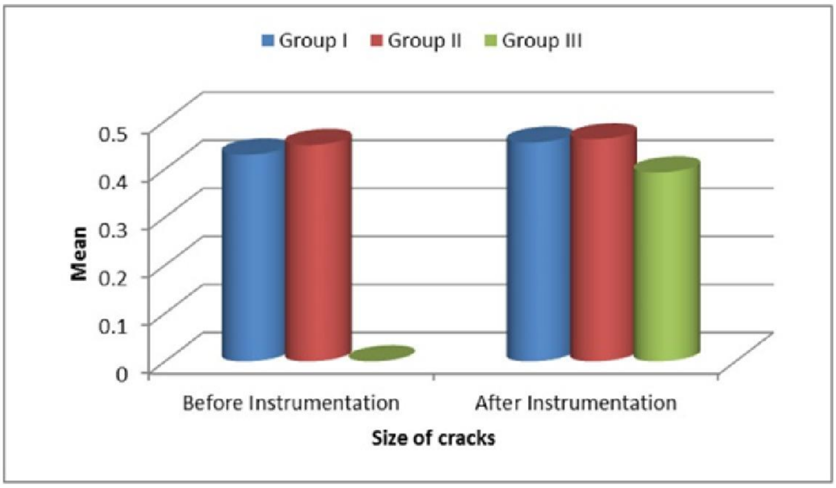

Figure 1. Comparison between the size of cracks before and after instrumentation in the three studied groups

Figure (2) shows a tooth with no defects before and after instrumentation. An incomplete defect formed after instrumentation is illustrated in Fig (3), in comparison to the same tooth before instrumentation showing no defects.

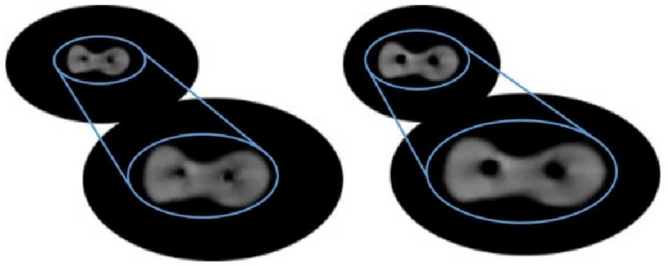

Figure 2. Left: A tooth showing no defects before instrumentation Right: Same tooth showing no defects after instrumentation

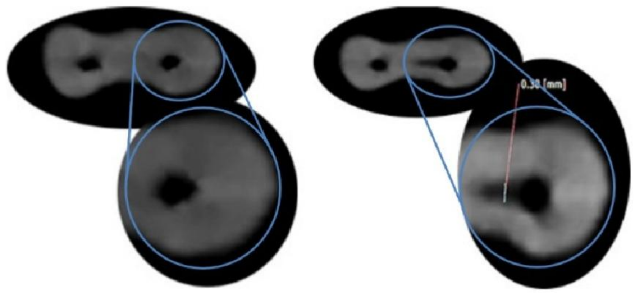

Figure 3. Left: A tooth showing no defects before instrumentation. Right: Same tooth showing an incomplete bucco-lingual crack formed after instrumentation detected in the middle third of the root

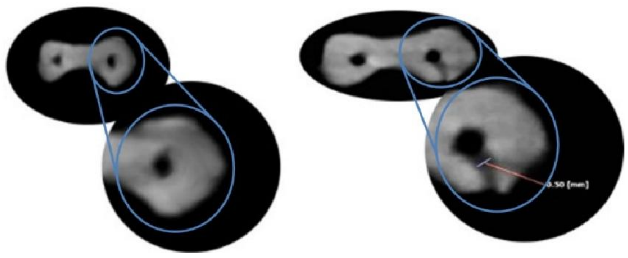

Figure 4. Left: A tooth showing no defects before instrumentation. Right: Same tooth showing a complete mesio-distal crack formed after instrumentation detected in the coronal third of the root

A complete defect formed after instrumentation is shown in Fig (4), in comparison to the same tooth showing no defects before instrumentation.

DISCUSSION

One of the most important aspects to be considered during root canal instrumentation, is minimizing the formation of dentinal defects, as they may decrease the longevity of endodontically treated teeth, due to their possible propagation into root fractures. In the present study, three different instrumentation motions were used to evaluate their effect on formation of dentinal defects; reciprocating motion (WaveOne), continuous rotation motion (One Shape), and manual motion (K-flexofiles). Cone beam computed tomography was selected in our study as a non-invasive method to identify dentinal defects, eliminating the need to section the teeth in order to view them under the microscope, as the sectioning procedure might have induced defects leading to non-objectivity of the results. Also the use of CBCT allowed us to evaluate the root along its entire length, opposed to sectioning the root which allowed the examination of only a few sections; overlooking defects that might be present in other locations.

On the other hand, several studies such as that carried out by Bier *et al*., 2009; Shemesh *et al*., 2009, used stereomicroscopy in identifying dentinal defects, as it is considered the standard method in observing dentinal defects. In the present study, by comparing the number of defects (before and after instrumentation) between the three studied groups, the reciprocating group (WaveOne) displayed the same results as the manual group (K-Flexo files), while the continuous rotation group (One Shape), lead to the formation of more defects than the reciprocating and the manual groups, although no statistically significant difference was found.

This may be attributed to the releasing motion that characterizes reciprocating systems, which minimizes the stresses on dentinal walls, creating less defects than that formed by continuous rotation motion. In conjunction with our study, Liu *et al*., 2013 stated that on comparing a reciprocating system (Reciproc) to a continuous rotation system (One Shape), Reciproc displayed less defects than that produced by One Shape, however, a statistically significant difference was found between the two groups. Also, Kansal *et al*., 2014, reported that reciprocating sytems (WaveOne, F2 ProTaper in reciprocating motion), produced less cracks than continuous rotation systems (F2 ProTaper in continuous rotation motion). Moreover, in accordance with the current study, Helvacioglu-Yigit *et al*., 2015, stated that no difference was found in defects formation between reciprocating files (WaveOne, Reciproc) and hand files.

On distribution of defects according to the location (coronal, middle, apical), and according to the type of defects (complete, incomplete, craze line), the WaveOne group showed more incomplete cracks apically when compared with the One Shape group and the hand files group. These results were in conjunction with the study carried out by Bürklein *et al*., 2013, where he found that reciprocating files (WaveOne and Reciproc) created more incomplete defects apically than continuous rotation files (Mtwo, ProTaper) also with no significant difference. Although in the present study, defects were detected on all levels (coronal, middle, apical), however Bürklein didn't detect any defects on the coronal or middle levels.

WaveOne primary file is characterized by a modified convex cross section, and an apical taper of 8% that reduces towards the coronal end, while One Shape is characterized by different cross sectional designs over the entire length of the working part and has continuous constant taper of 6%. Although each file has a different cross section and taper, this didn't contribute in a significant difference in dentinal defects formation. In accordance with these findings, Helvacioglu-Yigit *et al*., 2015, also reported no effect on the formation of dentinal defects using different files with different cross sections and tapers. In the present study, no correlation has been found between the material of file construction and the formation of dentinal defects, as WaveOne files are constructed of M-wire, One Shape files are constructed of regular Ni-Ti alloy, and K-Flexo files are made of stainless steel. On the contrary, Abou El Nasr and Abd El Kader 2014, reached the conclusion of that the material from which the file is constructed had an important effect on defects formation, in which WaveOne files being constructed from M-wire, decreased the formation of dentinal defects. Minimal studies evaluated the direction of dentinal defects (mesio-distal or bucco-lingual), emphasizing the need to study the effect of the type of instrumentation motion on the direction of dentinal defects formed. Accordingly, no correlation was found between them. On the contrary, Arias *et al*., 2014 reported that all the defects formed were in a bucco-lingual direction, when comparing the GT Profile hand files to WaveOne files in the formation of dentinal cracks.

In the present study, results were collected by comparing the pre-instrumentation images of the specimens to the post-instrumentation images taken by cone beam computed tomography, where no significant change was reported. This regimen was carried out by De-Deus *et al*. 2014, however using micro computed tomography instead of cone beam computed tomography. De-Deus also found no difference between the images taken before and after instrumentation using Reciproc, WaveOne, and BioRace.

In the current study, measurement of the width of the dentinal defects was carried out. This was enabled by the ruler option found on the software of the cone beam computed tomography. A procedure that wasn't carried out in most studies covering dentinal defects. The smallest defect detected was 0.26mm which is equivalent to 260 µm. This indicates that this imaging system couldn't detect any defects smaller than this size, which can be considered as a drawback for this method in detecting dentinal defects. On the other hand, Matsushita-Tokugawa *et al*., 2013 used vibrothermopgraphy in the detection of dentinal defects. After the detection test, the micro-crack width was measured with an optical microscope detecting micro-cracks with a width of 4 to 35.5 µm, however this device had limitations in detecting defects at different locations of the root due to the size of the equipment used.

In the present study, a relation between the ratio of the length of curvature and incidence of defects was studied. This was carried out in order to eliminate the fact that different lengths of curvatures of teeth could have had an effect on the results. However no correlation between the ratio of length of curvature to the incidence of dentinal defects was found.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

- All of the tested instrumentation systems produced dentinal defects, irrespective of the instrumentation motion used, with no significant difference detected between the three techniques used.
- The dentinal defects formed were found in both directions; mesio-distal and bucco-lingual.
- The use of cone beam computed tomography facilitated the diagnosis of dentinal defects, and allowed the measurement of such defects.

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