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RESEARCH ARTICLE

COMPARISON OF DENTINAL CRACK FORMATION DURING CANAL INSTRUMENTATION WITH NEW RECIPROCATION FILE SYSTEM AND CONVENTIONAL ROTARY SYSTEM BY OPTICAL COHERENCE TOMOGRAPHY (OCT) SCAN

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Abstract

Background/Purpose: Canal instrumentation with rotary nickel-titanium (NiTi) instruments might weaken the dentinal wall. This study aims to investigate the apical root cracks during canal instrumentation with new reciprocatory system and comparing it with the conventional rotary systems by using optical coherencetomography (OCT) scans.

Materials and methods: Twenty mandibular incisors were selected and divided into two groups that are instrumented using S-One pro (S-one) and ProTaper Universal (PTU) systems. OCT scans were taken immediately after canal instrumentation with file #25, #30 and #40. Each cross-sectional reconstructed image of 1, 2 and 3 mm from the apex was examined, root cracks were scored, and dentin thickness was measured at 12 sites. Our null hypothesis was that there would be no difference in root cracks formation between different file systems used.

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Introduction:-

Root canal treatment consists of proper cleaning and shaping of the canal and a three-dimensional obturation. In these phases, there is the possibility of vertical fracture of the root or development of cracks due to the use of rotational or ultrasonic instruments and particularly when using lateral compaction as an obturation technique[1]. Because root cracks have various types and their development can lead to failure in endodontic treatment or loss of the tooth, it is necessary to diagnose factors involved in its development and efforts should be made to reduce its abundance[2]. There is no definitive perspective on whether small dentinal cracks can lead to root fracture[3]; however, these damages must be prevented as much as possible [4]. Recent studies have shown that there is always a chance of crack formation in the root following the use of Nickel-Titanium (Ni-Ti) rotary files, and its incidence varies between 12% and 60% [5, 6]. Recently, an increasing number of rotary (Ni-Ti) instruments have been used for the preparation of root canals during root canal therapy, and despite their numerous benefits compared with hand instruments, they can produce greater stress within the canal[7]. This stress is produced due to greater rotation of the instrument within the canal in order to terminate the preparations[8]. Considering these factors, it seems there will be more dentinal cracks with the use of these files [9]. ProTaper universal (Dentsply, Maillefer, Switzerland) rotary files are popular files for endodontic treatment with increased taper, thus they have active cutting motion and ultimately remove more dentin of coronal areas compared to other systems[10]. It seems that ProTaper rotary files make more dentinal damages compared to rotary instruments.

Recently, preparation of the root canal by a Reciprocating motion has been raised. In this study, canal preparation is performed by a new reciprocating single file instrument(S-one PRO, Soco, China) and so the preparation time will

be reduced in comparison with rotary files [11]. These files are made from particular Ni-Tialloys named M-wire that have more flexibility and cyclic fatigue resistance [12]. Since the motions of these files are 150 degrees in a counterclockwise direction and 30 degrees in the clockwise direction, there is also the possibility of cracks forming by these files. It seems that by using these files, the remaining stress on the tool is released andits reciprocating motion reduces the risk of cyclic fatigue caused by compression and tension [(13-15)]. At the sametime, it is possible that during the use of an instrument in full preparation of a canal, there will be more stress during the mechanical preparation compared to preparation of canals by the full sequence protocol. Therefore, dentin damages such as cracks are increased compared to conventional systems, although all these conclusions need further investigation.

Stereomicroscopy was commonly used to observe dentin defects in root sections after canal instrumentation.[6,8,16] However, it cannot provide dynamic information about dentin changes caused by the use of each file during the process of root canal instrumentation. Pertinently, optical coherence tomography (OCT) is a new diagnostic method for creating high-resolution cross-sectional imaging of the internal biological structures based on depth-resolved optical reflectivity.[17] In dentistry, OCT has been proven to be a reliable method for observing pulp-dentin complex,[18] root perforations,[19] intracanal anatomy cleanliness of the root canal after preparation,[18] and detecting root cracks of extracted human teeth.[18-20]

Materials And Methods:-

Twenty extracted mandibular incisors were selected according to the inclusion criteria: Radiographs were taken from bucco-lingual and mesio-distal angles to verify the presence of a single canal with curvature less than 10 degrees. All the roots were observed under 20x magnification in a stereomicroscope (Kywota, Japan) to exclude root with cracks. The included teeth weredecoronated under water cooling with a low-speed saw (Leica sp1600, Wetzlar, Germany), leaving roots approximately 16 mm in length. Canal patency was established with a size#15/.02 K-file (Dentsply Maillefer, Ballaigues, Switzerland).The roots were mounted in resin blocks with simulatedperiodontal ligaments as suggested.[6] A hydrophilicvinyl polysiloxane impression material (Affinis, Coltene, Whaledent) was used to simulatethe periodontal ligaments. The apical 3 mm of the root was exposed and immersed in purified filtered water (Fig.1).

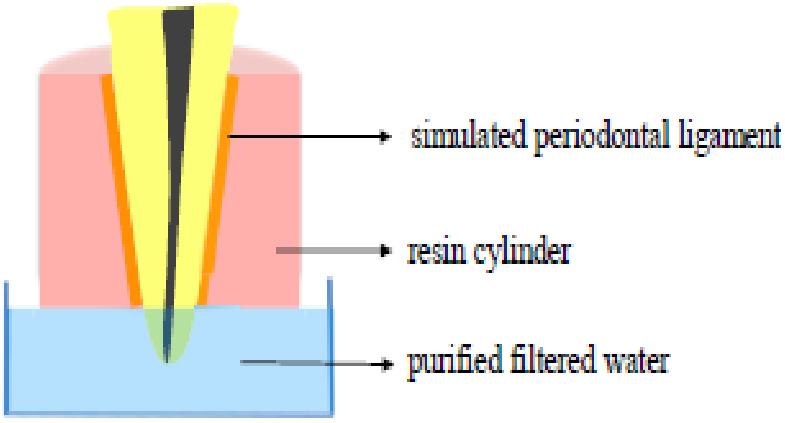

Figure 1:- Schematic representation of the experimentalsetup.

Sample preparation

The roots were divided into 2 experimental groups (n =10) with comparable bucco-lingual and mesio-distal widths at3 mm from the apex. To balance the influence of a deviatedapical foramen (AF) on the development of root cracks, each group contained 5 teeth with a centered AF and 5teeth with a deviated AF. The mean distances from theanatomical apex to the most occlusal point of the majorforamen was 0.41 mm and 0.40 mm in the twogroups. Then, canals were instrumented with a low-torque motor (X-smart plus, Dentsply Maillefer, Switzerland)using S-One pro (S-one) or ProTaper Universal (PTU) system. An Endodontist with 5 years of experience performed the canalinstrumentation. Each file was discarded after preparing 5canals. The same irrigation protocol was used for the two groups. Each canal was irrigated with 2 mL of a freshlyprepared 1% sodium hypochlorite solution between the use of each instrument and administered with a syringe and a27-G needle which was performed at 1 mm short of the working length from size #25 file. In S-one group, the S-One pro reciprocatory files of sizes #20 to #40 were performed with a constant speed of 300 rpm and 200 g/cm torque. The files: #20/.07, #25/.07, #30/.06, and #40/.06 were used individually to instrument different canals that terminated at the apical foramen.In PTU group, for each

ProTaper rotary file(DentsplyMaillefer), the individual rotational speed (250 rpm) andthe torque limit programmed in the file library of the motorwere used. Sx was used to prepare the coronal half of thecanal; thereafter, S1, S2, F1, F2, and F3 files were used toreach the working length. The last file used was F4, whichcorresponds to file #40 with a taper of 0.06.OCT scanning and image reconstructionAfter instrumentation using file #25, #30 and #40, the apicalroots of the 2 groups were scanned from the root surface byOCT (Optical OCT, GMC Srinagar, J&K) with a light source that repetitively sweepsthe wavelengths from 1300 to 1310 nm at a 20 kHz sweep-rate (Fig. 2). Images were reconstructed by using three- dimensional(3D) image processing software (Multireference opticalpath image registration program, GMC Srinagar). The images were inspectedwith this software on a liquid crystal display at a resolution of 1024 _ 1024 pixels.

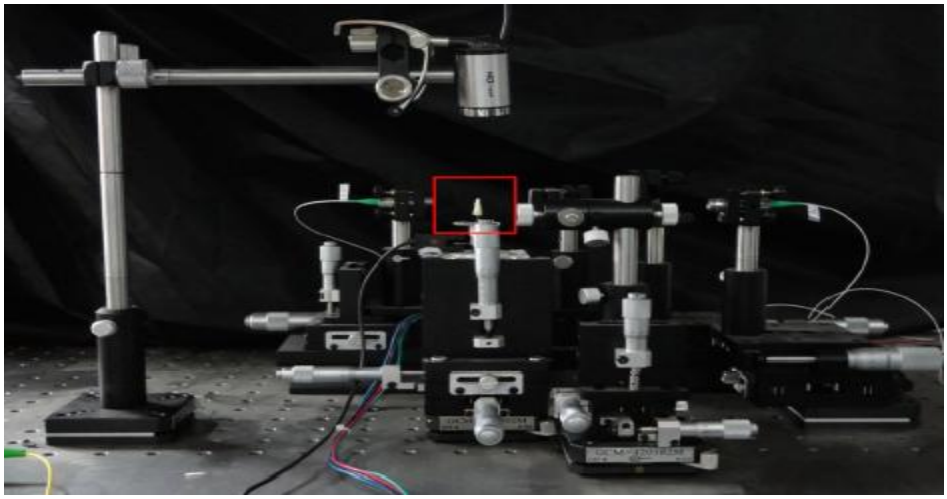

Figure 2:- Schematic representation of OCT system. A root sample was shown in the red box.

Evaluation of apical root defects:
Two observers evaluated the cross-sectional scanning images from the two groups taken 1, 2 and 3 mm from the apex after each file was used. On OCT scans, a root crack was defined as a bright line extending from the canal or 2 bright lines with a void between them separating the dentin (Fig. 3). The presence of root cracks was noted by two observers. Then, the observers reviewed the same scans again after an interval of 2weeks. In case of disagreement in detection of cracks, the image was discussed until consensus was obtained. The crack degree of each tooth was scored based on the number of cross-sectional scanning images with cracks. The scores were defined as explained below.
Score 0: no root crack;
Score 1: one cross-sectional image showing cracks;
Score 2: two cross-sectional images showing cracks;
Score 3: all three cross-sectional images showing cracks.

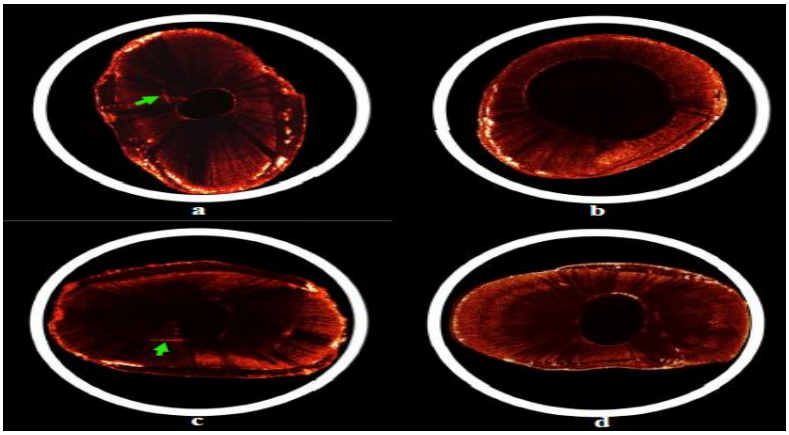

Figure 3:- OCT scan showed a root crack (green arrow) (a) (c) and an intact wall (b) (d).

Statistical analysis

The data was evaluated using SPSS ver. 20.0 (SPSS Inc., Chicago, IL). The Cohen kappa was used to compare the inter-observer and intra-observer consistency in detecting root cracks. The Mann-Whitney U test was used to analyze the different root crack scores in S-one and PTU groups after each file was used. The chi-square test was performed to compare the risk sites. The level of significance was set at a Z 0.05.

Results:-

For intra-observer agreement in detecting root crack, the kappa values were 0.80 and 1.00 for the two observers. For inter-observer agreement, the kappa value was 0.90, showing high reproducibility. Table 1shows the distribution of teeth with different root crack scores in the two groups after each file was used. When apical canals were instrumented with file #25/.07 and #30/.06 in S-one group, the score was 0. In PTU group, the crack scores were 3 and 9, respectively, after using F2(#25/.08) and F3 (#30/.09). After file #40 was used, one tooth was observed crack with a score of 1 in S-one group, while root cracks were found in 8 teeth with a total score of14 in PTU group. When the apical canals were instrumented with files #30 and #40, more cracks were shown in PTU group than in S-one group ($P < 0.05$).Dentinal thickness was measured on OCT scans at 36sites in 3 cross-sections of each tooth after each file was used. The dentinal wall with thickness thinner than0.30 mm was defined as risk site. All risk sites were located in the mesio-distal canal walls.

Table 1:- Number of teeth in the two groups with different root crack scores after each file was used (n = 10).

Group	File	Root crack score			
0	**1**	**2**	**3**		
PTU	F2 (#25/.08)	7	3	0	0
	F3 (#30/.09)	4	4	1	1
	F4 (#40/.06)	2	3	4	1
S-one	#25/.07	10	0	0	0
	#30/.06	10	0	0	0
	#40/.06	9	1	0	0

PTU, ProTaper Universal; S-one, S-ONE pro.
0: no scan image showed cracks.
1: one scan image showed cracks.
2: two scan images showed cracks.
3: all three scan images showed cracks.
Ex: In PTU group, after using F2, 7 teeth were scored 0, 3 teeth were scored 1 and no teeth was scored 2 or 3.

Discussion:-

According to the results of this study, the incidence of cracks was observed in both studied preparation systems andin apical, median and coronal sections from the apex, with no relationship with the anatomical location of the apex or the system. Under the conditions in this study, PTU could produce significantly more dentinal defects than S-one when the canals were instrumented with files #30 and #40.The difference between the various root canal preparation instruments in terms of dentinal cracks can be associated with preparation techniques and the cross-sectional design of files. As reported in recent studies, instrumentation with rotary NiTi instruments could potentially cause localized dentinal cracks;[5] these cracks might have the potential to develop into root fractures.[21] S-ONE pro reciprocatory preparation system has S-shaped cross-sectional design and their cutting tips are extremely sharp, while the ProTaper system has a triangular cross-section and lower cutting performance and also it has limited filings space [22]. High cutting ability is usually associated with increased cleaning efficiency [22,23]. Reciprocating motions can also increase the movement of debris towards the apex [24], and there is a possibility of increasing torsional forces following these motions. In PTU group, there were 3, 6 and 8 teeth with varying root crack scores when apical canals were instrumented with F2 (#25/.08), F3 (#30/.09) and F4 (#40/.06) files, respectively. ProTaper Universal system has multiple tapers of increasing and decreasing size on a single file. This design is supposed to reduce torsional loads and potential breakage. Whereas, when transitioning from file S2 to F3, the apical taper increases from 0.04 to 0.09. It has been reported that the torque of PTU system increases for each instrument with increasing tip size and taper.[25] PTU system caused more root cracks than other instruments in all the studies by Bier, Liu andCapar.[4,26] Notably, Liu reported that 50% of the mandibular incisors were found cracks after canal preparation with F2 in the PTU system.[4]

In the present study, less cracks were observed in S-one group when canals were instrumented with files #25/.07 and #30/.06. When the #40/.06 file was used, one tooth received a score of 1. This suggests that the superior flexibility of S-one pro files might reduce the risk of dentin cracks during root canal instrumentation. In the study of Ustun and colleagues (2015), the incidence of dentinal crack was compared between handmade K file, ProTaper universal, ProTapernext, and Reciproc systems. In this study ProTaper universal and ProTaper next systems caused more cracks than Reciproc systems, which corresponds with the data of this study [27].

Mandibular incisors with a single canal were used in this study. Wolf et al. reported that more than 50% of the physiological foramen of lower incisors are oval.[28] The difficulty in instrumenting oval canals lies in the possibility of creating strip perforations. Weller et al. observed that the minimum thickness of dentinal wall at 1, 2, and 3 mm from the apex was 0.52 mm, 0.67 mm, 0.76 mm, respectively, in mandibular incisors.[27] These thinnest areas were all present in mesio-distal wall. In Katz's study, the minimum dentin thickness of mesial and distal walls in the apical 1/3 region were 0.82 and 0.74 mm, respectively. After instrumentation with a size #40/.02 K-file, the thicknesses of the mesial and distal walls were reduced to 0.70 mm and 0.62 mm, respectively.[28] During canal instrumentation, excessive removal of dentin contributes to weakening the tooth structure. Lim proposed that the thickness of dentinal wall should retain at least 0.3 mm after root canal preparation to resist canal filling pressure and functional load during chewing.[29] Thus, the present result suggests that using a file with a taper that is too large to instrument mandibular incisor canals may lead to overpreparation in the mesio-distal wall, thus weakening the fracture resistance of the root.

In dentistry, OCT has previously been shown to be a valuable tool in assessing intracanal anatomy,[17]measuring remaining dentin thickness (RDT) and detecting root cracks of extracted human teeth.[18-20] Rashed[22] reported that OCT could accurately measure RDT compared with CBCT and micro-CT. In the studies of Yoshioka and Lee,[30] the ability of OCT for detecting the presence of cracks was comparable to that with micro-CT. In this in vitro study, the OCT which provided a high- resolution images with resolutions of 16 mm and 25 mm in axial and transverse images, respectively, was first used to evaluate root defects during canal instrumentation. Although OCT is a high-resolution, noninvasive, real-time display and nonradiative technique for tooth scanning, its use is limited due to its shallow penetrating depth. The penetration depth is dependent on optical attenuation from tissue scattering and absorption, which is about 2e3 mm in dental hard tissue.[30]

Conclusion:-

Regarding the study limitations, dentinal cracks were observed in all files and distances from the apex. When the canals of mandibular incisors were instrumented with apical size #30 and #40 files, the S-ONE pro reciprocating system could create less root defects in the apical dentin wall than the Protaper universal (PTU) system.

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