An in-vitro evaluation of root canal instrumentation with ProTaper-Next Rotary files, K-files with Nd:YAG Laser and ProTaper-Next Rotary files with Nd:YAG Laser on the removal of smear layer from root canals using Scanning electron microscopic analysis.

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Abstract:

Sixty freshly extracted human permanent mandibular premolar teeth were included. Endodontic access cavity preparations were made in all the teeth using endo access bur, canal orifices located, pulp tissue was extirpated and working length determined in all the specimens. The apical foramens were sealed with sticky wax and teeth were embedded in acrylic resin blocks. All the teeth were then randomly divided into 3 groups with 20 specimens per group. Group A:ProTaper Next rotary files were used for root canal instrumentation upto X4 file in crown-down technique following manufacturer's instructions along with the use of root canal irrigants. Group B: Root canals were instrumented with K-files upto no. 30 size along with the use of root canal irrigants followed by irradiation with Nd:YAG Laser of root canals following manufacturer's instructions. Group C: ProTaper Next rotary files used for root canal instrumentation along with the use of root canal irrigants followed by irradiation of root canals with Nd:YAG Laser. The root canals were then finally rinsed with distilled water and dried with sterile paper points. All the specimens were then longitudinally split using a diamond disc and chisel into 2 halves, with the best 1 halve of each specimen used and the other halve discarded. The specimens were then prepared and subjected to Scanning electron microscopic analysis for the evaluation in the extent of presence or absence of smear layer in the coronal- third, middle-third and apical-third of root canals in all the specimens following Torabinejad et al; Smear layer grading system and the data was recorded, tabulated and statistically analysed with computer software; SPSS Version 20 using Kruskal-Wallis test and Mann-Whitney U-test. The obtained results showed; Root canal instrumentation with ProTaper Next rotary files followed by irradiation with Nd:YAG Laser (Group C) showed maximum efficiency in the removal of smear layer at all the 3 levels of root canal. Whereas root canal instrumentation with ProTaper Next rotary files without the use of Nd:YAG Laser (Group A) and root canal instrumentation with Conventional K-files followed by irradiation with Nd:YAG Laser were found to be least effective in the removal of smear layer at all the 3 levels of root canal with no significant difference seen between them. However, significant difference was seen in the efficiency of removal of smear layer between Group C and Group A, Group C and Group B.

Key words: Irradiation; Laser; ProTaper Next; Nd: YAG; Smear layer.

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Introduction:

Endodontic treatment begins with adequate knowledge of biology and diseases of pulp and peri-radicular tissues, endodontic access cavity preparation, removal of infected tissues and disinfection of the root canal space followed by dense filling of root canals.[1,2] Among all the steps, Cleaning and Shaping of the root canal system is a crucial step for the success of endodontic therapy as; "What we remove from the root canal space is far more important than what we replace it with".[3] During endodontic therapy, we use both mechanical instrumentation and root canal irrigants to three-dimensionally clean and disinfect the root canal system followed by filling of the root canal space with an inert obturating material and creation of a fluid-tight seal and in order to create this seal, it is imperative that the endodontic filling/obturation material closely adapts or bonds to the dentinal walls of the root canal.[4]

Root canal instrumentation is associated with disadvantages such as the formation of Smear layer. The presence of a smear layer prevents the penetration of root canal irrigants, intracanal medicaments and root canal sealers into the dentinal tubules, preventing proper adaptation of obturation materials to the dentinal walls of root canal, thus it is imperative to completely remove this smear layer.[5] Smear layer was first reported by Eick JD et al[6] and it is composed of organic debris, inorganic debris, bacteria and its by-products. During the root canal instrumentation either with hand files or rotary files, the mineralized tissues of the root canal are not shredded or cleaved, but are shattered to create considerable quantities of debris.[6] McComb D and Smith DC[7] reported that the smear layer in the instrumented root canals consisted not only of dentin debris but also the remnants of odontoblastic processes, pulp tissue and bacteria.

The instrument's cutting efficiency and ability to shape the canal is highly dependent on the file design and its dynamics during motion within the root canal. However, it becomes impossible to totally remove all the smear layer and debris from the canal, as frequently there remain certain un-instrumented areas after root canal preparation.[8] So, there is a need to find newer root canal instrumentation techniques to improve the quality of root canal preparation with efficient removal of smear layer. It is important to develop an instrument file system that produces minimal amounts of debris and smear layer on root canal walls. Since most hand instrumentation techniques are time-consuming and may lead to iatrogenic errors (ledging, zipping, canal transportation and apical blockage), much attention has been given towards the use of Nickel-Titanium Rotary file systems.[9]

Recently, ProTaper Next (PTN) rotary file system was introduced in 2013 as a successor to ProTaper Rotary Universal file system. PTN exhibit a unique off-centred rectangular cross section with an asymmetric rotary motion like a snake, improving canal shaping effectiveness and M-wire NiTi alloy for increased cyclic fatigue resistance with superior flexibility.[10] This system consists of 5 Shaping Files (X_1, X_2, X_3, X_4, X_5). Each file has an increasing and decreasing percentage of taper through-out its length and this serves to minimize the contact between the file and dentinal walls of root canal, improving the flexibility and decreasing the potential for “taper lock” and the rotational movement of the file makes it an “Operator controlled variable factor.”[9]

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. Laser light is a man-made single photon wavelength and the spontaneous emission of a photon by one atom stimulates the release of a subsequent photons, creating a chain event.[11] The most studied Laser in dental literature is the Neodymium:Yttrium-Aluminium-Garnet (Nd:YAG) Laser, is a near infrared laser with a wavelength of 1064 nm and shows partial water absorption. In Endodontics, irradiation of Nd:YAG Laser on root canal walls helps in the removal of smear layer, remnants of pulp tissue and vaporization of organic tissues inside the dentinal tubules, fusion and crystallization of the inorganic constituents of dentin and also helps in root canal disinfection.[10]

In our study, Scanning Electron Microscope (SEM) was used to evaluate the efficiency of root canal instrumentation with ProTaper-Next rotary files, K-files followed by irradiation with Nd: YAG Laser and ProTaper-Next rotary files followed by irradiation with Nd:YAG Laser on the removal of smear layer from root canals. SEM is considered as an ideal method to evaluate the removal of smear layer from the root canal walls. The basic principle in the working of SEM; an electron beam scans the surface of the root canal wall to produce a variety of signals and are collected by a detector. It proved to be a valuable method in the evaluation of volume of debris and smear layer remnants on root canal walls. The advantage of SEM is the ability to produce higher magnification offering remarkable resolution compared to optical microscopes.[11]

Materials and method:

Sixty freshly extracted human permanent mandibular premolar teeth were collected in Triveni Institute of Dental Sciences, Hospital and Research centre, Bilaspur. India. Inclusion criteria: Single rooted, single canal, non-carious, non-fractured, un-restored, visible cracks, matured teeth with closed root apices. Teeth were checked by conventional radiographs to prove the presence of single canal and absence of calcifications, resorptive defects. Teeth extracted only for orthodontic purpose or periodontally compromised teeth were included. Exclusion criteria: Carious, fractured, restored, open root apices, multi-canal and previously endodontically treated teeth. All the teeth were cleaned of superficial debris, calculus and residual tissue tags with ultrasonic instrument and were then stored in 0.5% thymol at room temperature until used.

A standardized endodontic access cavity preparations were made in all the teeth using Endo access bur no. 2 (Dentsply Maillefer, Switzerland) in a high speed conta-angled airoter handpiece (NSK, Japan), canal orifices were located and pulp tissue was extirpated with barbed broaches (Dentsply Maillefer, Switzerland). An ISO No.10 K(Kerr)-file(Mani INC, Japan) was placed into the root canal to establish the patency till the apical foramen and working length was determined by subtracting 0.5mm from the length achieved with the tip of the trial file just visible at the apical foramen of each root canal in all specimens. In each specimen, the apical foramen was sealed with sticky wax and embedded in cylindrical acrylic resin blocks (DPI-RR Cold cure, Dental products of India, Mumbai) till the cervical line for better stabilization and ease of handling. All the teeth were then randomly divided into 3 groups with 20 specimens per group.

Group A (n=20): ProTaper Next rotary files (Dentsply Maillefer, Ballaigues, Switzerland)(Figure 1) were used for root canal instrumentation. All teeth were instrumented upto their pre-determined working length with the files; X1(size 17, 4% taper), X2 (size 25, 6% taper), X3(size 30, 7% taper) and X4(size 40, 6% taper) as the Master Apical File (MAF) in crown-down technique following manufacturer's instructions at 300 rpm, 2 Ncm of torque using a torque-controlled Endomotor handpiece (Canal Pro CL2, Coltene Endo, Coltene Whaledent, Germany)(Figure 1). In each specimen during root canal instrumentation, 2ml of 17% EDTA solution (EthylineDiamineTetraAcetic acid) (Prevest Denpro, Jammu, India) and 2ml of 3% Sodium hypochlorite solution (Neelkaanth Health Care Pvt Ltd, Ahmedabad, India) were used as root canal irrigants with the aid of a Max-I-Probe (Dentsply Maileffer, Switzerland) irrigation needle at 4 mm coronal of pre-determined working length. The root canals were then finally rinsed with 2ml of distilled water (Sadbhavna Chemicals, Gujarat, India) and dried with sterile paper points (Dia Dent International, Korea).

Figure 1

ProTaper Next Rotary files with Canal-Pro Endomotar handpiece

Group B (n=20): K-file followed by irradiation with Nd:YAG Laser (Wontech, Pastelle, Tokyo, Japan) (Figure 2). Initially the root canals were instrumented with Conventional K-files upto ISO no. 30 size (2% Taper) till the pre-determined working length in step-back technique and during root canal instrumentation, 2ml of 17% EDTA solution and 2ml of 3% Sodium hypochlorite solution were used per specimen as root canal irrigants with the aid of a Max-I-Probe irrigation needle at 4 mm coronal of pre-determined working length. The root canals were then finally rinsed with 2ml of distilled water and dried with sterile paper points followed by irradiation with Nd:YAG Laser. The laser device was adjusted to the parameters recommended for endodontic therapy by the manufacturer; With the attachment of 200 micrometer fiberoptic tip(Figure 3) reaching upto pre-determined working length in each root canal, Nd:YAG Laser was used with wavelength of 2940 nm, energy of 1.8 W, pulse rate of 120 mJ, frequency of 15 Hz and energy level of 381 J/cm^2. During irradiation, the fiberoptic tip was moved from apex to the root canal orifice in circular fashion at a speed of 2mm per second applied parallel to the canal surface with each application lasted for 20 seconds and the same process was repeated for three times, with 15 seconds interval and the total time of laser irradiation in each root canal was 60 seconds.[2] The optical fiber is provided with a cooling system, which delivered a spray of air and water during irradiation to avoid heat production in the treated areas. Each root canal was then finally rinsed with 2ml of distilled water and dried with sterile paper points.

Figure 2

Neodymium:Yttrium-Aluminium-Garnet (Nd:YAG) Laser unit

Figure 3

Nd:YAG Laser Handpiece with fiberoptic tip and protective eye wear

Group C: (n=20): ProTaper Next rotary files used for root canal instrumentation followed by irradiation with Nd:YAG Laser. All teeth were instrumented upto their pre-determined working length with the files; X1 (size 17, 4% taper), X2 (size 25, 6% taper), X3(size 30, 7% taper) and X4(size 40, 6% taper) as the master apical file in crown-down technique following manufacturer's instructions at 300 rpm, 2 Ncm of torque using a torque-controlled Endomotor handpiece. In each specimen during root canal instrumentation, 2ml of 17% EDTA solution and 2ml of 3% Sodium hypochlorite solution were used as root canal irrigants with the aid of a Max-I-Probe irrigation needle at 4 mm coronal of pre-determined working length. The root canals were then finally rinsed with 2ml of distilled water and dried with sterile paper points. This was followed by irradiation with Nd:YAG Laser; The laser device was attached to 200 micrometer fiberoptic tip reaching upto pre-determined working length in each root canal with wavelength of 2940 nm, energy of 1.8 W, pulse rate of 120 mJ, frequency of 15 Hz and energy level of 381 J/cm^2 following the parameters recommended for endodontic therapy by the manufacturer (Figure 4). During irradiation, the fiberoptic tip was moved from apex to the root canal orifice in circular fashion at a speed of 2mm per second applied parallel to the canal surface with each application lasted for 20 seconds and the same process was repeated for three times, with 15 seconds interval and the total time of laser irradiation in each root canal was 60 seconds.[2] The root canals were then finally rinsed with distilled water and dried with sterile paper points.

Figure 4
ProTaper Next rotary files and Nd:YAG Laser-Hand piece with fiberoptic tip

Root canal instrumentation in all specimens among the 3 groups were done by a single endodontist; who was not blind to the groups to prevent any inter-operator variability and during Laser irradiation of specimens, the endodontist used protective eye wear. All the teeth were removed from acrylic resin blocks and sticky wax. All specimens were then grooved bucco-lingually using a diamond disc (DFS, Germany) fitted to a straight handpiece (NSK, Japan) at low speed and were longitudinally split with a chisel into 2 halves very carefully. For each specimen, the half containing the most visible part of the entire root canal (from root apex to the orifice) was selected and the other half was discarded. Each selected halve of all specimens were then divided into 3 levels; at 3mm(Apical-third), 10 mm(Middle-third) and 17mm(Coronal-third) along the length of each root canal by making grooves using a tapered fissure bur TF-21(Mani, Japan) and were then fixed with 25% glutaraldehyde solution for 24 hours. The fixed specimens were then dehydrated with ascending concentrations of 25%-100% ethyl alcohol (10 minutes for each concentration) and were placed in a desiccator for atleast 24 hours.

The specimens were then mounted on aluminum stubs, gold-sputtered and subjected to Scanning Electron Microscope(SEM)(Sigma 300 VP, Carl Zeiss, Oberkochen, Germany)(Figure 5) evaluation. The SEM photomicrographs were taken at the selected three levels (3mm, 10mm and 17mm) of root canal in each specimen and to prevent any inter-operator variability, SEM-photomicrographs of all specimens were analyzed by one examiner who was specialist in Endodontics, but was blind to group status. The examiner graded the extent of presence or absence of smear layer in the apical-third, middle-third and coronal-third of root canals in all the specimens following "Torabinejad et al[12] Smear layer grading system" and the data was recorded.

Grade 1: No smear layer; no smear layer on root canal walls, all the dentinal tubules were clean and open.

Grade 2: Moderate smear layer; no smear layer on root canal walls, but the dentinal tubules contained debris.

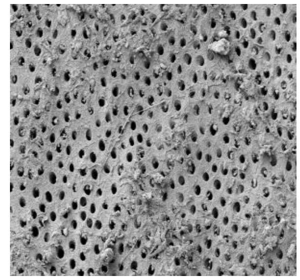
Grade 3: Heavy smear layer; the smear layer covered the root canal walls and dentinal tubules.

Figure 5

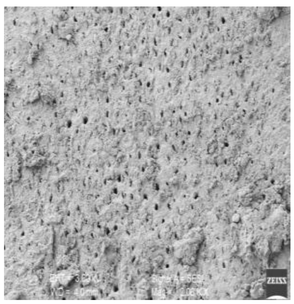
Scanning Electron Microscope(SEM)

Group A: PTN Rotary file (Coronal-third)

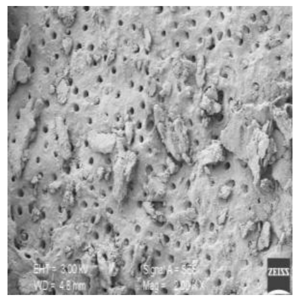
Group B: K-file + Nd:YAG (Coronal-third)



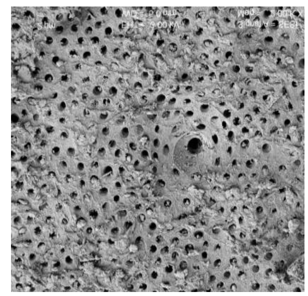
Group C: PTN Rotary file + Nd:YAG (Coronal-third)



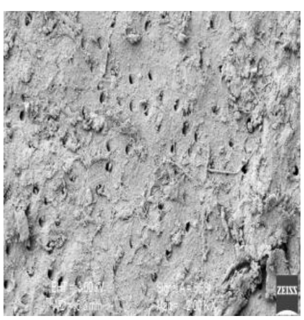
Group A: PTN Rotary file (Middle-third)



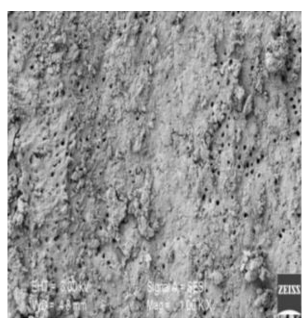
Group B: K-file + Nd:YAG (Middle-third)



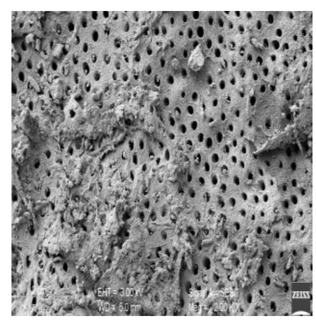
Group C: PTN Rotary file + Nd:YAG (Middle-third)



Group A: PTN Rotary file (Apical-third)



Group B: K-file + Nd:YAG (Apical-third)



Group C: PTN Rotary file + Nd:YAG (Apical-third)

Figure 6

Scanning Electron Microscope –Photomicrographs of Group A, Group B, Group C specimens at 3 levels of root canal (Coronal-third, Middle-third, Apical-third)

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Results:

GROUPS	Root Canal Levels	Sum rank	Kruskal-Wallis (K-W) Value	P* Value
Group: A (ProTaper Next Rotary files)	Coronal-third	493.5	5.6068	**>0.05** NS*
	Middle-third	496.5		
	Apical-third	511.0		
Group: B (Hand K-files + Nd:YAG Laser)	Coronal-third	490.0	8.9128	**<0.05** S*
	Middle-third	491.5		
	Apical-third	521.0		
Group: C (ProTaper Next Rotary files + Nd:YAG Laser)	Coronal-third	330.0	1.023	**>0.05** NS*
	Middle-third	343.5		
	Apical-third	349.0		

Table 1: Kruskal-Wallis(K-W) test for Inter-Group comparison

*NS: Non-significant *S: Significant *P: Probability

The recorded data was tabulated and statistically analysed with computer software; Statistical Package for Social Sciences (SPSS) Version 20 using Kruskal-Wallis(K-W) test and Mann-Whitney U-test.

Kruskal-Wallis test is a non-parametric analysis of variance and it was done to find whether there was any significant difference in the presence of smear layer between the three Groups (A,B,C) and it was found that in Group A; No-significant difference was seen in the presence of smear layer, as K-W value was 5.6068 and P value >0.05. Group B; Significant difference was seen in the presence of smear layer, as K-W value was 8.9128 and P value <0.05 and Group C; No-significant difference was seen in the presence of smear layer, as K-W value was 1.023 and P value >0.05.

In Group A; The presence of smear layer was: Apical-third > Coronal-third = Middle-third. The difference between the Coronal-third and Middle-third was not statistically significant, but the difference between the Coronal-third and Apical-third, Middle-third and Apical third were statistically significant. In Group B; The presence of smear layer was: Apical-third > Middle-third = Coronal-third. The difference between the Coronal-third and Middle-third was not statistically significant, but the difference between Coronal-third and Apical-third, Middle-third and Apical-third were statistically significant. In Group C; The presence of smear layer was: Apical-third = Middle-third = Coronal-third, as no significant differences were seen between the apical-middle-coronal third's of root canals.

So, to find out where the significant difference was; Two by Two - Mann–Whitney U Tests of Mean values of the presence of smear layer at three levels(Coronal, Middle and Apical-third's) of root canal in the Study Groups were done.

Root Canal Levels	Groups	MEAN ± SD*	P* value	Significance
Coronal-third	A	1.80 ± 0.52	>0.05	NS*
	B	1.75 ± 0.44		
	A	1.80 ± 0.52	<0.05	S*
	C	1.35 ± 0.49		
	B	1.75 ± 0.44	<0.05	S
	C	1.35 ± 0.49		
Middle-third	A	1.80 ± 0.52	>0.05	NS
	B	1.85 ± 0.36		
	A	1.80 ± 0.52	<0.05	S
	C	1.45 ± 0.61		
	B	1.85 ± 0.36	<0.05	S
	C	1.45 ± 0.61		
Apical-third	A	2.25 ± 0.55	>0.05	NS
	B	2.35 ± 0.58		
	A	2.25 ± 0.55	<0.05	S
	C	1.60 ± 0.68		
	B	2.35 ± 0.58	<0.05	S
	C	1.60 ± 0.68		

Table 2: Mann-Whitney U-Test: Mean values of the presence of smear layer at 3 Root canal levels in the Study groups.

In coronal-third of root canals, the mean value of the presence of smear layer was: Group A > Group B > Group C. The difference between Group A and Group B was not statistically significant (P>0.05), but there was statistically significant difference (P<0.05) seen between Group A and Group C, Group B and Group C.

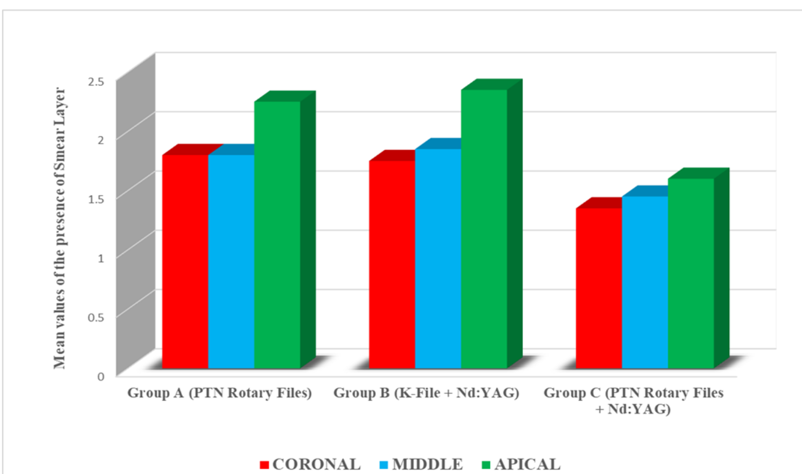
In middle-third of root canals, the mean value of the presence of smear layer was: Group B > Group A > Group C. The difference between Group A and Group B was not statistically significant (P>0.05), but there was statistically significant difference (P<0.05) seen between Group A and Group C, Group B and Group C.

In apical-third of root canals, the mean value of the presence of smear layer was: Group B > Group A > Group C. The difference between Group A and Group B was not statistically significant (P>0.05), but there was statistically significant difference (P<0.05) seen between Group A and Group C, Group B and Group C.

In our study, Both Kruskal-Wallis(K-W) test and Mann-Whitney U-test showed; Group: C (ProTaper Next rotary files followed by irradiation with Nd:YAG Laser) showed maximum efficiency in the removal of smear layer at all the 3 levels of root canals; as it showed lesser mean values in the presence of smear layer at the coronal-third(1.35), middle-third(1.45) and apical-third(1.60) compared to Group; A and Group; B specimens. Especially in the apical-third of root canals, instrumentation with ProTaper Next Rotary files followed by irradiation with Nd:YAG Laser (Group C) was found to be highly effective in the removal of smear layer compared to other test methodologies used in Group A and Group B specimens.

Whereas, Group: A (ProTaper Next rotary files) was found to be least effective in the removal of smear layer at all the 3 levels of root canals; as it showed higher mean values in the presence of smear layer at the coronal-third(1.80), middle-third(1.80) and apical-third(2.25). Group: B (Hand K-files + Nd:YAG Laser) was also found to be as least effective in the removal of smear layer at all the 3 levels of root canals; as it showed higher mean values in the presence of smear layer at the coronal-third(1.75), middle-third(1.85) and apical-third(2.35). Especially in the apical-third of root canals among the specimens of Group A and Group B; showed maximum amount of smear layer. However, No significant difference was seen between Group A and Group B specimens in the efficiency of smear layer removal at all the 3 levels of root canal.

Graph 1: Mean values of the presence of smear layer in Group A, Group B, Group C at Coronal-third, Middle-third and Apical-third of root canals.



Discussion:

An accepted axiom in endodontic therapy is 3-dimensional cleaning, shaping and obturation of root canals. The elimination of microorganisms from root canal is an important step in the success of root canal treatment. The colonization of dentinal walls with biofilm, along with the anatomical complexity of the root canal and the possibility of invasion of dentinal tubules can compromise the success of endodontic therapy.[13] During bio-mechanical preparation of root canals with either hand or rotary files results in the production of considerable amount of mineralized debris that is not shredded or cleaved but shattered and it is called as Smear layer.[14]

Identification of smear layer over the tooth surface was made possible using Scanning Electron Microscope (SEM) and was first reported by Eick et al[6] in 1970, as a layer made of particles ranging in size from less than 0.5–15 micrometers. American Association of Endodontists (AAE)[15] defined Smear layer as a surface film of debris retained on dentin or other surfaces after instrumentation with either rotary instruments or endodontic files; consists of dentin particles, remnants of vital or necrotic pulp tissue, bacterial components and retained irrigant. Cameron JA et al[16] and Mader CL et al[17] discussed the smear layer material in two parts: First; the superficial smear layer (25 micrometer) and Second; the material packed into the dentinal tubules (smear plug upto 40 micrometer).

ProTaper Next rotary files are manufactured with M-wire technology, have an increasingly percentage-tapered design on each file. M-wires receive further thermo-mechanical treatment and their nano-crystalline martensitic microstructure presents mechanical assets with improved super-elastic and resistant to fatigue. PTN files create exclusive unique rotary movements inside the root canals and at any particular cross-section, it only contacts the canal surface in two areas.[18] However in our study, Group A; in which ProTaper rotary files were used for canal instrumentation was least effective in smear layer removal. This is in accordance with the previous studies of Sarikahya M et al[18] and Lopes RMV et al[19] presented similar untouched canal surface areas with accumulated hard tissue debris.

The first use of Laser in endodontics was reported by Weichman and Johnson in 1971;[20] they attempted in-vitro sealing of the apical foramen using a high power-infrared CO_2 laser. This was unsuccessful, but the data they obtained encouraged the use of laser, including attempts to seal the apical foramen using the Nd:YAG laser. Kaitsas V et al[21] investigated the morphological and histological changes on the root canal walls after Nd:YAG laser irradiation and observed a clear glazed surface, some open dentinal tubules and some surface craters with cracks indicating that smear layer and debris can be removed using Nd:YAG laser.

Group B; in which conventional K-files were used for root canal instrumentation followed by irradiation with Nd:YAG Laser, was least effective in the removal of smear layer. This can be attributed to the use of conventional 2% Taper hand K-files, as during the root canal instrumentation there tends to be maximum contact of the file along the entire length of dentinal walls of root canal, producing maximum amount of smear layer. Such that, even when Nd:YAG laser was used followed by the use K-files, it failed to remove smear layer from root canals. However their was no significant difference in the smear layer removal ability between specimens of Group A and Group B,

Levy G[8] found that Nd:YAG irradiation can produce clean and regular root canal walls with complete removal of smear layer. Camargo SE et al[22] evaluated the effects of Nd:YAG laser irradiation applied perpendicular or parallel to the root canal dentinal wall and SEM analysis indicated that intracanal laser application using circular movements parallel to the root canal surface produced limited morphological changes in the root dentin. Anic I et al[23] reported that morphological changes varied from dentin being unaffected to melted; Unaffected, when the laser beam was applied perpendicular to the root canal surface and Melted, when the laser beam was applied parallel to the root canal surface. Stabholz A et al[24] used Nd:YAG laser to remove the smear layer from the root canal and showed melted, recrystallized and glazed dentin surfaces.

A standard ISO size no. 30 file preparation is needed to allow any traditional Laser tips (200-320 micrometer) to reach close to the root apex.[25] So in our study, in Group B; initially root canals were instrumented with conventional K-files upto ISO No. 30 size (2% Taper) till the pre-determined working length followed by the use of Nd:YAG laser; so as the fiber-optic tip of laser reaches as close as to the working length, however it showed least efficiency in the removal of smear layer in coronal-third, middle-third and apical-third of root canals. The results of our study contradicts with a previous study of Moogi PP et al[26] reported, root canal instrumentation with conventional K-file upto ISO no. 20 size till the working length followed irradiation with Nd:YAG laser showed superior ability in the removal of smear layer from the root canal walls compared to conventional method of root canal instrumentation with K-files upto ISO size no. 35 size till the working length without the use of Nd:YAG laser.

In our study, among specimens in which root canal instrumentation was done with ProTaper Next rotary files till X4 file(apical size of 40) followed by irradiation with Nd:YAG laser (Group C) showed maximum efficiency in the removal of smear layer from the walls of root canals at all the 3 levels(coronal-third, middle-third and apical-third) compared to Conventional hand K-file for root canal instrumentation followed by Nd:YAG laser (Group B). This can be attributed to the fact that in Group C; the root canals were enlarged upto size 40(PTN, X4 file) compared to Group B; canals were enlarged upto K-file no. 30(apical size of 30, 2% taper). The fact that in Group C; the root canals were instrumented to a greater apical size of 40 and 6% taper with PTN files followed by irradiation with Nd:YAG laser was more effective in smear layer removal at all the 3 levels of root canals compared to specimens in Group B.

The findings obtained in our study demonstrated that the effectiveness of all the three root canal instrumentation techniques used for the elimination of smear layer, dropped in the apical-third of root canals in all the groups and this incompetence in eliminating the smear layer in the apical-third was justified by the truth that the apical end of root canals are tinier and narrower in size than the middle-third and coronal-third with a superior level of tubular sclerosis.[27]

The superior ability in the removal of smear layer at all the 3 levels of root canal among the specimens of Group C compared to Group A was due to the fact; PTN files at any particular cross-section, it only contacts the canal surface in two areas[18] leaving behind untouched canal surface areas with accumulated hard tissue debris[19] and when it was followed by irradiation with Nd:YAG laser, it eliminates these short-comings of PTN files; this can be attributed to the manner in which the laser cuts dentin, as the Nd: YAG laser gets focused to a small spot at a very short duration, the high-peak power level of laser breaks down these untouched dentin surfaces of canal and accumulated hard tissue debris due to the formation of plasma. Plasma formation occurs due to the ionization of the molecules. As plasma effect is reached during cleaning, there is a transformation of dentin into ionized gas, which leaves no debris on the dentinal walls of root canal, thus showing maximum efficiency in the removal of smear layer and this is in accordance with a previous study of Levy G.[8]

Matsumoto K[28] reported Nd:YAG laser as the most popular laser used, because a thin fibre-optic delivery system for entering narrow root canals is available with this device and the ease with which the laser energy and laser fiber-optic tip can be controlled. The results of our study was in accordance with previous studies of Minamisako M et al,[29] Asnaashari M et al[30] reported that Nd:YAG laser was effective in the removal of debris, smear layer, pulp tissue and therefore, it can effectively increase the success rate of endodontic treatment.

In our study, Single rooted teeth with single canal were chosen as the specimens; since they have an oval cross-section and the cleaning ability of rotary files is restricted by the rounded cross-sectional design of files, leaving large areas of canal walls untouched with accu-mulation of hard-tissue debris and smear layer. Thus is the importance of irradiation of root canals with Nd:YAG laser along with the use of rotary Ni-Ti files during routine root canal instrumentation for effective removal of hard tissue debris and smear layer.

In our study, the root apices of all specimens were sealed to simulate in-vivo condiations, as during the use of Nd:YAG laser in root canals, there is transformation of surface dentin into ionized gas,[8] thus trapping these gases within root canal and also to allow the root canal space to act as a reservoir for root canal irrigants during canal instrumentation with either conventional K-files or PTN rotary files for effective removal of smear layer.

Conclusion:

Within the limitations of this study it was found that; Root canal instrumentation with ProTaper Next Rotary files followed by irradiation with Nd:YAG Laser showed Maximum efficiency in the removal of smear layer at all the 3 levels of root canal (coronal-third, middle-third and apical-third). Whereas root canal instrumentation with PTN rotary files without irradiation with Nd:YAG Laser and root canal instrumentation with Conventional K-files followed by irradiation with Nd:YAG Laser were least effective in the removal of smear layer at all the 3 levels of root canal with no significant difference seen between them. However, further in-vivo studies are recommended to confirm and correlate the findings of this in-vitro study to a clinical scenario.

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References:

1) Deepak Raisingani, GK Meshram. Cleanliness in the root canal system: A Scanning Electron Microscopic evaluation of manual and automated instrumentation using 4% Sodium Hypochlorite and EDTA (Glyde File Prep) – An in vitro study. International Journal of Clinical Pediatric Dentistry; 2010:3:3:173-182.

2) Norbert Gutknecht. Lasers in Endodontics. Journal of the Laser and Health Academy; 2008: 4:1:1-14.

3) B. Suresh Chandra, V. Gopikrishna. Grossman's Endodontic Practice.13th edition. Chapter 13: Shaping and cleaning of the Radicular Space: Instruments and Techniques. Wolters Kluwer Publishers (India) Pvt. Ltd, New Delhi; 2014:Page no: 287.

4) Sathe S, Vivek Hegde, Jain PA. et al. Effectiveness of Er: YAG (PIPS) and Nd: YAG activation on final irrigants for smear layer removal-SEM observation. J Dent Lasers; 2014:1:8:8-13.

5) Grasei Assis da Costa Lima, Carlos Menezes Aguiar, Andrea Cruz Camara. et al. Comparison of smear layer removal using the Nd: YAG laser, ultrasound, ProTaper universal system, and Canalbrush methods: An in vitro study. J. Endod; 2015:41:3:400-404.

6) Eick JD, Wilko RA, Anderson CH, Sorensen SE. Scanning electron microscopy of cut tooth surfaces and identification of debris by use of the electron microprobe. J Dent Res; 1970: 49:1359–1368.

7) McComb D, Smith DC. A preliminary Scanning electron microscopic study of root canals after endodontic procedures. J Endod; 1975:1:238–242.

8) Levy G. Cleaning and shaping the root canal with a Nd:YAG laser beam: A comparative study. J Endod; 1992:18;123-127.

9) Chandrasekhar P, Shetty RU, Adlakha T, Shende S. et al. A comparison of two NiTi rotary systems, ProTaper Next and Silk for root canal cleaning ability-an in vitro study. Ind J Conserv Endod; 2016:1:1:22-24.

10) Paloma-Montero-Miralles, Roberto-Estevez-Luana, Cesar-Degregorio-Gonzalez. Effectiveness of Nd: YAG Laser on the elimination of debris and smear layer. A comparative study with two different irrigation solutions: EDTA and QMix in addition to NaOCl. Journal of Clin Exp Dent; 2018;10:1:70-74.

11) Jadhav GR, Mittal P, Kulkarni A. et al. Comparative evaluation of canal cleaning ability of various rotary endodontic files in apical third: A Scanning Electron

Microscopic study. Dent Res J; 2016:13:508-514.

12) Torabinejad M, Handysides R, Khademi AA. et al. Clinical implications of the smear layer in endodontics: A review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod; 2002:94:658-666.
13. Haapasalo M, Orstavik D. In vitro infection and disinfection of dentinal tubules. Journal of Dental Research; 1987;66:1375–1379.
14. D.R. Violich, N.P. Chandler. The smear layer in endodontics – A review. International Endodontic Journal; 2010:43:2–15.
15. American Association of Endodontists (AAE). Glossary of Endodontic Terms; 2020: Page No.44. 10th Edition, Chicago. United States of America.
16. Cameron JA. The use of ultrasonics in the removal of the smear layer: A scanning electron microscope study. J Endod; 1983;9:289-292.
17. Mader CL, Baumgartner JC, Peters DD. Scanning electron microscopic investigation of the smeared layer on root canal walls. J Endod; 1984;10:477-483.
18. Sarıkahya M, Alaçam T. Preparation Ability of ProTaper Next and XP-endo Shaper Instruments in Isthmus-containing Root Canal System. Cons Dent Endod J; 2020:5:2:28–35.
19. Lopes RMV, Marins FC, Belladonna FG. et al. Untouched canal areas and debris accumulation after root canal preparation with rotary and adaptive systems. Austr Endod J; 2018:44:3:260–266.
20. Weichman JA, Johnson FM. Laser use in endodontics. A preliminary investigation. Oral Surg Oral Med Oral Pathol; 1971:31:416-420
21. Kaitsas V, Signore A, Fonzi L. et al. Effects of Nd:YAG laser irradiation on the root canal wall dentin of human teeth: A SEM study. Bull Group Int Rech Sci Stomatol Odontol; 2001;43:87-92
22. Camargo SE, Varela MC, Camargo CH. et al. Effects of Nd:YAG laser irradiation on root canal dentin wall: A scanning electron microscopic study. Photomed Laser Surg; 2005:23:399-404
23. Anic I, Segovic S, Katanec D. et al. Scanning electron microscopic study of dentin lased with argon, CO2 and Nd: YAG laser. J Endod; 1998:24:77-81.
24. Stabholz A, Sahar-Helft S, Moshonov J. et al. Lasers in endodontics. Dent Clin North Am; 2004:48:809–832.
25. Takeda FH, Harashima T, Kimura Y, Matsumoto K. A comparative study of the removal of smear layer by

three endodontic irrigants and two types of laser. Int Endod J; 1999:32:32‑39.
26. Moogi PP, Rao R Nageshwar. Cleaning and shaping the root canal with an Nd: YAG laser beam: A comparative study. J Conserv Dent; 2010:13:2:84-88
27. Ayranci LB, Arslan H, Akcay M, Capar ID, Gok T, Saygili G. Effectiveness of laser-assisted irrigation and passive ultrasonic irrigation techniques on smear layer removal in middle and apical thirds. J. Scanning; 2016:38:2:121-127.
28. Matsumoto K. Lasers in endodontics: Dent Clin N Am; 2000:44:889-906.
29. Minamisako M, Kinoshita J, Matsimoto K, Stolf D, Morques J. A study on root canal cleaning by Nd:YAG laser with black dye solution. J Oral Laser Applications; 2009:9;2:101-109.
30. Asnaashari M, Safavi N. Disinfection of contaminated canals by different laser wavelengths, while performing root canal therapy. J Lasers Med Sci; 2013;4;1:8-16.