Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

ISSN NO. 2320-5407

Article DOI:10.21474/IJAR01/13790
DOI URL: http://dx.doi.org/10.21474/IJAR01/13790

RESEARCH ARTICLE

"INCIDENCE OF APICAL ROOT CRACK FORMATION AFTER ROTARY ROOT CANAL INSTRUMENTATION AT DIFFERENT INSTRUMENTATION LENGTHS USING PROTAPER UNIVERSAL, PROTAPER NEXT AND PROTAPER GOLD FILES - AN IN-VITRO STUDY"

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Manuscript Info

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Manuscript History
Received: 25 September 2021
Final Accepted: 27 October 2021
Published: November 2021

Key words:-
Dentinal Cracks, Protaper Universal, Protaper Next, Protaper Gold, Apical Root Crack, Root Canal Instrumentation, Vertical Root Fracture, NiTi Rotary Instruments

Abstract

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Aim: To evaluate the incidence of apical root crack formation after root canal preparation using ProTaper Universal (PTU), ProTaper Next (PTN) and ProTaper Gold (PTG) rotary file systems and compare the crack formation at various instrumentation lengths.

Subjects and Methods: One hundred single rooted extracted mandibular premolar teeth were mounted in acrylic resin blocks after simulating periodontal ligament. The teeth were divided into four groups. Group I was instrumented using PTU, group II using PTN and group III using PTG rotary files, while group IV was left untreated, serving as a negative control group. Each group was subdivided into three subgroups: A, B and C; instrumented till root canal length (RCL), RCL-1 and RCL+1. Root apex was sectioned horizontally 1-2mm from apical foramen and was stained with 1% methylene blue dye followed by stereomicroscopic evaluation to determine apical root cracks. The data was analyzed using chi-square, Shapiro Wilkinson and Cramers phi test. The significance level was set at $P<0.05$.

Result: Significant difference was seen in percentage of cracks after instrumentation with PTU and PTG, while no significant difference with PTU and PTN. Specimen instrumented upto RCL-1 showed less cracks as compared to those instrumented upto RCL and RCL+1.

Conclusion: PTG produced least number of cracks followed by PTN and PTU. Moreover, instrumentation at RCL-1 reduced the crack formation.

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Introduction:-

Successful endodontic therapy relies upon the strict adherence to 'endodontic triad' of proper access opening, thorough biomechanical preparation and three-dimensional obturation of the root canal system. The ultimate objective of endodontic instrumentation is to remove microorganisms, debris, and necrotic tissues by enlarging the canal diameter and create a canal form that allows a proper seal. Clinical evidence demonstrates that root canal systems that have been cleaned and shaped in three dimensions can be obturated with high degree of predictability, approaching 100% success.[1]

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Endodontic instruments have undergone immense development over the recent years. The first endodontic file was crafted by Edward Maynard by notching round wires at first from watch springs and then from piano wires, into files that were capable of removing pulp debris fromteeth.[2] Later, William Bueller developed a novel Nickel-Titanium alloy in Silver Springs, Maryland at the United States Naval Ordinance Laboratory, in 1960. The development of Nickel-Titanium (Ni-Ti) alloys for the manufacture of manual instruments initially and then rotary endodontic instruments, has revolutionized endodontic practice.During root canal preparation, rotational force is applied to the canals by Ni-Ti rotary instruments, during which there is contact between instrument and dentin walls. This contact creates many momentary stress concentrations in dentin thus creating craze lines or microcracks in root dentin.[3]Dentinal cracks or root fractures occur when the tensile stress in the root canal wall exceeds the tensile stress of dentin. Rotary Ni-Ti files with large tapers can produce increased friction and stresses on the canal wall and cause dentinal cracks in root dentin.[4]

Vertical root fracture (VRF) is one of the most common clinical complications following crack propagation in dentin of the root once the tooth has been endodontically treated. The fracture lines which are advanced into deeper structures permit invasion by significant amount of bacteria which may further cause biofilms and hence chances of re-infection persist.[5] Instrumentation of a large apical size helps in reducing debris and residual microrganisms meanwhile instrumentation of small apical size reduces the chances of VRF. Furthermore, instrumentation beyond and upto the apical foramen could cause more apical cracks than instrumentation short of it.[6] Design of the file has an impact on stress concentration and apical stress during instrumentation of root canal.

ProTaper Universal rotary files (PTU) manufactured by Dentsply Maillefer, have a convex triangular cross-sectional design and various percentage tapers that enable an active cutting motion and removal of relatively more dentin coronally. They are made from a conventional super-elastic Ni-Tiwire.[7] ProTaper Next instruments (PTN) manufactured by Dentsply Maillefer, have an off-centered rectangular design and progressive and regressive tapers on a single file, which is made from M-wire technology. Having an off-centered rectangular design decreases the screw effect, dangerous taper lock and torque on any given file by minimizing the contact between the file and dentin.[8] ProTaper Gold (PTG) manufactured by Dentsply Maillefer, Baillagues, Switzerland. PTG provides more than twice the resistance to cyclic fatigue as PTU and PTG's advanced metallurgy creates an increase in flexibility. Its advanced metallurgy with two - stage specific transformation behaviour and high austenite finish temperature is responsible for its increased flexibility.[9] The PTG instruments have been developed with proprietary advanced metallurgy. It has enhanced flexibility and resistance to cyclic fatigue.

The aim of the present study was to compare the incidence of apical root crack formation after rotary root canal instrumentation at different instrumentation lengths using ProTaper Universal, ProTaper Next and ProTaper Gold files.

Subjects and Methods:-

Subject:

One hundred single-rooted extracted humanmandibular premolar teeth were selected and stored in distilled water. Teeth with immature root apices, caries, developmental anomalies, calcified canals and resorption were excluded from the study.

Method:-

All teeth were observed under stereomicroscope to exclude teeth with cracks. To ensure a straight-line access and to provide a reference plane, decoronation from cemento-enamel junction was done with a diamond disc 15 mm from the apex.A single layer of aluminium foil was used to wrap the root portion of teeth. The teeth were then embedded into autopolymerizing acrylic resin set in aluminium hollow block such that 3-4 mm of apical root-end portion was visible.The foil was then peeled off from the roots and a thin layer of hydrophilic vinyl polysiloxane impression material was used to fill the space created by the foil to simulate the periodontal ligament and the root was immediately repositioned into the acrylic block.Patency of canal and glide path was established using number 10 K-file and 15 K-file. The distance between coronal and apical foramen of each root (root canal length) was determined by inserting a 15 K file into the canal until tip of the file was visible.

Grouping of samples:

The teeth were instrumented at different instrumentation lengths:

RCL: instrumentation terminated at apical foramen
RCL-1: instrumentation terminated 1mm short of apical foramen
RCL+1: instrumentation terminated 1mm beyond apical foramen
The teeth were divided into one control group (negative control) and three experimental groups:
GROUP I (n=30): the teeth were instrumented using PTU. It was further subdivided into three subgroups:
Subgroup A (n=10) : teeth instrumented tillRCL
Subgroup B (n=10) : teeth instrumented tillRCL-1
Subgroup C (n=10) : teeth instrumented tillRCL+1
GROUP II (n=30): the teeth were instrumented using PTN rotary files.
It was further subdivided into three subgroups:
Subgroup A (n=10) : teeth instrumented till theRCL
Subgroup B (n=10) : teeth instrumented tillRCL-1
Subgroup C (n=10) : teeth instrumented tillRCL+1
GROUP III (n=30): the teeth were instrumented using PTG rotary files.
It was further subdivided into three subgroups:
Subgroup A (n=10) : teeth instrumented till theRCL
Subgroup B (n=10) : teeth instrumented tillRCL-1
Subgroup C (n=10) : teeth instrumented tillRCL+1
GROUP IV (n=10): negative control group which was left untreated.

The following sequences were used for PTU andPTG: Sx file (half of working length), S1, S2 files (two-third of working length), F1, F2, F3 files (full working length). All the files were used with a torque-controlled endodontic motor (X-SMART DENTSPLY) at 300 rpm with a torque of 3.0 Ncm for Sx and S1 and 1.5 Ncm for S2, F1, F2 andF3.PTN was instrumented with file sequence of X1, X2 and X3 at 300 rpm with 2.0 Ncm torque. All files were used in brushing motion along the root canal except for F1, F2 and F3 which were used in ‘in and out’ motion.Irrigation was done after each file using 1% NaOCl solution.

Sectioning:
Root apex was horizontally sectioned 1-2 mm from the apical foramen with low speed under water cooling.

Microscopic Examination:
Root apex was stained with 1% methylene blue dye and were then examined under a stereomicroscope (Olympus-SZX, 12, Japan) at 25X magnification to determine the presence ofcracks.

Evaluation:
Each sample was classified into two different categories:

NO CRACK	Defined as root dentin without cracks or craze lines either at the internal surface of therootwallortheexternalsurfaceoftheroot. (Figure 1)
CRACK	Defined as all lines observed that extended from the root canal lumen to dentin or from the outer root surface into dentin. (Figure 2)

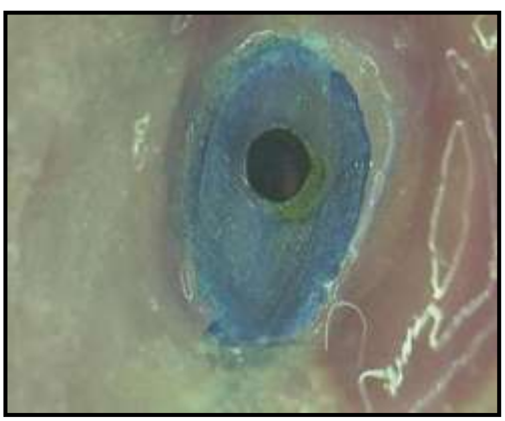

Figure 1:-

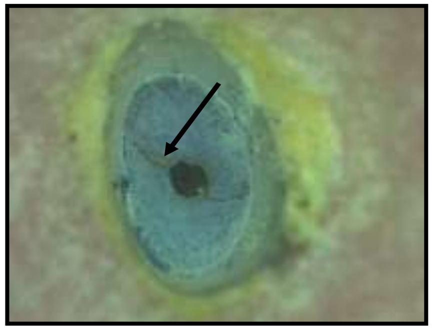

Figure 2:-

Statistical Analysis:
Results were expressed as the number and percentage of cracks found in each group. Descriptive statistics was performed to assess the proportion of the respective groups. Normality of the data was assessed using Shapiro Wilkinson test. Inferential statistics to find out the difference between the groups was done using chi square test. Cramers phi test was used to find out the strength of correlation (0-1) between the groups.

Result:-
There was no significant difference in the percentage of dentinalcracks after instrumentation with PTU and PTN. There was significant difference in the percentage of cracks after instrumentation with PTU and PTG. There was no significant difference in the percentage of dentinal cracks after instrumentation with PTN and PTG. There was no significant difference in the percentage of dentinal cracks after instrumentation at different instrumentationlengths.

PTU (70%)> PTN (56.6%) > PTG (33.3%)> control group (0%)
RCL+1 > RCL > RCL-1 for PTU, PTN and PTG.

Table 1:- Incidence of apical root cracks after canal preparation withrotary files at different instrumentation length.

File type	**Number of cracks**	**RCL**	**RCL-1**	**RCL+1**
PTU (n=30)	21(70%)	7(33.3%)	5(16.6%)	9(42.8%)
PTN (n=30)	17(56.6%)	6(35.2%)	3(17.6%)	8(47%)
PTG (n=30)	10(33.3%)	3(30%)	3(30%)	4(40%)
Control group (n=10)	0	0	0	0
Total (n=100)	**47**	**16**	**10**	**21**

The table shows the incidence of cracks is as follows PTU (70%)> PTN (56.6%) > PTG (33.3%).

Table 2:- Comparison of incidence of cracks at different instrumentationlengths between PTU and PTN groups.

File type	Number of cracks	RCL	RCL-1	RCL+1
PTU (n=30)	21(70%)	7(33.3%)	5(16.6%)	9(42.8%)
PTN (n=30)	19(63.3%)	6(35.2%)	3(17.6%)	8(47%)
$\chi 2$ value	0.13	0.15	0.11	0.08
P VALUE	0.74	0.84	0.91	0.76
Cramer phi value	0.145	0.094	0.083	0.159

*P<0.05 is statistically significant
Chi square test showed no significant difference between PTU and PTN with regard to number of cracks, RCL, RCL-1 and RCL +1. (P>0.5). Cramer phi test showed weak correlation between the groups with respect to each category. (NUMBER OF CRACKS, RCL, RCL-1&RCL+1)

Table 3:- Comparison of incidence of cracks at different instrumentationlengths between PTU and PTG groups.

File type	Number of cracks	RCL	RCL-1	RCL+1
PTU (n=30)	21(70%)	7(33.3%)	5(16.6%)	9(42.8%)
PTG(n=30)	10(33.3%)	3(30%)	3(30%)	4(40%)
$\chi 2$ value	6.42	0.12	1.85	0.13
P VALUE	0.001*	0.72	0.17	0.87
Cramer phi value	0.534	0.185	0.321	0.121

*P<0.05 is statistically significant

Chi square test showed significant difference between PTU and PTG with regard to number of cracks (p=0.001), whereas significant difference not found with respect to RCL-1 and RCL +1. (P>0.5). Cramer phi test showed good correlation (0.534) between the groups with respect to number of cracks and weak correlation with respect to RCL, RCL-1, RCL+1.

Table 4:- Comparison of incidence of cracks at different instrumentationlengths between PTN and PTG groups.

File type	Number of cracks	RCL	RCL-1	RCL+1
PTN(n=30)	17(56.6%)	6(35.2%)	3(17.6%)	8(47%)
PTG(n=30)	10(33.3%)	3(30%)	3(30%)	4(40%)
$\chi 2$ value	3.25	0.27	1.52	0.28
P VALUE	0.07	0.60	0.21	0.59
Cramer phi value	0.382	0.201	0.118	0.195

*P<0.05 is statistically significant

There was no significant difference in the percentage of dentinalcracks after instrumentation with PTU and PTN. There was significant difference in the percentage of cracks after instrumentation with PTU and PTG. There was no significant difference in the percentage of dentinal cracks after instrumentation with PTN and PTG. There was no significant difference in the percentage of dentinal cracks after instrumentation at different instrumentation lengths.

PTU (70%)> PTN (56.6%) > PTG (33.3%)> control group (0%)
RCL+1 > RCL > RCL-1 for PTU, PTN and PTG.

Discussion:-

The endodontic triad conventionally includes access opening, cleaning and shaping followed by three‑dimensional obturation of the tooth. Vertical root fracture is a common occurrence following apical dentinal crack propagation of the root canal after the tooth has been endodontically treated.

Various studies have been conducted regarding the metallurgical characteristic of various Ni-Ti file systems concluding it as an important factor in determining the dentin damaging potential than the motion of instrumentation. Thermomechanical processing is a frequently used method to optimize the microstructure and transformation behavior of Ni-Ti alloys thus improving the mechanical properties. Thermal treatment of Ni-Ti alloys, such as M-Wire, R-phase and controlled memory has been used to optimize the mechanical properties of thefiles.[1]

ProTaper Universal belongs to the second generation of rotary files with active cutting edges, composed of the conventional Ni-Ti wire. It has a progressive taper design improvingits flexibility and cutting efficiency while reducing torsional loading. A progressively changing helical angle and pitch balance, effectively reduced threating and aids in debris removal.

ProTaper Next belongs to the fifth generation, which is known for its offset centre of mass. It provides shaping advantages due to three unique design features through the convergence of variable tapers, M-wire and offset mass of rotation. The offset design creates an asymmetrical wave of motion along its active portion, resulting in only two points of contact between the file and root dentin. Various studies have concluded that M-wire, a metallurgically superior version of Ni-Ti, improves the resistance to cyclic fatigue by 400%.

ProTaper Gold has convex triangular cross-section and progressive taper enhancing its cutting action while decreasing rotational friction between the blade of the file and dentin. It has progressively tapered design that significantly improves cutting efficiency and safety. PTG is know to have a two‑stage‑specific transformation behavior, responsible for the reverse transformation of the alloy which passes through the intermediate R-phase, explaining the added advantage during the manufacturing process adding a strong impact on its transformation behavior and high transition temperature explaining the super elasticity of PTG.[10]

In this study, extracted mandibular first premolars were used because their smaller dimensions and thin dentinal walls are more prone to the forces generated during instrumentation. If large tapered files cannot induce cracks inmandibular premolars, chances of rotary files inducing cracks in other teeth are unlikely. Also because majority of them have single root and singlecanal.[11]

The apical 1 mm of the root was removed as it is usually noted in cases of periapical pathosis, causing damage to the apex of the root. Also due to the increased incidence of apical delta, ramifications and accessory canals in apical 1 mm of root may mimic cracks and affect the interpretation of results, thus avoiding it by the removal of 1 mm of apical root. Moreover it provided a flat surface for better visualization of cracks under stereomicroscope and helped in determining the working length accurately.[12]

It has been observed that instrumentation to apical foramen or beyond apical foramen may clean the most apical portion of the main canal but also increases the risk of apical dentinal defects. In the current study, the working length was kept 1 mm short of apex, at the apex and 1 mm beyond the apex, and it was seen that working within the canal at RCL – 1 mm produced the least amount of cracks on the apical surface, and this was significantly fewer compared with RCL and RCL + 1 mm.Working at RCL + 1 mm was used in the present study to evaluate whether or not accidental instrumentation might have an even more harmful effect on the apical root surface.

1% methylene blue dye was used to stain the specimen as it has a molecular size of 120 nm which is much smaller than the size of a bacterium. Since methylene blue has a low molecular weight (318.85) which is even lower than basic fuschin (323.45), it penetrates more deeply than other dyes.[13]

The specimen instrumented with PTN showed less cracks than the PTU though it was not statistically significant (Table 2). Due to swaggering motion, the PTN files contact less of the root dentin.Moreover due to their M‑wire technology, imparting PTN files an increased flexibility compared to the conventional Ni-Ti wire (PTU). In addition, PTN has off-centered rectangular design which generates swaggering motion, decreasing the screw effect, the dangerous taper lock, by minimizing contact between the file and root dentin, henceforth reducing the crack formation.

The specimen instrumented with PTG showed significantly less cracks than PTU (Table 3). The greater flexibility of PTG instruments might have led to fewer cracks than that caused by PTU instruments at the apical section.[14] Hence, PTG showed significantly least crack formation than PTU owing to its super elasticity.

The specimen instrumented with PTG showed less cracks than PTN though the difference was not statistically significant (Table 4). PTN having M‑Wire technology showed more cracks than PTGbecause the PTN file system has an offset mass of rotation which generates a mechanical wave of motion analogous to the oscillation noted along a sinusoidal wave. This results in cutting off a bigger envelope of motion as compared to a file with a symmetrical axis of rotation.[9] Moreover, PTG has the most recent metallurgical characteristic making it more flexible than PTN.

Specimen instrumented 1 mm beyond and upto RCL showed more cracks than their counterpart instrumented 1 mm short of RCL although there was no significant difference (Table 1). During instrumentation 1 mm beyond RCL and at RCL, file tips had proximity to the apical root dentin which resulted in more cracks. However file tips reaching RCL‑1 mm were left with sufficient amount of dentin adjacent to the file tip resisting the formation of cracks; although cracks were seen in fewer samples. Thus, as the files contact more to the root dentin, forces are generated directly adjacent to it resulting in root dentin defects.[15]

Conclusion:-

Within the limitations of this in vitro study, PTG showed least incidence of apical dentinal crack formation followed by PTN and PTU. Samples which were instrumented 1 mm beyond RCL and up to RCL showed more cracks than their counterparts which were instrumented 1 mm short ofRCL.

Financial Support and Sponsorship:
Nil.

Conflicts Of Interest:
There are no conflicts of interest.

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