"A COMPARATIVE EVALUATION OF STRESS DISTRIBUTION AGAINST ROOT CANAL WALL AT THREE DIFFERENT LEVELS BY USING TruNatomy, XP Endoshaper, F360 AND 2Shape FILES-A FINITE ELEMENT ANALYSIS:AN IN VITRO STUDY "

DISSERTATION

Submitted to

BABU BANARASI DAS UNIVERSITY, LUCKNOW, UTTAR PRADESH

In the partial fulfillment of the requirements for the degree

Of

MASTER OF DENTAL SURGERY

In

CONSERVATIVE DENTISTRY & ENDODONTICS

By

Dr. RIMJHIM SINGH

Under the guidance of

Dr. SANDEEP DUBEY

Reader

DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW

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BATCH: 2020-2023

Enrollment No.: 1200322006

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled **"A COMPARATIVE EVALUATION OF STRESS DISTRIBUTION AGAINST ROOT CANAL WALL AT THREE DIFFERENT LEVELS BY USING TruNatomy,XP Endoshaper,F360 AND 2Shape FILES-A FINITE ELEMENT ANALYSIS:AN IN VITRO STUDY"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. SANDEEP DUBEY,** Reader and **Dr. PALAK SINGH,** Senior lecturer as Co-Guide in Department of Conservative dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

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DEDICATED TO

MY BELOVED

PARENTS

ACKNOWLEDGEMENT

"DEDICATED TO MY PARENTS"

"Behind every young child who believes in himself is a parent who believed first."

- Matthew Jacobson.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ANCOVA	Analysis of co variance
3D	3 Dimensional
FEA	Finite element analysis
Ni-Ti	Nitinol
Ni	Nickel
Ti	Titanium
O	Oxygen
C	Carbon
Fe	Iron
EDS	Energy dispersive X-ray
SE	Scattered electrons
BSE	Back scattered electrons
A_F	Austenite finish temperature
A_S	Austenite start temperature
M_F	Martensite finish temperature
M_S	Martensite start temperature
CAD	Computer aided design
STL	Stereolithography
ANSYS	Analysis of systems

ADA	American dental association
DICOM	Digital imaging and communications in medicine
IGES	Initial graphics exchange specification

AIM: The present study was done to compare and evaluate the stress distribution against root canal wall at three different levels by using TruNatomy,XP Endoshaper,F360 AND 2Shape files by finite element analysis.

DESIGN: In vitro comparative study

MATERIALS AND METHODS:

The current study used a 3D finite model of 60 (N=15) novel rotary files from the A-TRUNATOMY, Group B-XP ENDOSHAPER, Group C-F360, and Group D- 2Shape groups to test the mechanical behaviour of each file at a different level of a simulated curved root canal. This model was then numerically analysed using ANSYS® 15 Workbench finite element software.

STATISTICAL ANALYSIS USED:

One-way ANOVA with post hoc Tukey analysis was used to compare von Mises stress between groups. The distribution and homogeneity of the variables were examined using the Shapiro-Wilk test and Levene's test, respectively.

RESULTS:

A comparison of the mean stress between the four groups at the different dentinal wall levels of the root canals found that Group C had the highest values, followed by Group A, Group D, and Group B with the lowest values. Statistics showed that the stress value difference was not statistically significant.

CONCLUSION:

Within the parameters of this study, no appreciable difference in stress generation was seen between the four different rotary file brands. It follows that advancements in rotary file design and metallurgy have the potential to lessen the strain experienced during canal shaping and the danger of instrument breakage during clinical use.

Mechanical preparation of the root canal system is one of the most important steps in root canal treatment procedure as it aids to optimize the shape of the root canal for disinfection and for attaining 3-D obturation. Therefore, for the success of endodontic procedure suitable instruments and precise instrumentation by means of biological and mechanical preparation are of utmost importance. [1]

Realizing the importance of mechanical preparation in an endodontic procedure, Edward Maynard in the year 1938 designed the first endodontic instrument preliminary made by the spring of a clock, shortly afterwards the primary endodontic instruments made up from carbon steel were designed.

Instrument made from Carbon steel were reported to be stiffer and had a hardness more than dentine but when they were used for instrumentation in curved canals, they tend to cause numerous iatrogenic errors. The most common errors were the deformation of the apical foramen, anatomical deviation of the canal and perforations and they had a major disadvantage of being highly corrosive in nature.

To overcome these problems, they were replaced by stainless steel instruments, which are in practice even at present because of the advantages they offer. These instruments are rigid in nature, and they are recognised to have superior strength, good cutting efficiency and they offer little flexibility during instrumentation in curved canals. However, despite having numerous advantages they possess a risk of producing iatrogenic errors.

For evading the risk associated with stainless steel, endodontic files made up of equiatomic NiTi alloy were introduced because of their superelastic and shape memory property. These files were manufactured by conventional NiTi alloy, comprising 56% nickel and 44% titanium. However, their composition may presently vary by manufacturer. [2]

Presently, the files fabricated with NiTi are most popular and has proved to have a revolutionary impact on the outcome of mechanical preparation of root canal, this could be due to its inherent property of super elasticity and shape memory which imparts additional elastic flexibility and resistance to torsional fracture into them but despite the advent of NiTi files with superior qualities there is still a risk of instrument fracture without any warning, during the preparation of root canals, especially in severely curved canals.[3,4,5]

Instrument separation is one of the common causes of treatment failure during endodontic management of tooth. It is a dilemma which not only lead to extreme stress for the clinician but can cause great anxiety for the patient as well. According to American association of endodontics the reported frequency rate for fractured instruments varies from 0.7% to 6% of cases.[6]

Having said that, according to the literature, residual stresses left in an instrument after usage can cause it to fracture at a variety of stress or strain levels, with or without obvious plastic deformation symptoms close to the fracture site. [7]

Clinical and metallographic forms can be used to categorize the causes of instrument separation or fracture.The clinical cause of separation includes the failure to remove coronal and cervical interference, and the metallographic causes are due to the NiTi instruments' insufficient kinetics, which results in the instruments failing either due to cyclical flexural fatigue, torsional failure, or a combination of both.

When an instrument is freely rotated inside a curved root canal, a continuous cycle of tension and compression at the instrument's greatest flexure point causes Cyclical flexural fatigue. It might be related to the excessive usage of metal alloys, or it might result from a variety of other variables like corrosion and changes brought on by thermal expansion and contraction. while torsional fracture happens when the elastic limit is surpassed, primarily because of the instrument's tip becoming locked in the canal wall and the shank rotating continuously.[8]

According to the study conducted by Cheung et al, the flexural fatigue failure was noticed to be the prevalent mechanism for the failure of instrument. [9] He later in one of his related studies found that 93% failure of endodontic file is due to flexural fatigue.[10]

There are various more contributing elements that affect the fracture of rotational NiTi files in addition to the reasons for fracture listed above (Saber 2008). [11] The geometrical design of rotary files is one such significant determinant factor because it directly affects the torsional and bending characteristics of the endodontic tool (Camps et al 1995) [7].

The literature claims that the geometry of the endodontic instrument, such as its cross section and taper, as well as the geometry of curved canals, such as the radius length, arc length, and position of the arc, determine the magnitude of tensile stress and compressive stress acting on the instrument [12]. Various studies have been done till now to numerically analyze the stress on the instrument against root canal and their impact on the clinical performance and durability of the instrument.

Change in design of rotary file imparts an additional property of super elasticity and strength into them. As, it influences the flexibility, cutting efficiency and safety of the instrument.[13]

Raw materials, design, and manufacturing method, according to Shen et al. (2016); Gavini et al. (2018), can significantly affect instrument fracture. So, manufacturers are creating new instruments with enhanced metallurgy and designs to meet the need for endodontic tools with improved mechanical qualities that will function more effectively and safely.[7]

Recently, there has been considerable development in the endodontic instruments, which has resulted in better root canal instruments with the increased success of the endodontic treatment.

Knowing the properties of files marketed is especially important in helping to choose an appropriate file system. Some of the recently marketed files with improved mechanical properties are as follows-

With the F360 file system, which was created from traditional, Super elastic NiTi alloy, only two files are needed to clean and shape the canal system. This tool's narrow core and double-S-shaped thin cross section enable highly fine cutting efficiency, flexibility, and canal transportation minimization [14].

A new generation file system called XP Endoshaper (FkG Dentaire Sa, La Chaux-De-Fonds, Switzerland) was just introduced because of manufacturers' ongoing improvements in metallurgy and design. This file, which features a snake-like design and exclusive max wire technology, has an initial taper of 0.01 in its M phase while it is cool. According to the molecular memory of the austenitic phase, the taper changes to 0.04 when exposed to body temperature (35°c). Due to their special qualities, these files reduce the possibility of dentin microcracks, are easily adaptable to canal imperfections, and have an exceptional resistance to cycle fatigue[15].

Another recently released file system is called TruNatomy (TN; Dentsply Sirona, Maillefer, Ballaigues, Switzerland). It is made of 0.8 mm NiTi wire rather of the 1.2 mm NiTi wire used to make most generic files, and it too has an off-centered parallelogram cross-sectional design. It consists of four shape files: prime (.04), small (.04), and medium (.03) in size. The company claims that TruNatomy has a lower chance of separation because of its enhanced flexibility and tolerance to cycle fatigue [16].

Similar to this, MicroMega's 2Shape (Besancon, France) recently released a rotational file system that comprises of two files, TS1 (25/.04) and TS2 (25/.06). They are created from T-Wire technology after grinding a NiTi alloy, and have a cross-section with a triple helix, two main cutting edges for cutting efficiency, and one secondary edge for increased debris removal [17]. It has been demonstrated that these files are more flexible and resistant to cycle fatigue and a low elastic modulus when compared to traditional instruments [18].

Till date, there have been few studies to assess the role of design and metallurgy of Ni-Ti rotary instruments and their part in developing stress on the instrument when subjected to rotational-bending force while instrumentation.

Finite element analysis has proved to be a beneficial method for calculating the amount of stress generated by complex structures. In endodontics, Finite element analysis is an efficacious tool in assessing the stress generated in endodontic files to understand fatigue development and performance of these files subjected to bending force inside root canals. It is a technique of discretizing a continuum into simple geometric shapes called elements, enforcing material properties and governing relationships on these elements, giving due consideration to loading and boundary conditions that results in a set of equations, and obtaining their solution to arrive at an approximate behavior of the continuum.[20]

With emerging technology, there is a plethora of different endodontic file systems made available by manufacturers with improved mechanical properties, however, they still possess a risk of fracture.

Therefore, the aim of this study is to compare the lateral forces exerted by tested novel NiTi endodontic files under simulated root canal shaping by using a 3-dimensional (3D) finite-element (FE) analysis.

AIM:

The aim of the present study is to evaluate and compare the stress generated by novel Ni-Ti rotary files against root canal wall at three different levels by finite element method.

OBJECTIVES:

1. To evaluate the lateral forces generated by Trunatomy files against apical, middle, and coronal level of root canal wall by finite element method.
2. To evaluate the lateral forces generated by XP Endo shaper files against apical, middle, and coronal level of root canal wall by finite element method.
3. To evaluate the lateral forces generated by F360 files against apical, middle, and coronal level of root canal wall by finite element method.
4. To evaluate the lateral forces generated by 2shape files against apical, middle, and coronal level of root canal wall by finite element method.
5. To compare the lateral forces generated by novel Ni-Ti files against apical, middle, and coronal level of root canal wall by finite element.

A structured review of scientific publications in English literature related to the dissertation topic **"COMPARATIVE EVALUATION OF STRESS DISTRIBUTION AGAINST ROOT CANAL WALL AT THREE DIFFERENT LEVELS BY USING TruNatomy,XP Endoshaper,F360 AND 2Shape FILES-A FINITE ELEMENT ANALYSIS:AN IN VITRO STUDY" WAS DONE.**

Turpin Y L, Chagneau F, Vulcain J M (2000)[21]Conducted a comparative study to evaluate the amount of torsional and bending stresses in triple helix and triple U models of NiTi instruments by boundary integral method. They found that both instruments generated different torsional stresses, together in terms of intensity and distribution. After mathematical computations they suggested that triple helix and triple U and instruments should be used for unlike operating procedures.

G, Kuhn, Tavernier et al (2001)[22] investigated the influence of Different thermal treatments and geometrical shapes on the fracture life of ProFile and Hero through scanning electron microscopy, X-ray diffraction and microhardness tests they concluded that the curvature of canals distorts the endodontic instruments during clinical conditions by recurrent tensile-compressive stress and the maximum of this stress was generated in the surface of the curve.

Parashos, P, Gordon, I et al(2004)[23] Evaluated the factors that might influence defects in endodontic nickel titanium rotary files. They examined total 7159 instruments obtained by 14 endodontists across 4 countries, including utilized and discarded instruments. Upon examination they observed that fracture occurred in 5% (1.5% torsional, 3.5% flexural) and Unwinding occurred in 12% of endodontic instruments. They stated that the design factor affects the defect rate.

Sathorn C, Joseph E A Palamara et al(2005)[24]Conducted a study to determine the extent to which canal size, radius of curvature and proximal root concavity influence fracture susceptibility and pattern by creating finite element analysis (FEA) model of mandibular incisor. They observed that the removal of dentin did not always result in increased fracture susceptibility.

Rundquist BD, Versluis A(2006)[25] constructed three FEA models of a root filled premolar tooth of variable tapers to calculate the stress distribution in the root during the occlusal loading and filling. He observed that the stress on root was decreased as the canal taper increased, maximum stress was generated at the apex and along the canal wall and after root filling, the stress at the cervical portion of the root surface was more and increases slightly as taper increases. They concluded that vertical root fractures initiated at the apex are a result of filling forces, whereas vertical root fractures initiated cervically are a manifestation of subsequent masticatory events on the root filled tooth.

Xu X, Eng M, Zheng Y, Eng D (2006) [26] Investigated the influence of cross-section profile on the mechanical behaviors ProTaper, Hero642, Mtwo, ProFile, Quantec, and NiTiflex by using methamatical method and they observed that The ProTaper and Hero642 models showed least generation of stress compared to NiTiflex model with maximum generation of stress. They concluded that the stress dissemination was noticed to be greatly predisposed by the cross-section profile, area of the inner core, depth of the flute, peripheral surface ground and radial land.

Subramaniam V, Indira R, Srinivasan M R et al 2007 [27] Conducted a finite element analysis study to compare the stress distribution and behaviour of profile and Protaper by applying a concentrated torsional and bending moment under equal loads, They observed Protaper model demonstrated uniform stress distribution and less elasticity compared to profile model.

Kim HC, Cheung GS, Lee CJ, Kim BM, Park J K, Kang S I et al (2008) [28]compared the amount of residual stress generated by the 3D finite model ProFile, ProTaper, and ProTaper Universal while instrumenting the simulated root canal after scanning it with Micro–computed tomography. They observed that the maximum residual stress was produced by ProTaper file in the apical direction along with the highest reaction torque from the root canal wall followed by ProTaper Universal and ProFile.

Necchi S, Taschieri S, Petrini L, Migliavacca F.(2008)[29] Observed mechanical behaviour of the 3D finite model of Ni-Ti ProTaper F1 during its interaction with differently shaped root canals during the insertion using ad hoc computational subroutine. They concluded that the location of the canal curvature and the radius are the crucial considerations for determining the stress in the instrument, more stress levels being generated by diminishing the radius and shifting from the apical to the mid root position.

Kim, T O, Cheung, Lee JM, Kim BM, Hur B, Kim HC. (**2009)** [30]Compared behaviour of ProFile,ProTaper and ProTaper Universal finite models under bending and torsional force and they observed that the flexibility of profile was more followed by Protaper Universal and Protaper.(10)

Kim HC, Kim HJ, Lee CJ, Kim BM, Park JK, Versluis A.(2009) [31]Evaluated the effect of stress distribution by different cross-sectional designs i.e.ProFile and HeroShaper systems with a common triangle-based cross section, Mtwo with an S-shaped rectangle-based design and NRT with a modified rectangle-based design in nickel-titanium (NiTi) instruments during bending, torsion and simulated shaping of a curved canal using finite element method and they concluded that endodontic instruments with rectangle-based cross-sectional designs produced more stress variances throughout virtual shaping of root canal and might face more remaining stress and plastic deformation compared to trianglular cross sections.(11)

He R, Ni J (2010)[32] evaluated the impact of geometric designs (helix angle, taper, and flute length) on the mechanical performance of V-Taper file through numerical simulations under bending and torsional loads. They concluded that the torsional stiffness increases with increasing taper or decreasing flute length, accompanied by a decrease in bending flexibility.

Zhang EW, Cheung GS, Zheng YF(2010)[33] conducted a study to evaluate the impact of the cross-sectional design i.e., square, triangular, U-type, S-type (large and small), convex-triangle, and 4 proprietary ones (Mani NRT and RT2, Quantec, and Mtwo) and measurements (size and taper) on the torsional and bending behaviour of endodontic instrument by considering the nonlinear mechanical properties of material using finite element method. They concluded that the cross-sectional design has more influence on the stress generation than taper or size of the instrument and are prone to fracture under either torsion or bending.

Lee MH, Versluis A, Kim BM, Lee CJ, Hur B, Kim HC. **(2011)**[34] Examined the cyclic fatigue resistance of 3D finite models of ProTaper, ProFile, HeroShaper, and Mtwo under different curvature of root canal. He observed that the maximum stress generation and the minimum cyclic fatigue was demonstrated by ProTaper (stiffer instrument), whereas Mtwo presented the maximum cyclic fatigue resistance. They concluded that with the Increase in the curvature of root canal, stress generation also increases.

Gao Y, Cheung GSP, Shen Yet al(2011)[35] evaluated and compared the stresses and strain distribution patterns inProTaper Universal F2 files under various conditions i.e. by constraining it to a curve of varying degree, curve length, and position by using a dynamic, three dimensional finite element model. They observed that a long curvature length generated lower values of stress and strain under the same angle of curvature, and they concluded that with an increase in the curvature angle the value of stress and strain also increases and for the same degree and curve length, the stress and strain increased if the curved portion was situated further up the shaft of the instrument (15)

Wycoff R C, Berzins D W(2012)[36] compared the torsional stress of EndoSequence , ProFile Vortex and Twisted Files with a similar cross-section by means of a scanning electron microscope and concluded that the twisted files showed highest angle of rotation with greater amount of torsional stress and they concluded that the innovative techniques used in manufacturing endodontic files do not make them additional resistant to torsional stress as compared with traditionally manufactured NiTi files of alike cross-sectional design.(16)

Versluis A, Kim H C , Lee W C (2012)[37]evaluated the role of pitch and cross-sectional design on flexural stiffness and stress generation. By preparing a Finite element model of rotary instruments with 4 cross-sectional geometries (triangle, slender-rectangle, rectangle, square) and 3 pitches (5- ,10-, 15-threads), featuring super elastic nickel-titanium properties. Stiffness and maximum stress decreased with decreasing pitch (increasing threads). Doubling or tripling the threads for the triangular or rectangular cross sections lessened the stiffness and stress 6% and 12%, respectively; square cross sections were less affected (1% and3% decrease, respectively), They found that flexural stiffness and stress correlated with centre-core area under the simulating canal curvature. Increasing the value of pitch will increase the flexural stiffness and stresses.(17)

Santos L D A,Lopez J B,Bahia M G D A., Casas E B D L, & Buono, V T L. (2013)[38] Compared the mechanical behavior of controlled memory file and super elastic NiTi files by finite element analysis. The controlled memory NITi showed highest degree of stress and least bending moment with least torsional stiffness leading to higher distortions when compared with the super elastic NiTi. CM NiTi manifested higher flexibility and potential fatigue resistance.(18)

Kim H C, Sung S Y, Ha J H, Solomonov M, Lee J M, Lee C J et al(2013)[39] compared the 3D finite models of Self Adjusting files, Profile and Protaper Universal F1 to evaluate stress generated in simulated curved root canal and they observed that the stress generated by self-adjusting file was minimum in apical portion root dentin, without dentinal defect and apical root cracking.(19)

Pujari H(2013 [40]evaluated and compared Twisted File with ProTaper to check the amount of stress distribution under bending or torsional conditions by creating a 3 D finite model and scanning the instruments using White light scanning system and they concluded that Twisted File produced more angular deflection and more flexibility but they didn't produce uniform stress compared to ProTaper Universal.(20)

Medha A, Patil S,Hoshing, Bandekar S. (2014)[41] evaluated the distribution of forces on the instrument in the apical 3rd of curved canal with (ProTaper Universal; DENTSPLY Maillefer), Revo S (Micro Mega) and Hyflex (Coltene Whaledent, Allstetten, Switzerland) by preparing finite model. They found that the RevoS files showed lowest values for force generation in the apical 3rd of canal as compared to Protaper which showed highest values, while Hyflex showed intermediate values for forces generated. They stated that different instrument designs would experience unequal degree of force generation in canal, as well as reaction torque from the root canal wall.(21)

Motharkar S, Batwe P, Khapre R (2014)[42]studied flexibility of Heroshaper, ProTaper and Mtwo endodontic file segments when subjected to torsion and bending loads and to identify most flexible cross section using finite element method. Based on the result obtained from finite element analysis, it was concluded by researchers that the Mtwo file model is most flexible as compared to Heroshaper and ProTaper file model.(22)

Mutlu, Bilcen, Kurt Mutlu B ,Kurt M ,Ekici , Atakok G. **(2014)**[43] evaluated the amount of stress generated by 3d finite model of ProTaper and HeroShaper on simulated curved root canal and observed that the concentration of stress of the ProTaper file system was more in the apical portion i.e. along the outer aspect of curvature and it was found to be maximum in the middle of root canal for the HeroShaper files.(23)

Diogo M,Francisca S A,Francisco M B F, Sancho D V C(2014)[44] evaluated and compared the mechanical flexibility of a Profile GT (conventional NiTi)and a Profile GT Series X (M wire alloy) with similar geometry, at body temperature through X-Ray Diffraction and Differential Scanning Calorimetry and by using finite element method and they concluded that flexibility of an instrument made up with M-Wire was more than conventional alloy due to the presence of R-phase at body temperature.(24)

Ibrahim A, Ashry S H E, Saber S M, Zaki D,Nassef T M, Ezzat M (2016)[45] evaluated and compared the mechanical behaviour of WaveOne, ProTaper and Twisted File during bending, torsion and instrumentation motions by means of Finite element analysis through Stereomicroscope and computed tomography (C.T) and they concluded that in bending conditions the maximum stress was generated by twisted file value followed by WaveOne primary file and Protaper F2 file and the maximum stress was generated by twisted files during torsion followed by Protaper F2 file and WaveOne primary file and during of continuous rotation motion, the maximum stress was produced by Twisted file size 25. Taper 8% followed by waveOne primary file and Protaper F2 file. (25)

Eken R, Sen O G, Eskitascioglu G, Belli S (2016)[46] evaluated the effects of rotary systems on stresses in photo polymerized resin root models of mandibular second premolar tooth with oval-shaped canals. Root canals were prepared by OneShape (OS; MicroMega, Besancon,France); ProTaper Universal (PTU; Dentsply Tulsa Dental,Tulsa, OK); WaveOne (WO, Dentsply Maillefer, Ballaigues, Switzerland); Mtwo (MT; VDW, Munich, Germany);Twisted File (TF; Kerr Dental, Orange, CA);ProTaper Next (PTN, Dentsply Tulsa Dental), and hand files (HFs) (control). The models were scanned with micro–computed tomographic imaging, and finite element analysis was performed. The maximum stress values were found to be higher when the roots were loaded at an angle. The range of the stress values was ProTaper Universal > Mtwo > WaveOne > hand files > ProTaper Next > OneShape > Twisted File. They observed that the stress was directed more towards the apical area in the ProTaper Next, OneShape, and Twisted File models. They also concluded that oval-shaped canals prepared by hand files and Waveone were less likely to result in root fracture.(26)

Ahamed B ,Bughari S, Vanajassun P P, Rajkumar K, Mahalaxmi S (2018) [47] **e**valuated the stress distribution in experimentally designed rotary files using 2 new experimental of Convex triangle, Triangle, Triple U (CTU)design and Triple U, Triangle and Convex triangle (UTC)and 3 theoretical single files with combination of triple U(TU) ,convex triangle(TC) and triangle(TR) by using a finite element analysis and the researchers concluded that the UTC and TC generated higher stress at apical area whereas CTU showed least bending stress generation on the file.(27)

Garcia E S V, Vieira V T L, Petitet N P D S F, Moreira E J L, Lopes H P, Elias C N Silva E J N L, Antunes H D S. (2018)[48] conducted a study to evaluate the mechanical properties of XP-Endo Finisher and XP-Clean files by using SEM method and they concluded that XP-Endo Finisher instruments demonstrated higher cyclic fatigue resistance and lower roughness than XP clean instrument.

Silva E J N L, Vieira VTL, Belladonna FG, Zuolo AS, Antunes HDS, Cavalcante DM et al(2018)[49] They evaluated the cyclic and torsional fatigue resistance of the XP-endo Shaper files and TRUShape instruments and they concluded that the XP-endo Shaper instruments showed more cyclic fatigue resistance and angle of rotation to fracture but lesser torque to failure than TRUShape instruments.

Staffoli S., Grande N , Plotino G, Özyürek T, Gündoğar M, Fortunato L, Polimeni A (2018) [50] evaluated the influence of environmental temperature, heat-treatment and design of One Shape , OneShape new generationand One Curve NiTi rotary single-file instruments at 3 unlike temperatures of 0°, 20° and 35 °C for cyclic fatigue. They concluded that the fatigue resistance of the files increases with the decrease in environmental temperature. One Curve files showed to be more resistant to cyclic fatigue than OneShape new generation and OneShape instruments at the tested temperatures of 0°, 20° and 35 °C .

Elnaghy A, Elsaka S (2018) [51] evaluated and compared the cyclic fatigue resistance of TRUShape, XP-endo Shaper, Vortex Blue ,HyFlex CM, and iRace nickel-titanium rotary endodontic instruments at body temperature and concluded that XPS exhibited greater cyclic fatigue resistance compared with the other tested files and therefore it can be used more safely in curved canals.

Sezgin, Pelin G, Gündoğar,Mustafa (2019)[52] evaluated the torsional resistance of One Shape, WaveOne Primary and Reciproc files using scanning electron microscope and observed that the Reciproc instruments exhibited the highest torsional resistance followed by WaveOne files and One Shape group. On the other hand, One Shape file demonstrated significantly greater angular rotation to fracture than Reciproc and WaveOne files.

Galal M (2019)[53] demonstrated the mechanical behaviour of controlled memory (CM), M-wire, NiTi alloy and R-phase files under bending and torsion conditions by using finite element method. They stated that the maximum stress was generated by NiTi alloy followed by M wire then CM and least amount of stress was generated by R phase.

Singh S, Abdul M S M, Sharma U, Sainudeen S, Jain C, Kalliath JT (2019)[54]comparatively evaluated the shaping ability of 2Shape , WaveOne Gold, and ProTaper Gold by using cone-beam computed tomography (CBCT)in extracted mandibular teeth and Author's concluded that Both WaveOne Gold and 2Shape preserved the original canal anatomy better and did not eliminate excess dentin while chemo mechanical preparation as compared to ProTaper Gold. They both performed better clinically for shaping root canal.

Alkahtany S, Alrumaih S, Alhassan M,Alnashmi, B, Ebtissam A (2020)[55] evaluated and compared the shaping ability of the XPEndoshaper file to that of the ProTaper Universal (PTU) file by micro-computed tomography (micro-CT) for measuring the cross-sectional area variation of the canal and canal transportation in all directions and they found that XPEndoshaper files caused less canal transportation than the Protaper universal.

Galal M and Hamdy T M(2020)[7] evaluated the impact of cross-sectional geometry i.e. Triangle, convex triangular, parallelogram, and rectangle, pitch of 5, 10, and 15 threads, taper of 0.04 and 0.06, and off-centred cross-section on the stress distribution in NiTi instruments under bending and torsion conditions using finite element analysis (FEA).They stated that no single geometrical design could be advantageous for all stress conditions. They also concluded that for curved root canals rectangle cross-section configuration, low pitch, reduced taper, and with centered cross section is beneficial and for narrow canals, the files designed with parallelogram cross-sectional, low pitch, increased taper, and eccentric cross-section design are suitable.

Alfadley A, Alrajhi, A, Alissa H, Alzeghaibi, F, Hamadah L, Alfouzan K, Jamleh, A (2020)[56] conducted a study to evaluate and compare the shaping ability of XPEndoshaper and waveone gold file and found that XP Endo Shaper and Waveone gold files can be used in shaping severely curved canals. They also stated that WaveOne gold file showed lesser deformation than XPEndoshaper files.

Riyahi A M, Bashiri A,Alshahrani K , Alshahrani S, Alamri HM, Al S D(2020)[57] conducted a study to evaluate and compare the cyclic fatigue resistance of TruNatomy files with Twisted Files and ProTaper Next and they observed that TruNatomy file showed superior cyclic fatigue resistance .Author's stated that the reason behind the less cyclic fatigue of TruNatomy is due to its offcentered parallelogram, thermomechanical processing and due to its thin NiTi wire (0.8 mm).

Jamleh A**, Alfadley A, Alghofaili N, Jamleh H, Al F K (2020)**[58] demonstrated the amount of force and torque developed by the XP Shaper and OneCurve while shaping of narrow root canals. It was demonstrated that lower vertical force and torque value was generated by XP Shaper system compared to the OneCurve system during shaping of narrow canals.(39)

Gündoğar M, Uslu G, Özyürek , Plotino G (2020) [59] **c**onducted a study to examine the cyclic fatigue resistance of TruNatomy, 2Shape, HyFlex CM and VDW.ROTATE endodontic rotary files at body temperature(37°C) inside the artificial canals of stainless steel. They stated that VDW.ROTATE showed maximum resistance to cyclic fatigue followed by HyFlex CM, 2Shape, and TruNatomy.

Casanova V R, Macho A Z, Marin F Z , Ezpeleta Ó A ,Martínez A A & Catalán A G (2021) [60] evaluated the amount of stress generation by a computer generated endodontic rotary file of 25 mm length, 0.25 mm at the tip, 1.20 mm at 16 mm from the tip, 2 mm pitch and squared cross section using finite element analysis under bending and torsional conditions. They concluded that the automated procedure is an accurate method to describe the geometry of the endodontic file to be obtained based on its design parameters as well as a finite element model of the endodontic file from the formerly generated geometry.

Prati C,Tribst J P M ,Piva A D ,Borges A L S ,Ventre M. Zamparini F et al (2021)[61] calculated the amount of stress generated in the root dentine canal during mechanical rotation of five different NiTi endodontic instruments by making 3D finite model by using F360, F6 Skytaper (conventional alloy NiTi)NiTI Hyflex,, Protaper Next and One Curve files(heat treated alloys).They found that conventional Ni-Ti endodontic instruments demonstrated higher stress whereas heat-treated endodontic instruments with higher flexibility values showed a reduced stress.

Elkholy M M A, Nawar N N, Ha W N, Saber SM, Kim HC et al (2021)[62] conducted a study for evaluating the life span of endodontically treated teeth by using 4 % ,6% tapers and access cavity designs on the life span of endodontically treated mandibular first molars constant taper or variable taper equivalent to the cumulative canal preparation shapes of TruNatomy Prime (Dentsply Sirona, Charlotte, NC) and ProTaper Gold F2 (Dentsply Sirona) and access cavity designs (traditional, conservative, and truss)by means of the finite element method., conservative, and truss). They stated that the traditional access models demonstrated an inferior life span than the conservative and truss models regardless of the tape of canal and the stress patterns drifted apically rather than concentrated in the peri cervical area.

Raouf A,Ali M, Elzahar S ,Hassan R (2021)[63] conducted a study using XP EndoShaper file, Hyflex EDM and TRUShape file to check for the shaping ability using CBCT and found that there was no statistical difference regarding the amount of canal transportation, and they concluded that these file systems can be securely used for the instrumentation of curved root canals.

Johnson J , Abd E H. , Elsewify T, El S W, Eid B (2022)[64] examined the amount of microcrack formed after shaping the root canals by evaluation of microcrack formation following shaping of premolars using XP Endo Shaper, TruNatomy and ProTaper using stereomicroscope at 50X magnification. They concluded that XPEndoShaper file produced 26.7% of cracks, followed by the ProTaper Gold - 15.6% and the least percentage of cracks 7.8% was shown by TruNatomy files.

Casanova R V, González P A, Macho Z A, Matoses F V-(2022)[65] conducted a study to examine the influence of pitch and cross-section upon the mechanical behaviour of Nickel Titanium endodontic rotary files by designing a set of total eight 3D finite models of rotary files, obtained from combinations of square and triangular cross sections and four pitches. They concluded that endodontic files with a square cross-section have double the stiffness of those with triangular cross-sections, both in terms of bending and torsion. Moreover, under equivalent boundary conditions, endodontic files with triangular cross-sections and a small pitch presented a higher fatigue life than those with square cross-sections in order to minimize ledging and maximize fatigue life.

ARMAMENTARIUM

Materials and Equipment's used in the study with specifications and Company.

- Trunatomy files (26 no 4 %) ;(Dentsply Sirona, Maillefer, Ballaigues, Switzerland)
- XP-Endo Shaper files (30 no 4%) ;(FKG Dentaire SA, La Chaux-de-Fonds, Switzerland)
- F360 files (25 no 4 %) ;(Komet, Brasseler GmbH & Co., Lemgo, Germany)
- 2shape files (25 no 4%); (Micro Mega, Besancon, France)
- High resolution scanning electron microscope (CARL ZEISS Microscopy Ltd EVO-SEM MA15/18)
- Laptop ,1TB (HP PAVILION Aero 13)
- Diamond paste (Index diamond lapping paste; Index industrial experts)
- Bench vise (PAHAL 100 mm cast iron bench vice)
- Hand plier

List of programmes and software used and their explanations-

1. **DICOM (Digital Imaging and Communications in Medicine)-**

Medical imaging information handling, archiving, printing, and transmission are all standardised by the DICOM protocol. It includes a definition of a file format and a protocol for network communications. The National Electrical Manufacturers Association is the legal owner of this standard's copyright (NEMA). DICOM has been generally embraced by hospitals and is advancing in more niche applications like dental and medical offices. The Visible Light Supplement to the DICOM Standard was authorised by the American Dental Association (ADA) in 1999 and applies to video, endoscopic, and microscopic images used in dentistry and dental specialties. In addition to being useful for guided endodontics and implant placement, DICOM is also useful for intraoral cameras, panoramic radiography, cephalometric radiography, tomography, skull and sinus radiography, and microscopy (surgical and histologic)[66].

2. **STL (Stereolithography)-**

A native file format for 3D Systems' stereolithography CAD programme is called STL. Backronyms for STL include "Standard Triangle Language" and "Standard Tessellation Language," among others. Rapid prototyping, 3D printing, and computer-aided manufacturing all make heavy use of it. The surface geometry of three-dimensional objects is all that is described in STL files; colour, texture, and other typical CAD model properties are not included. Dental guidelines made from 3D printed STL files are useful. Those are CAD/CAM manufactured Static Navigation (SN) stents. Stents help in Dynamic Navigation by guiding the preparation of the access cavity and micro-surgical orientation, preventing the need to remove extra tooth and bone structure. Real-time feedback improves accuracy, which lessens the access's complex effects of access cavity preparation of calcified canals, retreatments, and microsurgical procedures and helpful for placement of implant.[67,68]

3. **IGES (Initial Graphics Exchange Specification)**

IGES is a file format that is independent of vendors and enables the digital transfer of data between computer-aided design (CAD) systems. A CAD user can communicate product data models in the form of wireframe, freeform surface, or solid modelling representations, circuit diagrams, or wireframes using IGES. Traditional engineering drawings, models for analysis, and other production tasks are among the applications provided by IGES. Finite element study on rotational files, posts, implants, and restorations requires the conversion of STL files to IGES to analyse the images in the ANSYS software.[68,69]

4. **SOLIDWORKS 2013 VERSION (SOFTWARE)-**

Dassault Systèmes' SolidWorks is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) application. Models and assemblies are created using a parametric feature-based methodology. Engineers in the fields of mechanical, electrical, and electronics can use the software to create designs in both 2D and 3D. All engineers should be able to respond to changes in design requirements thanks to the suite of tools. This software is necessary for creating a 3D finite model of a complex dental structure (such as a tooth model or rotational files) so that it may be analysed[70].

5. **ANSYS WORKBENCH 15.0(SOFTWARE)-**

An American company called ANSYS (Analysis of Systems) creates computer-aided engineering software. Its headquarters are in Pennsylvania, just south of Pittsburgh. Software for finite element analysis, structural analysis, computational fluid dynamics, explicit and implicit methods, and heat transfer are all included[71].

Place of the study where it is conducted.

The present in vitro study was conducted in the Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, Lucknow in collaboration with Institute of information technology, Banaras Hindu University, Varanasi.

Study subjects

For the present study four different novel rotary NiTi rotary systems fabricated by different manufacturers were selected following the inclusion and exclusion criteria.

Study Sample and size

The GPower software (version 3.0) was used to estimate the sample size for a one-way ANOVA. It was determined that a minimal sample size of 53 was adequate for an alpha of 0.05, power of 95%, and effect size of 0.05. 60 was the final rounded-off sample size, or 15 in each group.

F tests - ANCOVA: Fixed effects, main effects, and interactions

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.75
	α err prob	=	0.05
	Power (1-β err prob)	=	0.95
	Numerator df	=	10
	Number of groups	=	4
	Number of covariates	=	1
Output:	Non-centrality parameter λ	=	29.8125000

Critical F	=	2.0345950
Denominator df	=	48
Total sample size	=	53
Actual power	=	0.9539737

Eligibility Criteria:

Inclusion criteria

- Unused Endodontic files having fixed taper
- Endodontic files with different metallurgy

Exclusion Criteria

- Endodontic files with any micro cracks and surface irregularities.

Sampling Method

Convenience sampling

Study was conducted on selected brand of NiTi rotary files in the Department of Conservative dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, Lucknow.

SPECIMEN PREPARATION

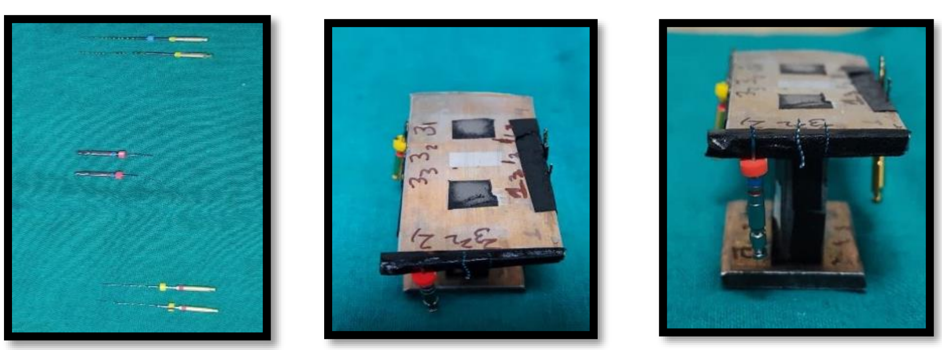
In the present study total 60 samples of four brands of NiTi instruments having a taper of 4 % were selected i.e., Trunatomy(26 no 4 %) ;(Dentsply Sirona, Maillefer, Ballaigues, Switzerland). XP-Endo Shaper (30 no 4 %) (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), F360(25 no 4 %); (Komet, Brasseler GmbH & Co., Lemgo, Germany) and 2shape (25 no 4 %); (Micro Mega, Besancon, France) were selected based on the inclusion criteria.

These novel NiTi files were cleaned with 70%w/v ethanol before starting the sample preparation to ensure no external polish or coating is present on the surface and to make the surface free from contamination. After cleaning these files with ethanol, the working surface of these files were marked at three equal parts with the help of marking pen as per the geometry to obtain the required Scanning electron microscope specimens.

Before undergoing the scanning of Xp endoshaper file, it was immersed in a distilled water customary at a temperature of 35 degree Celsius, this was done to simulate its clinical performance at a body temperature. It has a unique property to expand from 1% taper to attain a taper of 4 % when placed inside a canal in a clinical scenario. According to the guidelines of public safety standards of the republic of India under the division name of mechanical engineering and section name of powder metallurgical material and products (MTD25) the density of XPEndoshaper file was determined by IS:5642-1991 or ISO2738 at the simulated body temperature. (fig 2)

Marking was done on the working surface of file for obtaining surface properties i.e., Microcrack or surface irregularities at each dimension of the file. Later, files were clamped on bench vise made up of cast iron to hold the file without displacement and to break the file at the marked areas one by one with sudden impact through hand plier with up and down movement. Broken parts were collected, and their ends were straightened (fig 1). Then, sample's surfaces were gold coated before putting them into SEM chamber for better fractography results at the broken edges.

SEM (CARL ZEISS Microscopy Ltd EVO-SEM MA15/18) investigations were done in both scattered electrons (SEs) and backscattered electrons (BSEs) modes at a magnification of 250x,500x and 2500x (Fig 3) under high resolution. Likewise, few areas were exposed to energy-dispersive X-ray spectroscopy (EDS)analysis (fig 4) for elemental characterizations to check for the surface irregularities and the presence of microcrack. The real size images of these novel NiTi files were obtained in three dimensions and after that the files were scanned using Exocad software.



A B C

Fig 1-All the novel tested files (A) were broken and (B)clamped on SEM metal stub.

Fig 2 – A **The density of** B **Xp Endoshaper** C **(A)was determined**

at a D **temperature of** E **35 degrees using** F **PH meter(C). and dry weight of sample (B) and weight of the sample in distilled water (D,E,F) was determined using analogue balance.**

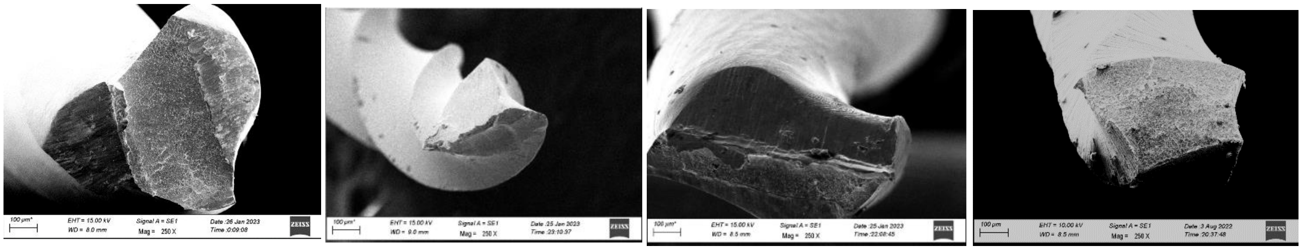


Fig 3.1 SEM images of all four samples at a magnification of 250X

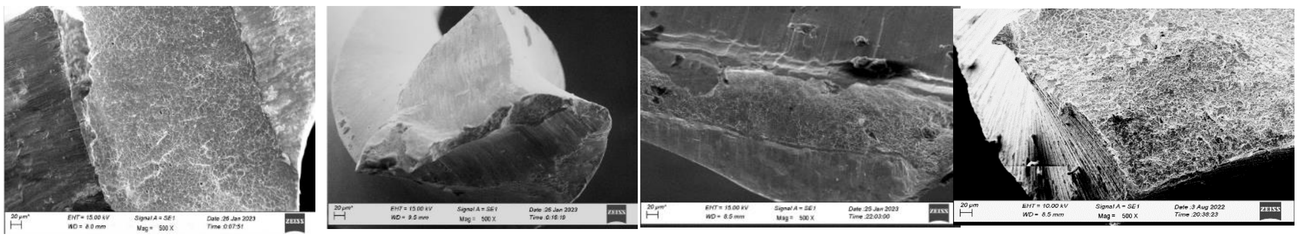


Fig 3.2 SEM images of all four samples at a magnification of 500X

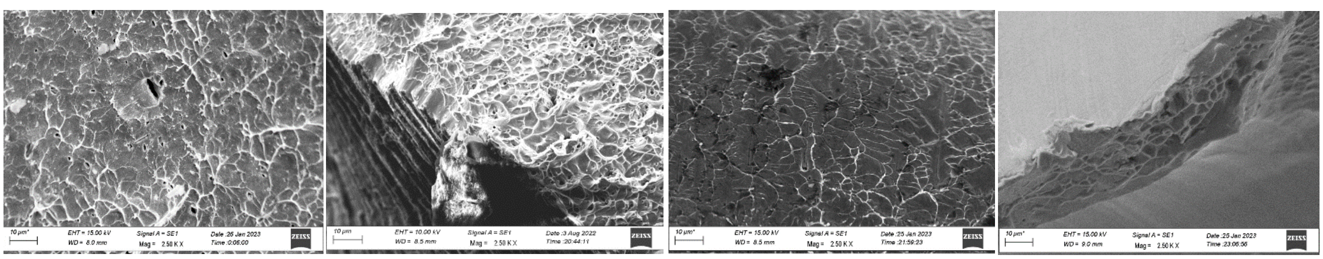
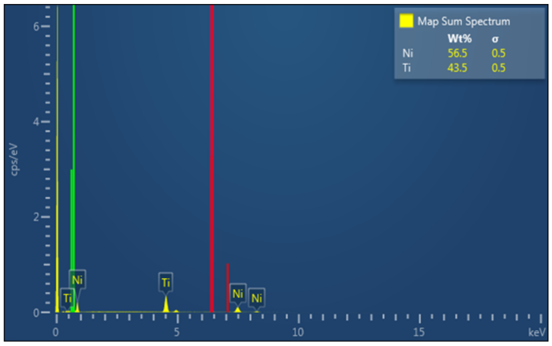
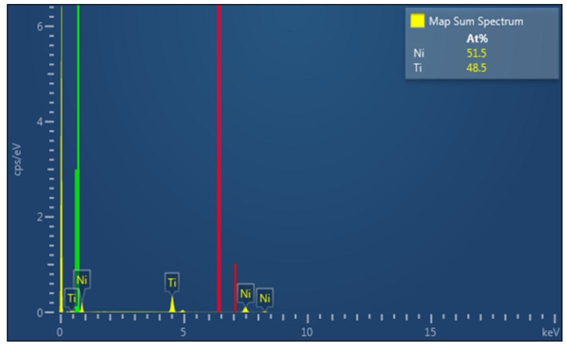


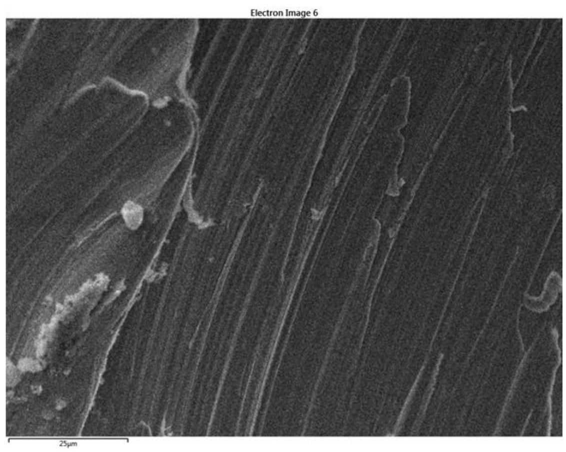
Fig 3.3 SEM images of all four tested files at a magnification of 2500 X


Map Sum Spectrum
Wt% σ
Ni 56.5 0.5
Ti 43.5 0.5
cps/eV
keV
Ni
Ti

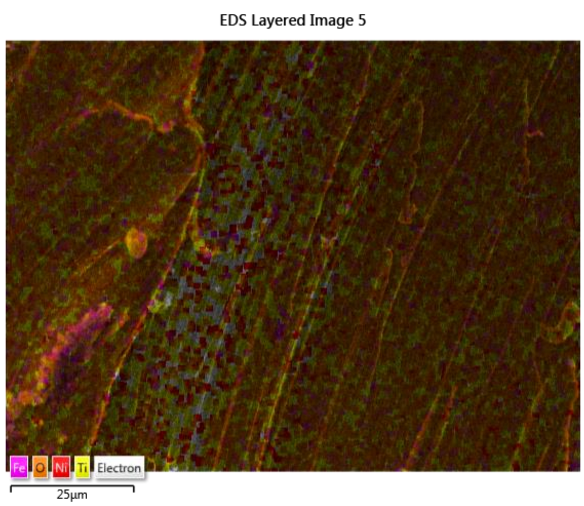
A


Map Sum Spectrum
At%
Ni 51.5
Ti 48.5
cps/eV
keV
Ni
Ti

B


Electron Image 6
25μm

C


EDS Layered Image 5
Fe
O
Ni
Ti
Electron
25μm

D

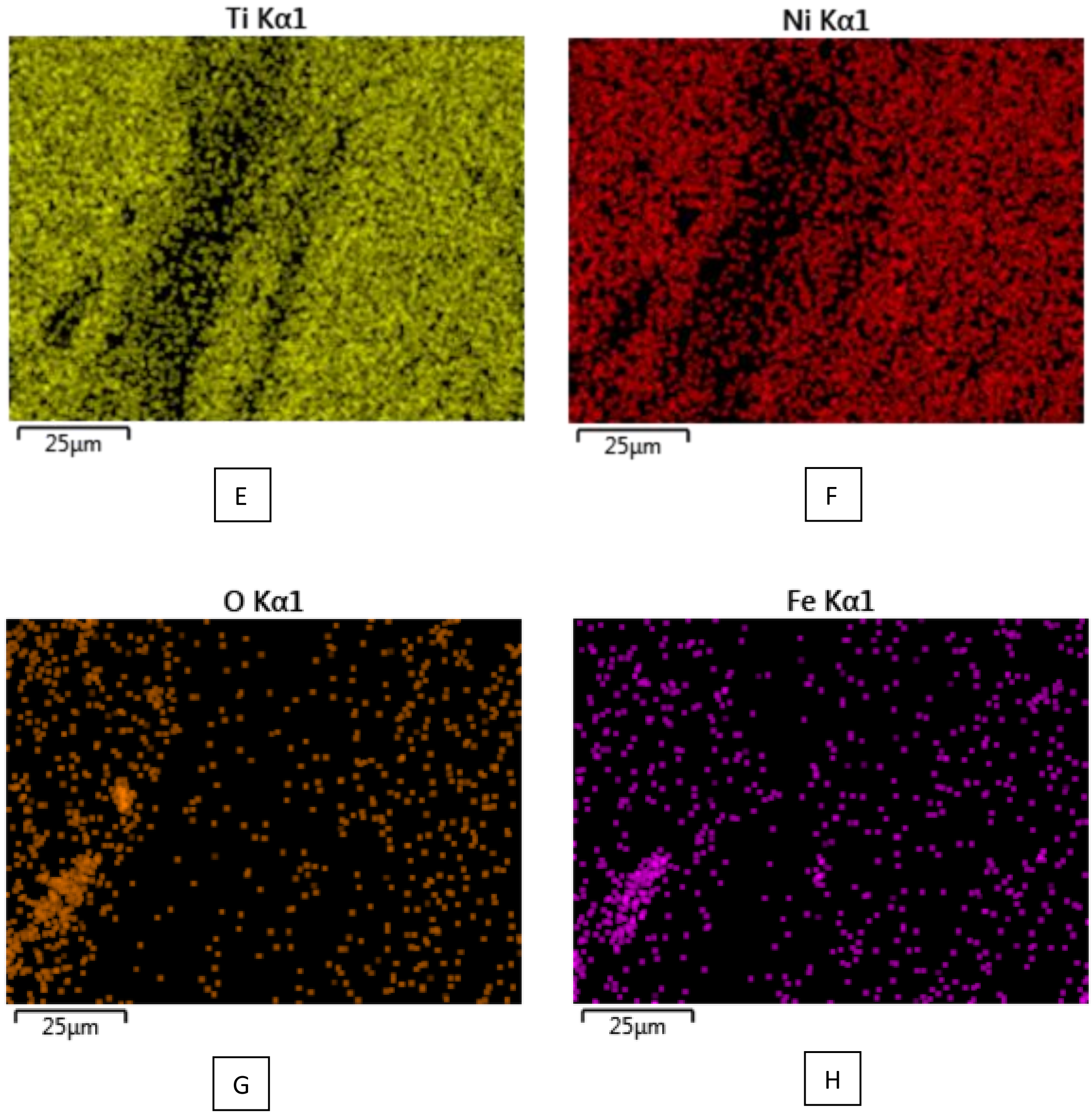
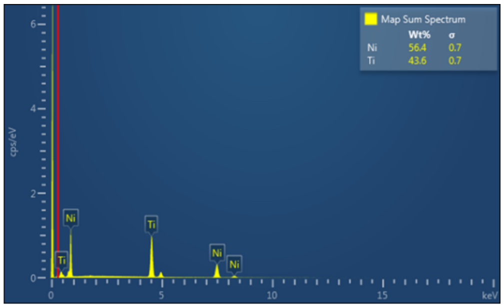
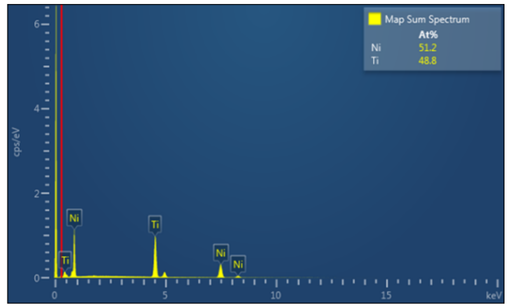


Fig 4.1- EDS micro-analysis of XP Endoshaper file, (A&B) the EDS spectrum of XP Endoshaper file, containing detectable Ni and Ti (C) SEM image of a segment of file(D)Represents the SEM image of file displaying the presence of elements- Ti(E),Ni(F),O(G) and Fe(H) on the surface of the segment of file.

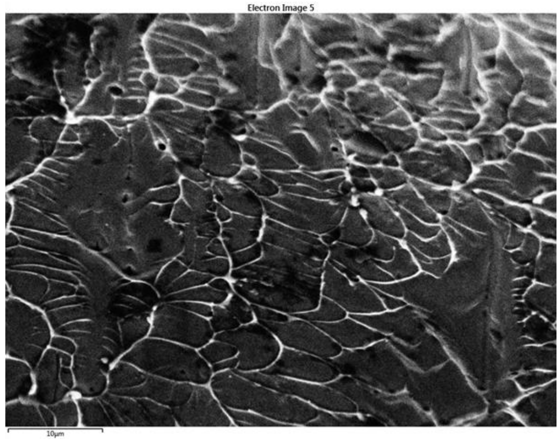




A

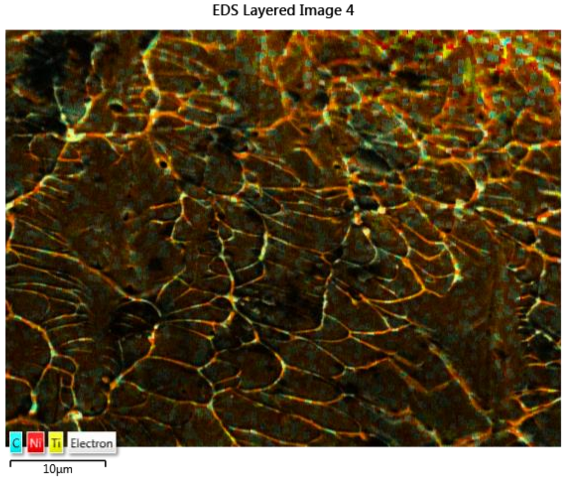
B

Electron Image 5



C

EDS Layered Image 4



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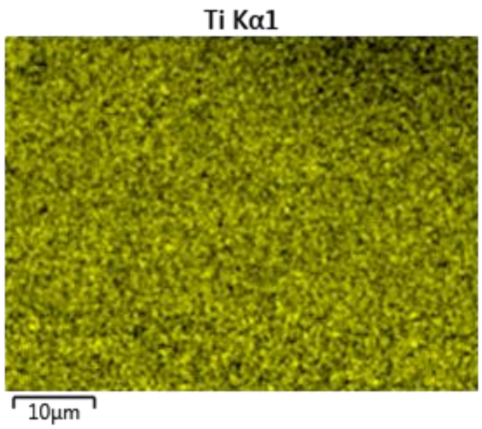

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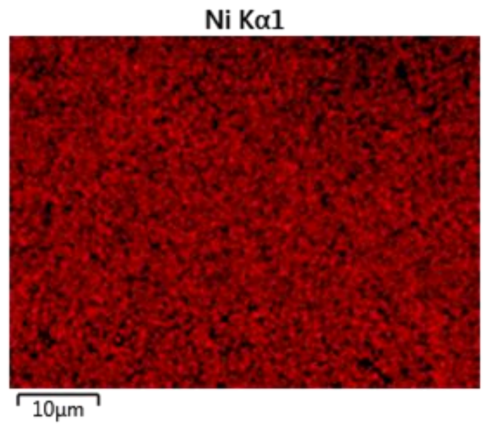

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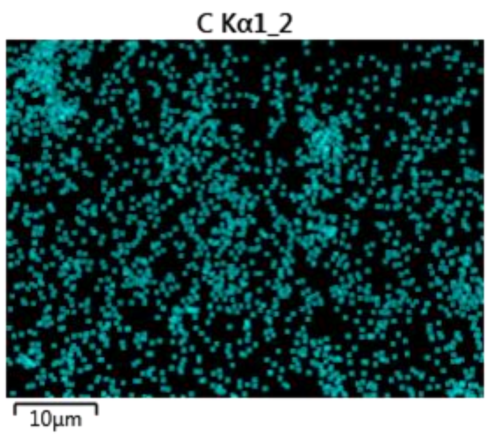
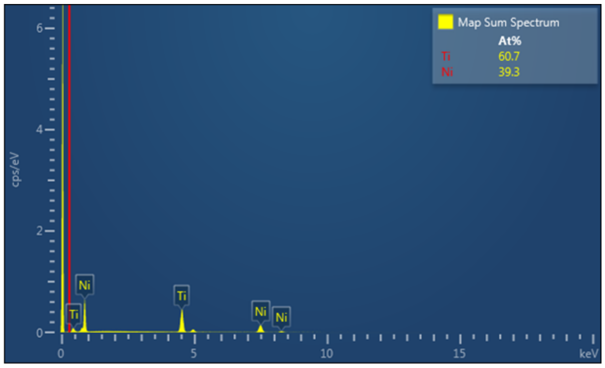
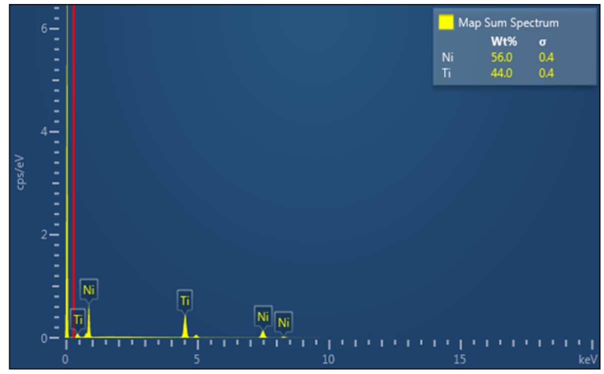


G

Fig 4.2 EDS micro-analysis of F360: A&B -represents the EDS spectrum of F360 file, containing detectable Ni and Ti(C) SEM image of a segment of file(D)Represents the SEM image of file displaying the presence of elements-Ti(E), Ni(F) and C(G) on the surface of the segment of file.



A



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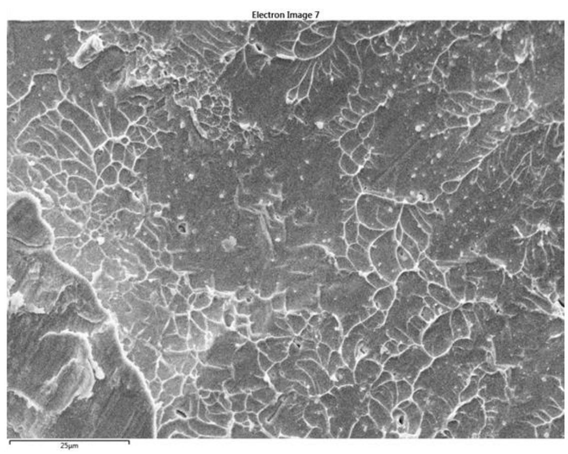
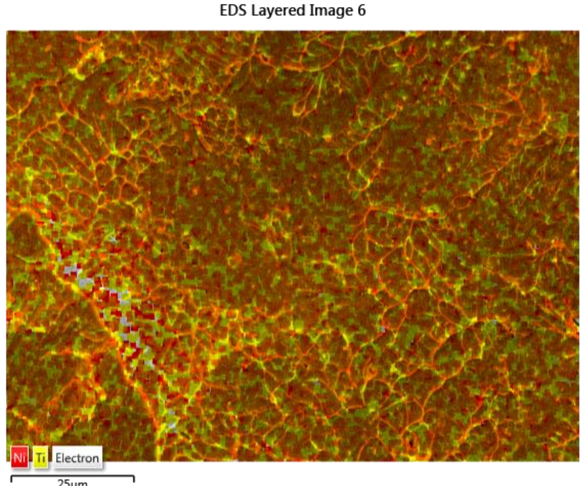


C

EDS Layered Image 6



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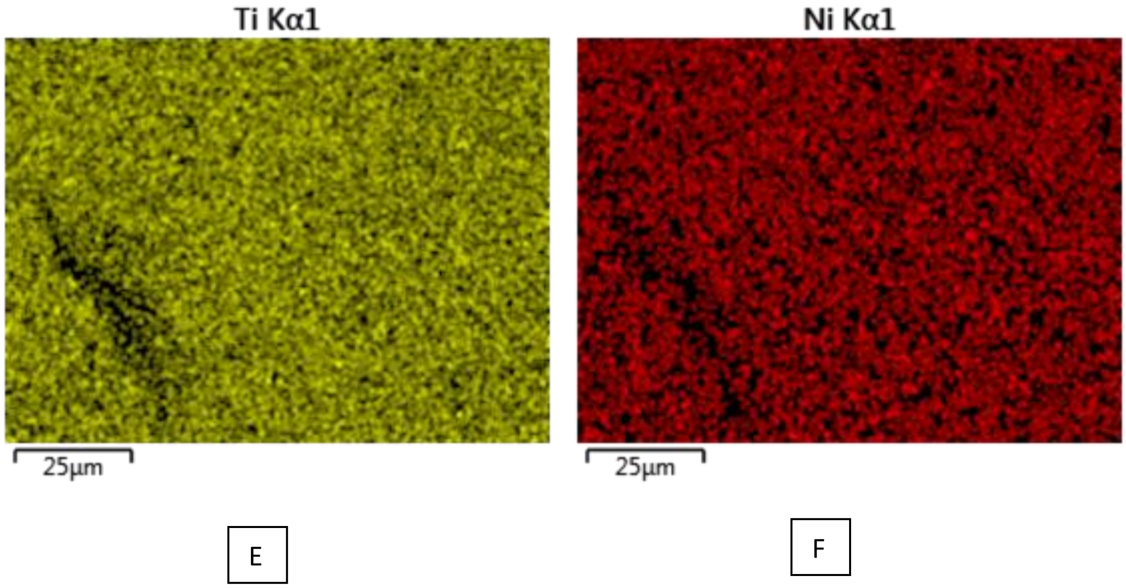


FIG 4.3 EDS micro- analysis of 2Shape, A&B -represents the EDS spectrum of 2Shape file, containing detectable Ni and Ti (C) SEM image of a segment of file(D)Represents the SEM image of file displaying the presence of elements-Ti(E) and Ni(F) on the surface of the segment of file.

Later a geometrical model i.e., 3D CAD model was designed (fig 5) after analysing the sample for geometrical variation through Solidworks version 2013 software.

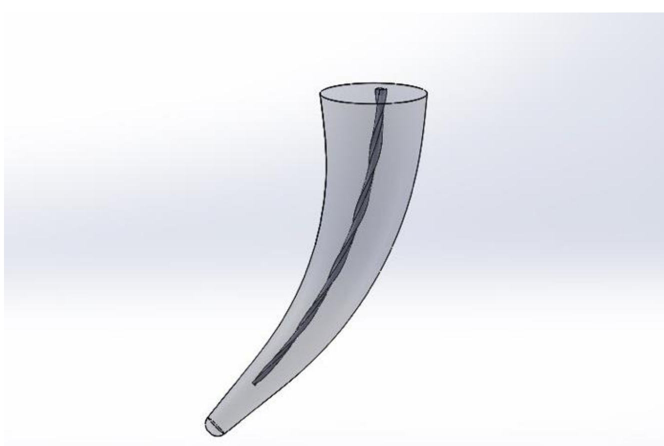


Fig 5- 3D CAD model of rotary file and root canal

The CAD file having STL format was converted into IgES format by Solidworks version 2013 software. Later the data was transferred from Solidworks to ANSYS workbench 15.0 to reproduce a 3D model of each instrument for further analysis.

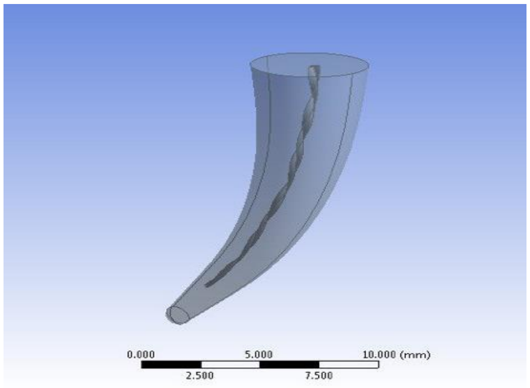
GROUPWISE DISTRIBUTION OF SAMPLES

GROUPS	**NO OF FILES(N)**	**FILES GROUP**
Group A	**15**	**Trunatomy files**
Group B	**15**	**XP-Endo Shaper files**
Group C	**15**	**F360 files**
Group D	**15**	**2shape files**

Preparation of 3D finite element models

The 3D finite model of the simulated root canal was constructed with a 16 mm ,45-degree root curvature, a 6 mm radius and with an apical diameter of 0.5mm of the apical foramen and NiTi rotary files were created using ANSYS workbench 15.0 software All simulated rotary files had a standard length of 25mm with a working surface of 16 mm, a taper of 0.04. (Fig 6.1)

After the designing of the virtual root canal and the rotary files, All the analysis had been done on structural analysis module of ANSYS for retrieving equivalent Von mises stress in later steps. Later the geometry of the file was specified in design modular workbench of ANSYS. (Fig 6.1) Later mesh was laid down for the further analysis of the 3D finite model using Solid186 in ANSYS to create 3D brick elements. (Fig 6.2)



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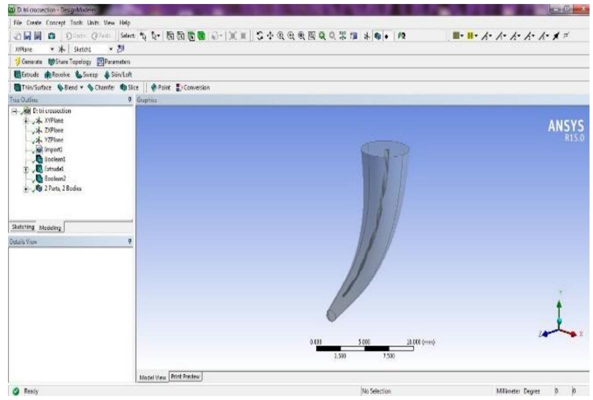
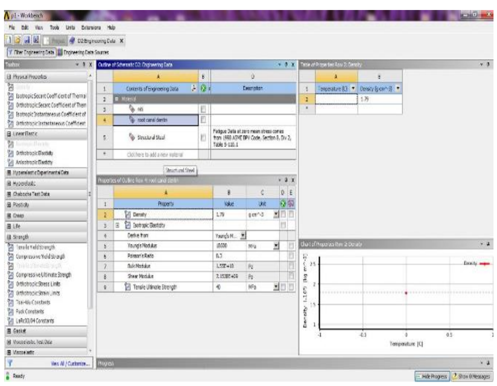
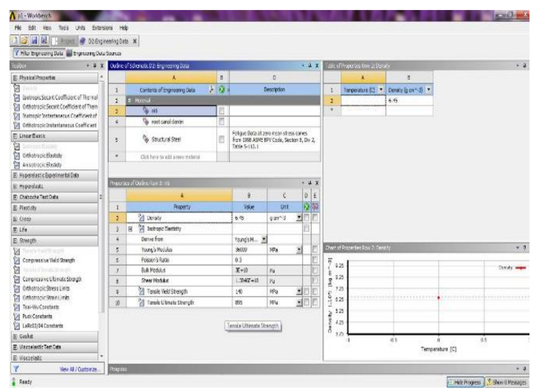


B

Fig 6.1 (A,B)the geometry of file was designed in design modular workbench of ANSYS



A



B

Fig 6.2(A,B) Material properties of files were assigned in the engineering data feature of ANSYS

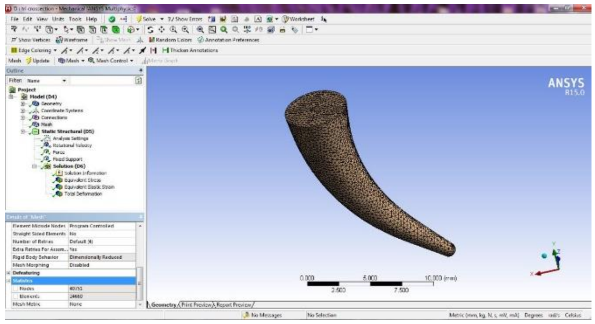


Fig 6.3 Meshing of root canal and nodes and antinodes were determined.

These virtual 3d finite models were then divided into small pieces i.e. small finite elements and these elements connect all characteristic points i,e. nodes that lie on their circumference.

For 3D finite model of root canal, the number of nodes and elements are as follows-nodes-40751 and elements-24660. (Fig 6.3) and similarly, the 3D finite models of all tested rotary files were divided into nodes and elements.

MATERIAL PROPERTIES

The characteristic material properties of each type of Niti were assigned as per the literature in the engineering data feature of ANSYS software. The elastic modulus for F360 was assigned to be 43.9 GPa, young modulus (martensite)-28-41GPa, yield strength (martensite)-70-140 MPa, Poisson ratio -0.3. For 2shape files young's modulus (Austenite) 42.530 GPa, Young's modulus (Martensite) 12.828 GPa, Poisson's ratio 0.33 Density of the NiTi instruments 6450 kg/m3, Shear modulus (Austenite) 15.98 GPa and shear modulus (Martensite) 4.82 GPa was taken. The young modulus of root canal dentin components was also assigned -18.60Gpa with a poisson ratio of 0.30.(fig 5.2)

For Xp endoshaper files the density was taken as 6.45 gm/cc at 35 degree centigrade and for trunatomy files the density was 6.44 gm/cc at 35 degree centigrade according to the IS:5642-1991 test method and the elastic modulus for TruNatomy files 0.00149 ± 0.00022 and for XP Endoshaper files was 0.00056 ± 0.00006.

The young modulus of root canal dentin components was also assigned -18.60Gpa with a poisson ratio of 0.30.

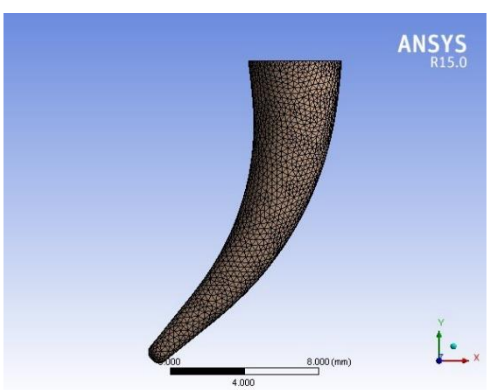
After assigning the data for geometry and material property, the data was transferred to mechanical modular for analysis for applying loading and boundary conditions.

Loading and boundary conditions

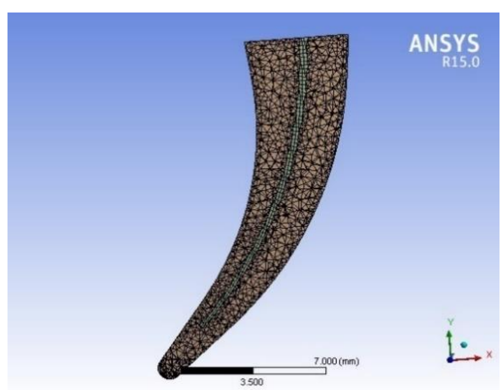
The loading and boundary conditions were provided in mechanical modular part of ANSYS .The file was allowed to be inserted up to the working length of the simulated root canals. After inserting the files inside the canal, the virtual rotations of 180 degree were performed at a rate of 300 rpm with 1.5 Nm torque in a root canal having a 45-degree curvature. Virtual rotation of files was performed three times inside the canal. After these the displacement of nodes was calculated, and the stress was calculated at a point where maximum stress generation was seen. (fig 7)

After applying loading and boundary conditions meshing operation was performed to achieve desired nodes and elements for accurate results. Fig 6

After meshing, the calculation for equivalent stress was performed from the data that were assigned earlier.



A



B

Fig 7 mesh was laid down for the root canal (A)and rotary files(B) followed by the determination of nodes and elements.

Later all the samples were analysed one by one based on their cross sections and based on change in metallurgy according to the material properties.

Later for calculating and evaluating the stress generated on the instrument von mises stress formula was used and their mean obtained were tabulated for statistical analysis.

<u>Stress analysis</u>

Stress in each integration point were recorded at each rotation angle for an individual file and stress at apical, middle, and coronal level were calculated for each file. Stress levels were characterized by von mises equivalent stress, which uses the von mises criterion to integrate the 3D stress state into a single value.

3-D Von mises stress formulae-

$$\sigma v=(21[(\sigma x-\sigma y)2+(\sigma y-\sigma x)2+(\sigma z-\sigma x)2]+3(\tau xy2+\tau yz2+\tau zx2))21$$

Here,

- $\sigma 3$ – Normal stress in the z-direction, sometimes denoted as $\sigma 33$ or σzz
- τxy- Shear stress in the XY direction
- τyz -Shear stress YZ, sometimes denoted as $\sigma 23$
- τzx– Shear stress ZX, sometimes denoted as $\sigma 31$

Principal stress.

- Shear stresses: $\tau xy= \tau yz= \tau zx=0$

$$\sigma v=(1/2[(\sigma 1-\sigma 2)2+(\sigma 2-\sigma 3)2+(\sigma 3-\sigma 1)2])^{1/2},$$

where $\sigma 3$ is the minimum principal stress.

The SPSS statistical programme 23.0 Version was used to evaluate the data for the current study, which was entered in Microsoft Excel 2007. Mean and standard deviation were among the descriptive statistics. The level of significance for the current study was set at 5%.

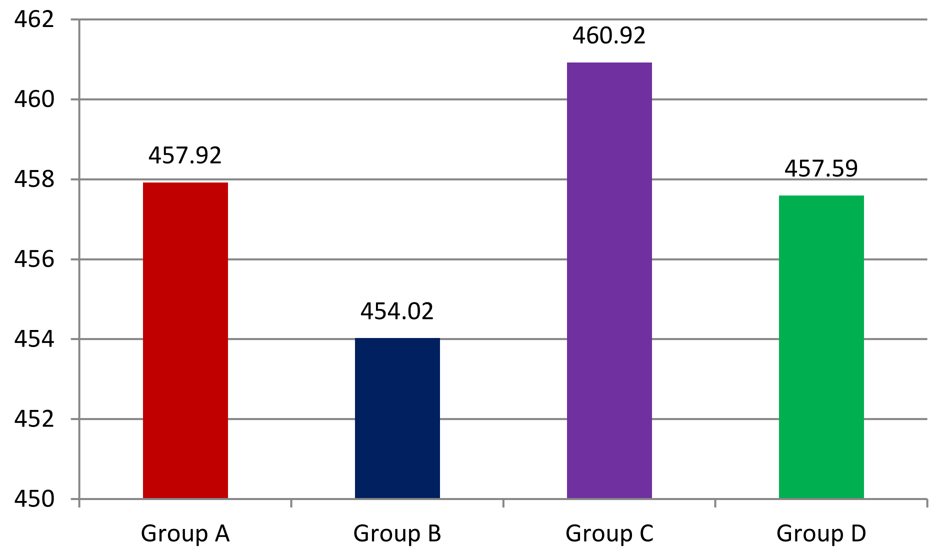
One Way ANOVA and Post Hoc Tukey Analyses were used to compare the mean scores of the different independent groups.

The Shapiro-Wilk test and the Levene test were used to look at the data distribution and variable homogeneity, respectively. All four groups—Group A-Trunatomy, Group B-XP Endoshaper, Group C-F360, and Group D- 2Shape—were found to have homogenous and consistently distributed data. For each variable, the mean and standard deviation (SD) were determined.

	Mean	Std. Deviation	Std. Error
Group A	457.92	1.8	0.47
Group B	454.02	0.86	0.23
Group C	460.92	1.83	0.48
Group D	457.59	1.84	0.47

When utilizing One Way ANOVA, a P value of less than 0.001 is considered significant.

Table 1. Intergroup comparison of stress amongst four groups revealed that the average stress was 457.92 in Group A, 454.02 in Group B, 460.92 in Group C, and 457.59 in Group D. Using the One Way ANOVA and post hoc analysis, the four groups were compared among themselves. Group C had the greatest stress levels, followed by Group A, Group D, and Group B with the lowest values. The difference in stress values between Group A and Group B, Group A and Group C, Group B and Group C, Group B and Group D, Group C and Group D, and Group A and Group D was statistically insignificant.



Graph 1- Revealed that for Groups A, B, C, and D, the average stress was 457.92, 454.02 and 457.59 respectively. The four groups were contrasted against one another using a one-way ANOVA and post hoc analysis. Group C had the greatest stress levels, followed by Group A, Group D, and Group B with the lowest values.

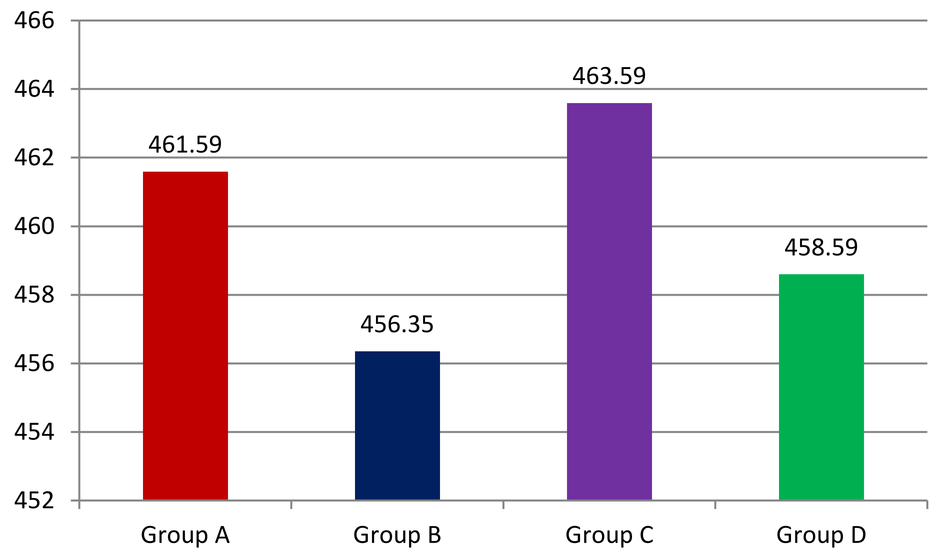
<u>A STRESS COMPARISON AMONG THE FOUR GROUPS AT APICAL THIRD</u>

	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Group A	461.59	1.78	0.466	458.04	465.19
Group B	456.35	0.88	0.221	454.81	457.84
Group C	463.59	1.81	0.459	460.04	467.19
Group D	458.59	1.84	0.483	455.04	462.19

When utilizing One Way ANOVA, a P value of less than 0.001 is considered significant.

TABLE 2 The intergroup comparisons of Four groups for stress indicated that the average stress was 461.59 in Group A, 456.35 in Group B, 605.9043.73 in Group C, and 458.59 in Group D. Using the One Way ANOVA and post hoc analysis, the four groups were compared among themselves. Group C had the greatest stress levels, followed by Group A, Group D, and Group B with the lowest values. The difference in stress values between Group A and

Group B, Group A and Group C, Group B and Group C, Group B and Group D, Group C and Group D, and Group A and Group D was statistically insignificant.



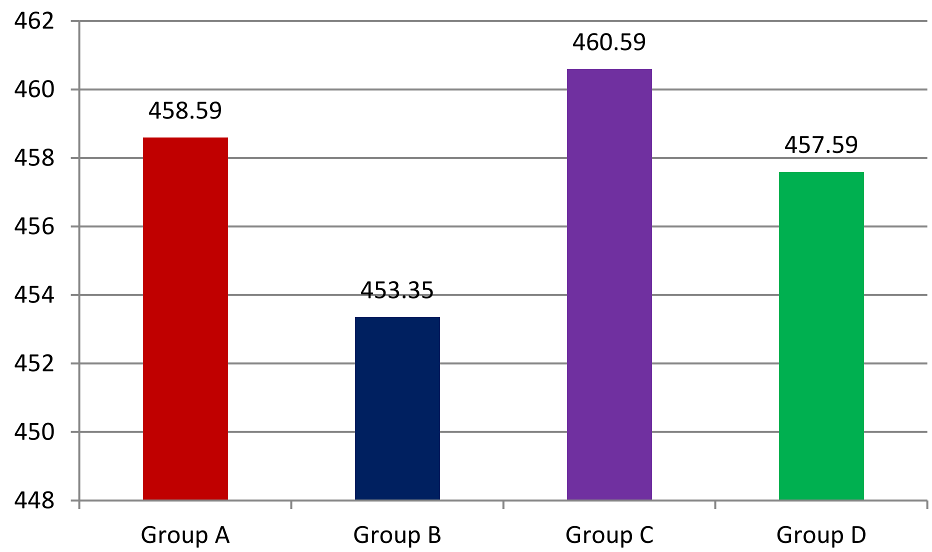
Graph 2: Revealed that for Groups A, B, C, and D The average stress was 461.59 in Group A, 456.35 in Group B, 605.9043.73 in Group C, and 458.59 in Group D. Using the One Way ANOVA and post hoc analysis, the four groups were compared among themselves. Group C had the greatest stress levels, followed by Group A, Group D, and Group B with the lowest values. The stress value difference was not statistically significant.

A STRESS COMPARISON AMONG THE FOUR GROUPS AT MIDDLE THIRD

	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Group A	458.59	1.81	0.467	455.04	462.19
Group B	453.35	0.87	0.224	451.81	454.84
Group C	460.59	1.82	0.468	457.04	464.19
Group D	457.59	1.84	0.469	452.04	459.19

When utilizing One Way ANOVA, a P value of less than 0.001 is considered significant.

TABLE 3: The intergroup comparisons of Four groups for stress the average stress was 458.59 in Group A, 453.35 in Group B, 460.59 in Group C, and 457.59 in Group D. Using the One Way ANOVA and post hoc analysis, the four groups were compared among themselves. Group C had the greatest stress levels, followed by Group A, Group D, and Group B with the lowest values. Between Group A and Group B, Group A and Group C, Group B and Group C, Group B and Group D, Group C and Group D, Group A and Group D, there was a statistically non-significant difference in the stress values.



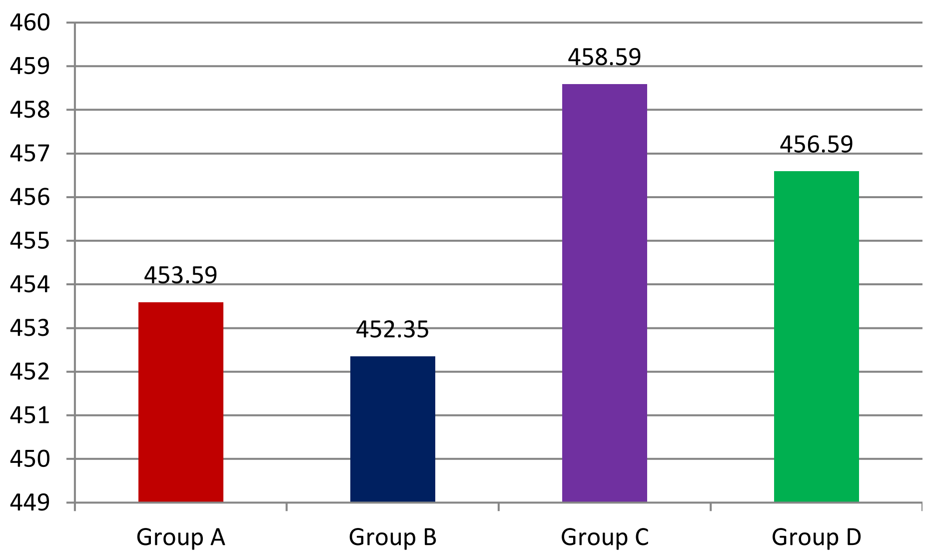
Graph 3: Revealed that for Groups A, B, C, and D, the average stress was 458.59 in Group A, 453.35 in Group B, 460.59 in Group C, and 457.59 in Group D. Using the One Way ANOVA and post hoc analysis, the four groups were compared among themselves. Group C had the greatest stress levels, followed by Group A, Group D, and Group B with the lowest values, there was a statistically non -significant difference in the stress values.

A STRESS COMPARISON AMONG THE FOUR GROUPS AT CORONAL THIRD

	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Group A	453.59	1.84	0.463	450.04	457.19
Group B	452.35	0.85	0.221	449.81	452.84
Group C	458.59	1.87	0.466	455.04	462.19
Group D	456.59	1.81	0.458	453.04	460.19

When utilizing One Way ANOVA, a P value of less than 0.001 is considered significant.

Table 4: In the intergroup comparisons of Four groups for stress, The average stress was 453.59 in Group A, 452.35 in Group B, 458.59 in Group C, and 456.59 in Group D. Using the One Way ANOVA and post hoc analysis, the four groups were compared among themselves. Group C had the greatest stress levels, followed by Group D, Group A, and Group B with the lowest values. Between Group A and Group B, Group A and Group C, Group B and Group C, Group B and Group D, Group C and Group D, there was no statistically significant difference in the stress values. The groups A and D



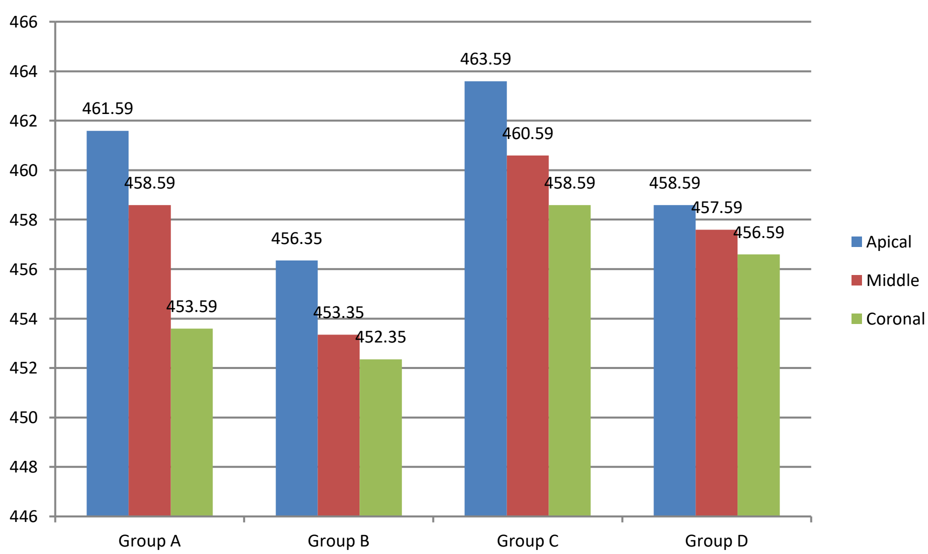
Graph 4 : : Revealed that for Groups A, B, C, and D , The average stress was 453.59 in Group A, 452.35 in Group B, 458.59 in Group C, and 456.59 in Group D. Using the One Way ANOVA and post hoc analysis, the four groups were compared among

themselves. Group C had the greatest stress levels, followed by Group D, Group A, and Group B with the lowest values, there was no statistically significant difference in the stress values.

COMPARISON WITHIN-GROUPS OF STRESS AT THE LEVEL OF APICAL MIDDLE AND CORONAL THIRD IN FOUR GROUPS

	Apical	Middle	Coronal	P value
Group A	461.59	458.59	453.59	0.715 (Non-Sig)
Group B	456.35	453.35	452.35	0.912 (Non-Sig)
Group C	463.59	460.59	458.59	0.769 (Non-Sig)
Group D	458.59	457.59	456.59	0.923 (Non-Sig)

Table 5: The mean Stress values in Group A were 461.59 in the apical third, 458.59 in the middle, and 453.59 in the coronal third. The difference between the Apical, Middle, and Coronal thirds was not statistically significant. The mean stress values in Group B were 456.35 in the apical third, 453.35 in the middle, and 452.35 in the coronal third. The difference between the Apical Middle Third and Coronal Third was not statistically significant. The mean Stress values in Group C were 463.59 in the apical third, 460.59 in the middle, and 458.59 in the coronal third. The difference between the Apical, Middle, and Coronal thirds was statistically non- significant. The mean Stress values in Group D were 458.59 in the apical third, 457.59 in the middle, and 456.59 in the coronal third. The difference between the Apical, Middle, and Coronal thirds was not statistically significant.

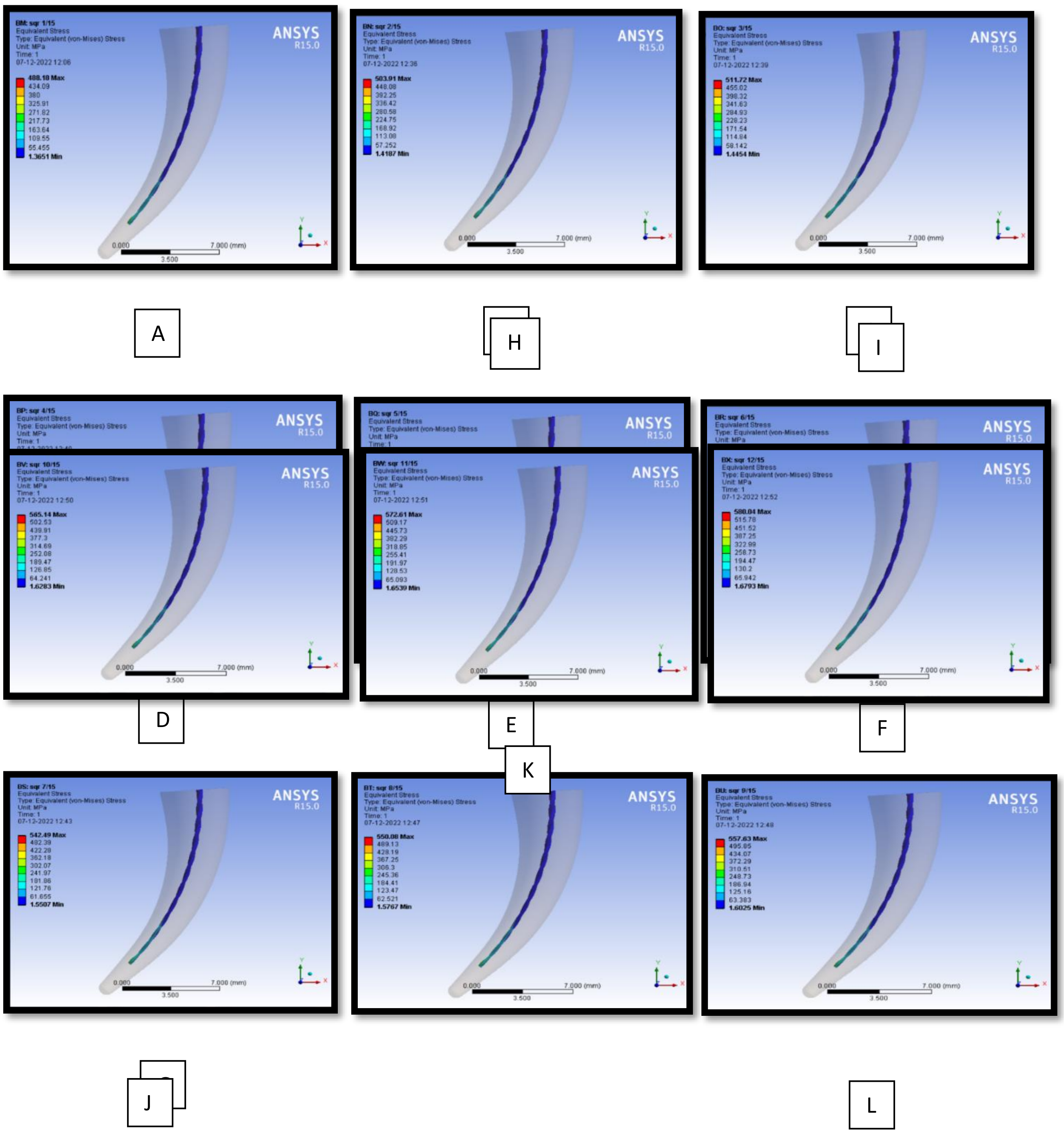


Graph 5: Mean stress levels produced by all four groups at the apical, middle, and coronal thirds of the root canal were compared within each group.

The mean of the stress produced by each of the four file systems in the current investigation is as follows:

TruNatomy files

Overall, the maximum stress value for TruNatomy files against the simulated dentinal wall in this investigation was-461.59 MPa. The mean stress values were 461.59, 458.59 and 453.59 MPa’s at the apical, middle, and coronal levels, respectively.



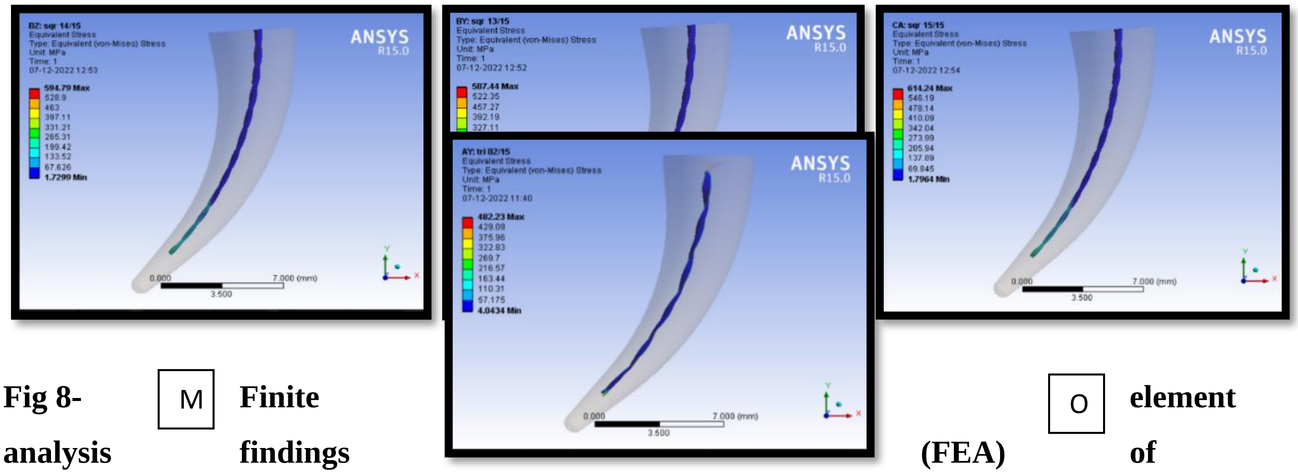
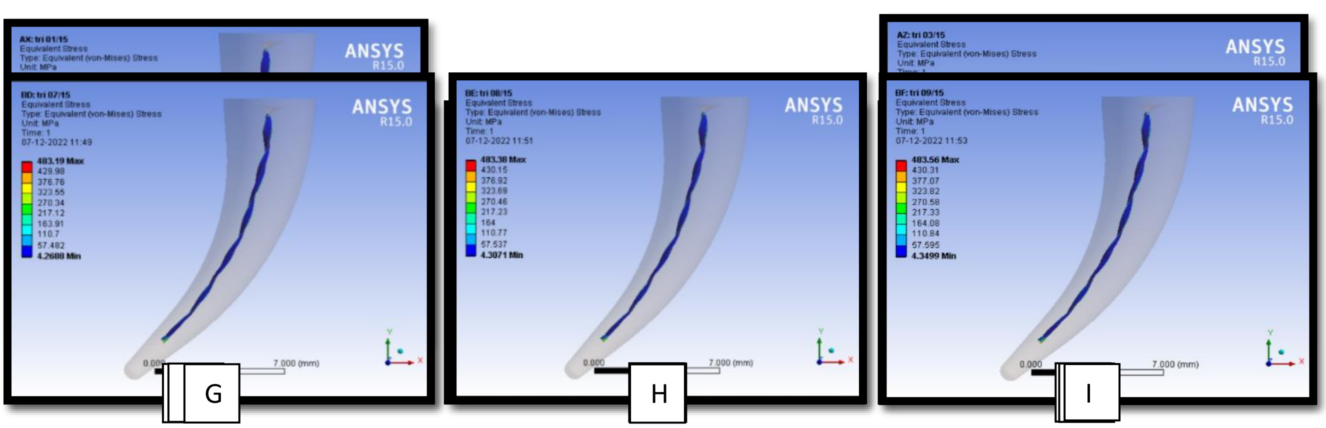
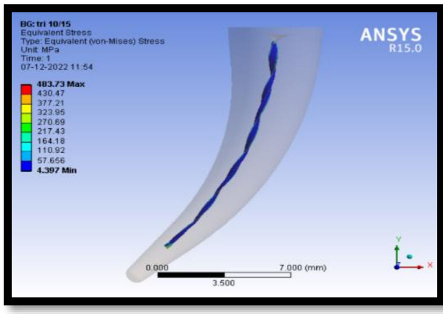


Fig 8- Finite element analysis findings (FEA) of TruNatomy files. Warmer hues denote areas of high mechanical stress because they show the severity of the mechanical stress. Areas with cooler colors are less stressful. From the coronal level to the apical level, stress values are rising.

<u>XP Endoshaper files</u>

Overall, the maximum stress value for XP Endoshaper files against the simulated dentinal wall in this investigation was-454.02. MPa The mean stress values were 456.35, 453.35and 452.35 MPa's at the apical, middle, and coronal levels, respectively.





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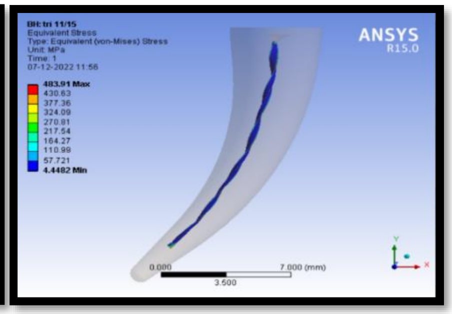

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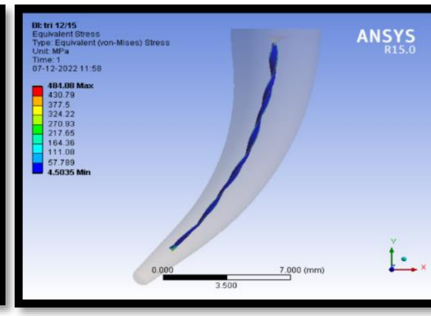

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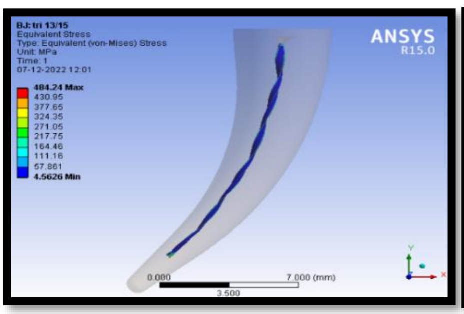

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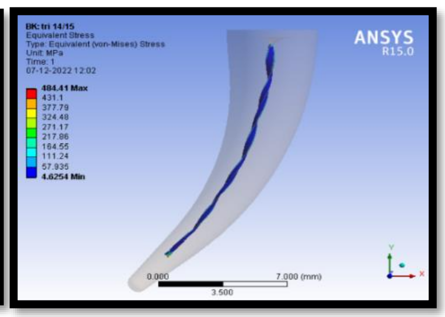

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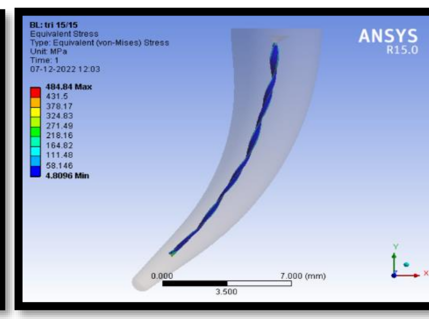
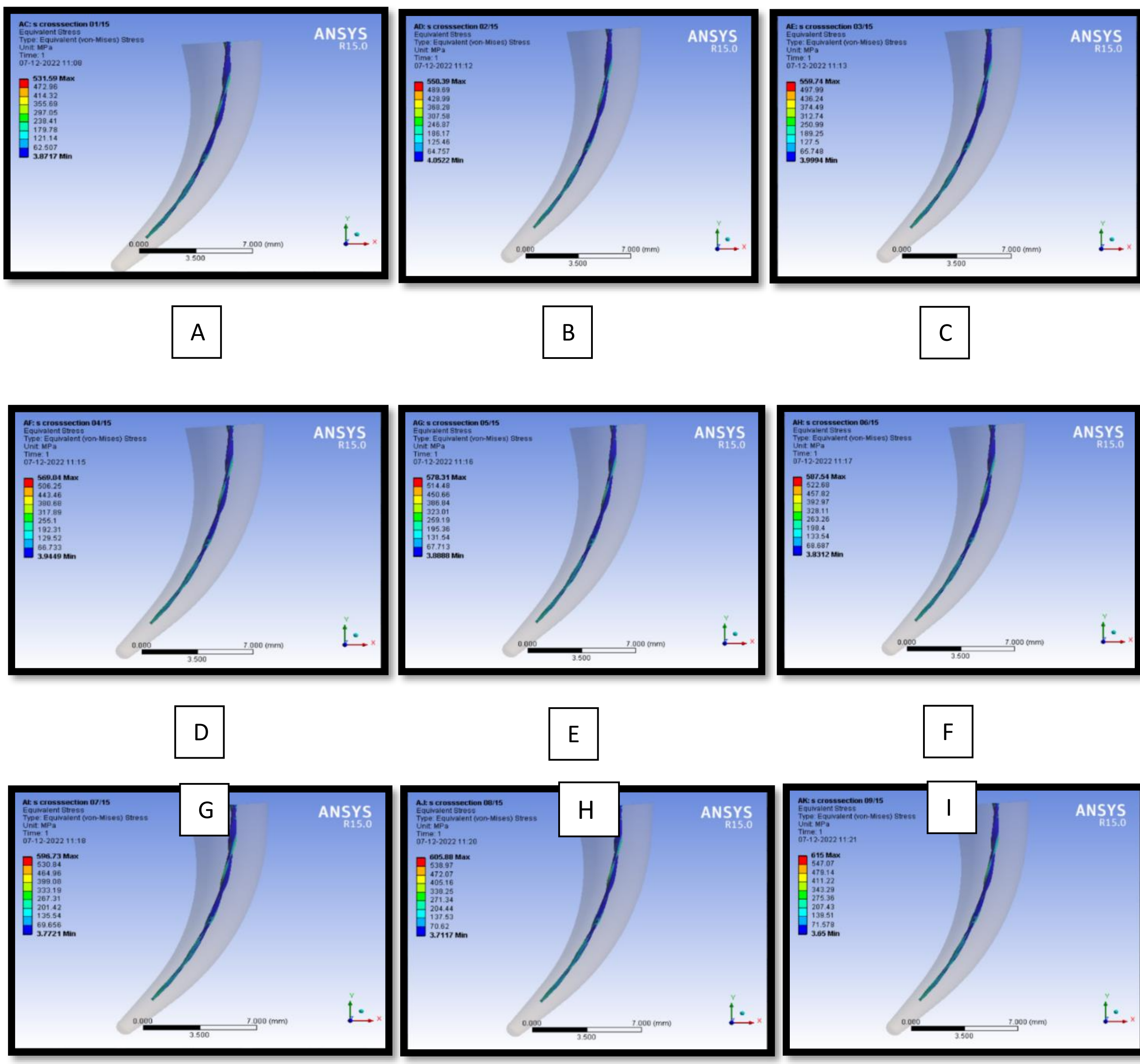


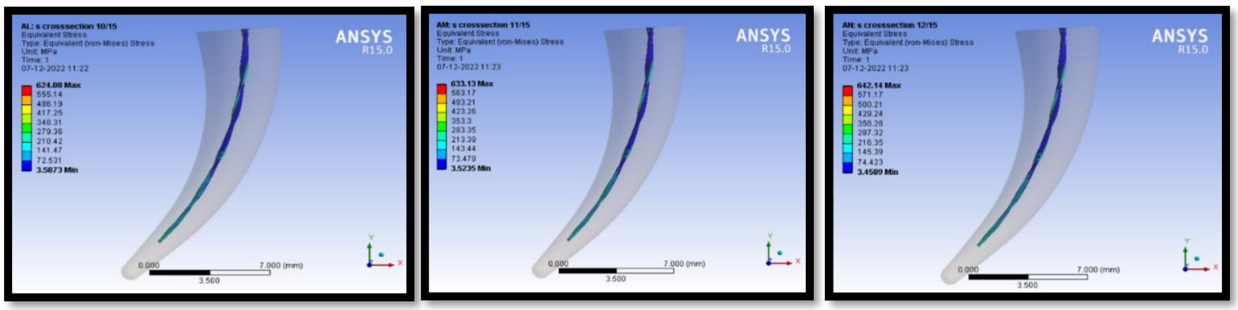
O

Fig 9 (A-O) Finite element analysis findings (FEA) of XP Endoshaper files. Warmer hues denote areas of high mechanical stress because they show the severity of the mechanical stress. Areas with cooler colors are less stressful. From the coronal level to the apical level, stress values are rising.

<u>F360 files</u>

Overall, the maximum stress value for F360 files against the simulated dentinal wall in this investigation was-460.92 MPa. The mean stress values were 463.59, 460.59 and 458.59 MPa's at the apical, middle, and coronal levels, respectively.





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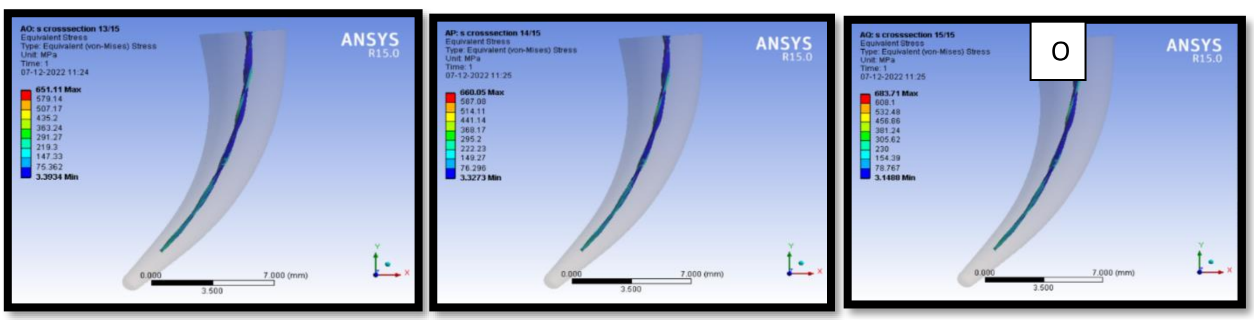
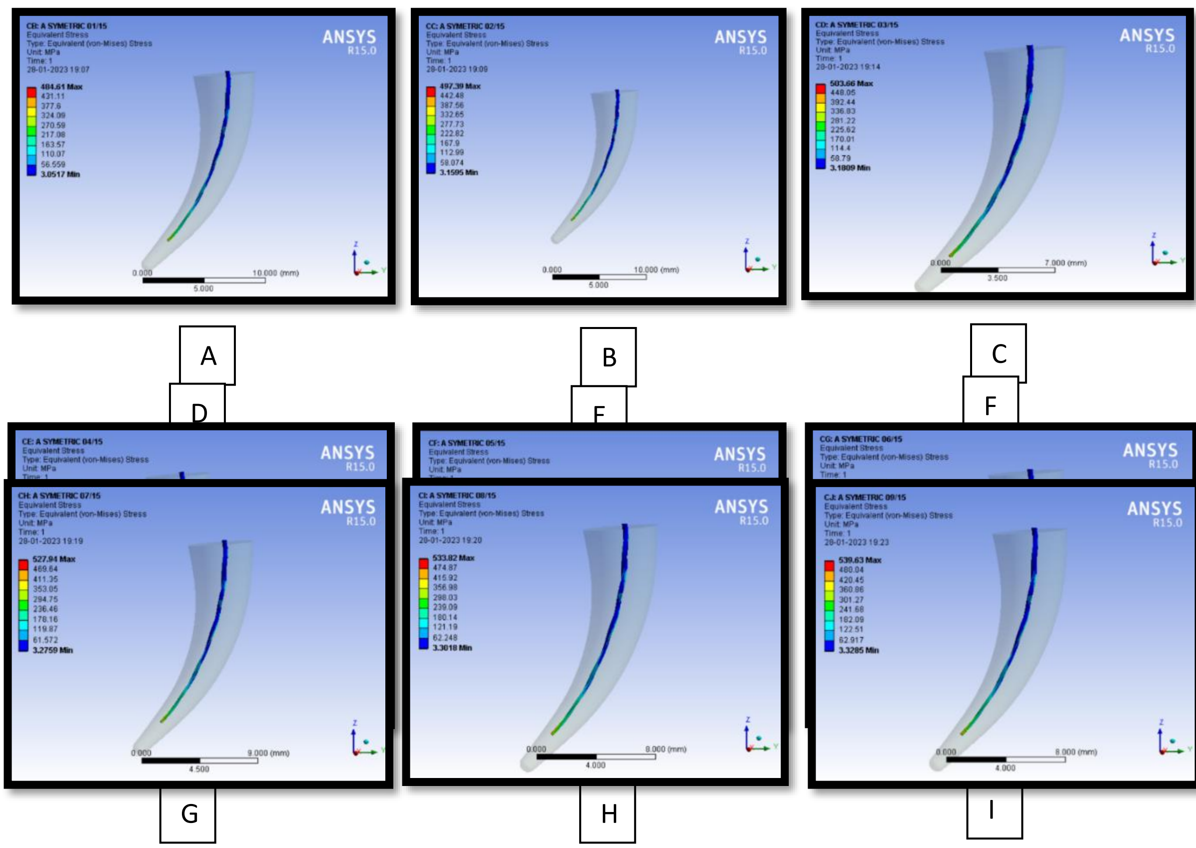


Fig 10 (A-O) Finite element analysis findings (FEA) of F360 files. Warmer hues denote areas of high mechanical stress because they show the severity of the mechanical stress. Areas with cooler colors are less stressful. From the coronal level to the apical level, stress values are rising.

2Shape files

Overall, the maximum stress value for 2Shape files against the simulated dentinal wall in this investigation was-457.59 MPa the mean stress values were 458.59, 457.59and 456.59 MPa's at the apical, middle, and coronal levels, respectively.



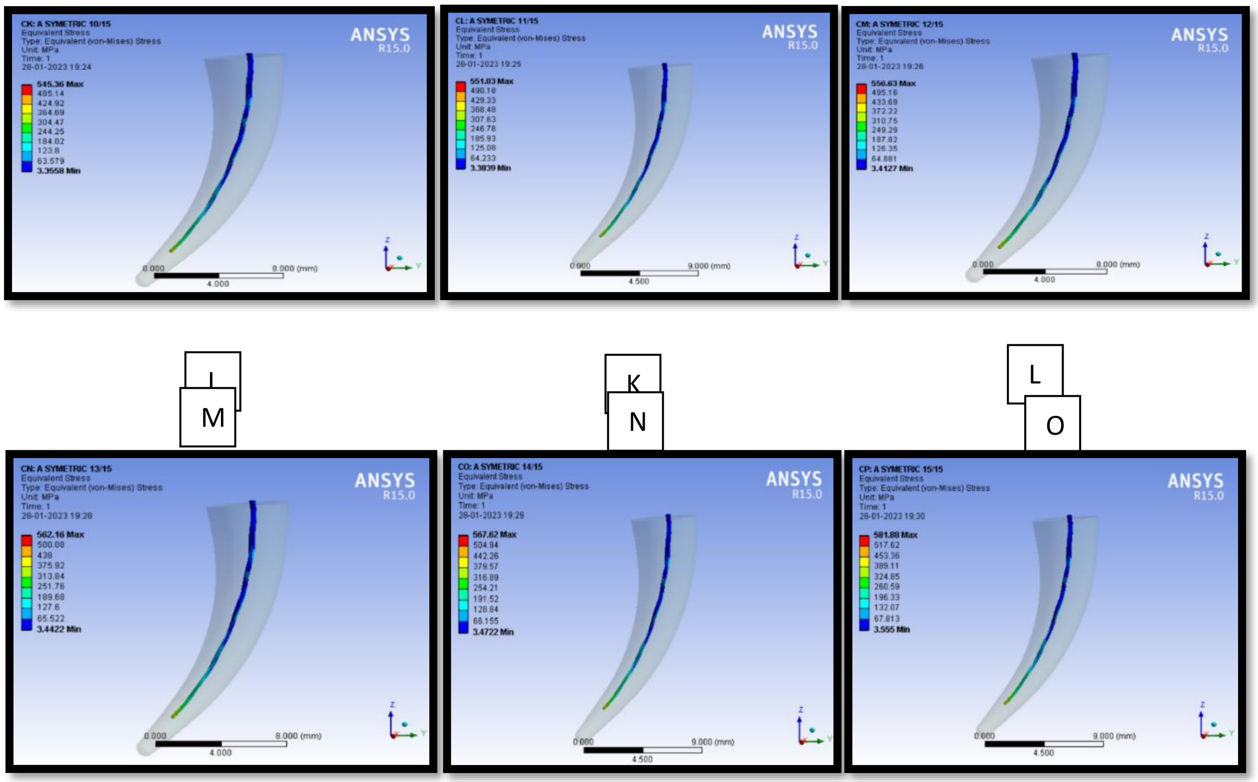


Fig 11(A-O) Finite element analysis findings (FEA) of 2Shape files. Warmer hues denote areas of high mechanical stress because they show the severity of the mechanical stress. Areas with cooler colors are less stressful. From the coronal level to the apical level, stress values are rising.

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During the last two decades, NiTi rotary endodontic instruments have gained recognition amongst the clinicians. As the instruments fabricated with these alloys are characterized by two main properties, super elasticity (SE) and shape memory effect (SME). Despite possessing superior properties these NiTi instruments tend to fail when they are normally subjected in a curved canal. Numerous researchers have shown the growing concern regarding the instrument fracture throughout their usage.[73]

When endodontic rotary file is allowed to rotate inside the curved canal, they are subjected to both compressive and tensile stresses, the concave portion of the instrument is under compression while the external portion is under tension. Therefore, instrument separation can occur due to either the flexural fatigue or torsional fatigue.

These forces faced by the files are associated with the contact areas, that is, the friction between the instrument and the root canal wall and the load applied is expected to cut out dentin. If the instrument is stuck in the canal, torsional (shear) stress builds up in the instrument, which, when the elastic limit of the material is exceeded, would lead to plastic deformation, and eventually lead to failure by shear inside the curved canal.[8,23]

Various manufacturers have claimed to improve the endodontic rotary files properties by modifying the design features of these files and its metallurgy which might enhance the efficacy of these instruments and reduces its separation inside the canal. In this process researchers have designed endodontic files with different asymmetrical cross sections (such as triple helix, double S shaped, small triangular cross section, variable cross section, off-centred designs). They have also attempted to alter the metallurgy of NiTi wire such as Max wire, T wire, special heat treatment etc. However, these files may still get separated inside the canal.

Therefore, present study was designed to evaluate the stress generated by four novel tested rotary files having different cross sections and fabricated by different metallurgical process against the simulated root canal wall during their instrumentation inside the simulated root canal having a curvature of 45 degree.

Initially all the novel NiTi rotary files were scanned under scanning electron microscope to determine the microcracks and surface irregularities on the unused files to follow an inclusion criterion, with a focused beam of high energy electrons to generate a variety of signals at a surface of solid specimens. As, SEM can perform analysis of point locations both quantitatively and semi quantitatively determining the crystalline structure, crystal orientations (using Electron backscattered diffraction). Çapar D et al. evaluated various imaging techniques for diagnosing microcracks and concluded that the SEM method is preferable to stereomicroscopy, cone beam computed tomography, and micro computed tomography for doing so. Because it examines items more closely and with a higher magnification (Peters et al, 2015) [74,75]. As a result, it was decided that the SEM approach would be best suited for this study's examination of the existence or absence of microcracks and surface imperfections.

By using SEM method, the fractographic (at high magnification) as well as longitudinal examination was done to examine the instrument from the site it was broken and to check the parts of working surface of the instrument, this was done to disclose features that might indicate the crack origin and surface irregularities. Many previous studies have used this method as a general procedure for performing the fractographic examination of rotary files. [76]

Instrument separation happens as a result of stress being created on the instrument's surface during root canal instrumentation. The SEM method is helpful in examining the surface of a broken fragment, but it is unable to assess how much stress is dispersed or whether any residual stress is present on the surface of an instrument. It is also impossible to assess how much stress is present on an instrument when it is being used in a clinical setting.

Thus, the stress distribution and residual stresses on the endodontic file system were estimated using a mathematical simulation, or finite element (FE) analysis approach. A complex structure can be broken down into a number of small, simply shaped pieces using FEA, which has been demonstrated to be an effective tool in the field of structural mechanical analysis. They are now employed in medical and dentistry research to analyse the stress of structural objects with complicated morphology due to their efficacy.[77]

Numerous studies indicate that FEA is an effective method for exploring different NiTi rotary instrument properties, although the formulas can be difficult, especially if the geometry is complex.

Out of various studies conducted on cross-section profile of instrument considering the flexural and torsional behaviour of NiTi instruments, till now very few studies have been considered on the role of metallurgy of NiTi alloy. However, in the present study, factors that have been considered are metallurgy (Max wire, special heat treatment wire and conventional NiTi) and cross section (off centered parallelogram, Small triangular, triple-helix and small double S-type) which has not been considered in any other studies in the literature, besides unlike many preceding works in the literature, which considered the canal as a rigid body, here the elastic behaviour of the canal was considered.

In the present study, computerized models of each 4 novel files of same size and taper (length-16 mm ,6 mm radius, apical diameter of 0.5mm of the apical foramen) in same boundary conditions (simulated curved canals of 45 degree as per Schneider's classification of curved canal) were generated and this classification is a universally accepted classification because of its mere simplicity(straight- 5 ° or less, moderate- 10-20 ° and severe- 25-70 °)in establishing root canal curvature[78].

The values of mechanical properties of the files were incorporated as per literature. The elastic modulus for F360 was assigned to be 43.9 GPa, young modulus (martensite)-28-41GPa, yield strength (martensite)-70-140 MPa, Poisson ratio -0.3 [47,79,]. For 2shape files young's modulus (Austenite) 42.530 GPa, Young's modulus (Martensite) 12.828 GPa, Poisson's ratio 0.33 Density of the NiTi instruments 6450 kg/m3, Shear modulus (Austenite) 15.98 GPa and shear modulus (Martensite) 4.82 GPa was taken. The young modulus of root canal dentin components was also assigned -18.60Gpa with a poisson ratio of 0.30.[80]

For Xp endoshaper files the density was taken as 6.45 gm/cc at 35 degrees centigrade and for trunatomy files the density was 6.44 gm/cc at 35 degree centigrade according to the IS:5642-1991 test method and the elastic modulus for TruNatomy files 0.00149 ± 0.00022 and for XP Endoshaper files was 0.00056 ± 0.00006. [81]

In the present study, the Speed was set to 350 rpm (based on the study done by Yared GM et al to check the influence of rotational speed on the failure of instrument [82] and torque was 1.5 Nm according to study conducted by Zhang et al in the year 2010 for the validation of the usage of torque-controlled motors to escape shear fracture of the rotary endodontic instruments. [33] followed by the virtual rotation of the files thrice at 180 degrees to maintain the standardization and to simulate the amount of compression and tension load the file must undergo in clinical use. These rotations were similar to the rotations performed in the study of Basheer et al.[47]

After the application of repeated cycle of tension and compression the value of Stresses in each integration point were documented at each rotation angle by the means of Von mises equivalent stress(Versluis et al ,2012) and then these stresses were calculated in x, y, and z (all)directions ,at the levels of apical, middle, and coronal part where the maximum displacement during the rotation and translation of nodes was noted to integrate the 3-dimensional stress state into a single value.[83]Analogous to this study various other authors [21,28,30,31]had used the same formula to calculate the value of von misses stress.

The present study validated the null hypothesis tested in that there was no difference in the distribution of stress seen on the surface of all four tested novel NiTi files during their simulation in root canal.

In the present study, XP Endoshaper files generated a stress of 454.02 MPa on dentinal wall which was least among all the tested files at a distinct level of the apical, middle, and coronal third of simulated root canal, this file system has a small triangular cross section and a thin metallic adaptive core, Therefore, the least amount of stress by these file is anticipated as the result of its unique design, permitting it to have nominal connexion- one point contact(Fig. 12) with the dentinal wall of root canal, to substantiate this reason, Galal et al (2020) in his study cited that an increase in cross-sectional area can increase the stress accumulation while bending.[14,53] Likewise, Kim H C et al (2009) stated the reason for increased value of von misses stress be increase in the cross-sectional perimeter and surface area of rotary file[31].So, eventually the reason for this reduced amount of stress generation could be a result of its reduced cross-sectional area and one point contact of these files. [14,31]

Fig 12-One point contact of XP Endoshaper files

Moreover, this file has generated overall minimal stress on dentinal wall, as it has got a unique tip design feature i.e. their booster tip with six cutting edges, which might have turned out to generate minimal stress during the apical progression of file inside the root canal i.e., 456.35 MPa. [84]

In the present study 2Shape files yielded a stress of 458.59 MPa on modelled dentinal wall, which can be pertained due to its triple helix cross section [85] which could have resulted in a reduced contact with the root canal leading to lower stress on walls which is in accordance with the study of Medha et al [41], they speculated that the forces acting on the files are interrelated with the contact areas, i.e. the friction transpiring in between the rotary files during instrumentation against the dentinal wall and the amount of load considered necessary to cut the dentin at the site of contact[86].However, in contrary to the above mentioned explanation, a different study by Fornari et al asserts that this type of design causes increase in the friction and loading while shaping of the canal.[86] Correspondingly, Turpin et al in a study pointed out that files possessing such design would result in the development of elevated average stresses during bending in curved canals, [21] The experimental conditions that were taken into consideration may be the cause of the study's opposite outcome.

In this contemporary study TruNatomy files generated a stress of 461.59 MPa. The rationale for the resultant stress is very likely to be as a consequence of its exclusive distinctive design of core diameter of 0.8 mm NiTi wire as a replacement for 1.2 mm NiTi wire for their manufacturing, which is related with reduction in cross sectional area of file, smaller radius and lesser contact with the wall, consequently, would have resulted in decreased amount of stress. [87,88]

Moreover, these files have an off centered cross sectional design which might have reduced stress by modifying the mechanical response of an instrument into a snake-like or swaggering movement to aid one point contact with the wall and might have consecutively resulted in reduction of the interaction time of instrument with root canal ,It is in conformity with the studies by Riyahi et al, Galal et al and J.-H. Ha et al [7,89,90].

As said by Galal et al, they affirmed that the slender rectangular (parallelogram cross section) have got one point connection with the canal to give out flexural responses that are clinically advantageous, perhaps this is why there was reduction in the value of stress generation [7]. Based on the findings of Oh et al, these files have smaller radius, which could have developed lesser friction against root canal wall. [91]

In comparison of 2shape with the Trunatomy files, 2shape files yielded a marginally lesser amount of stress of 457.59 MPa at middle level and a stress of 458.59 MPa apically. Whereas Trunatomy files generated a stress of 457.92 MPa at middle third and 457.59 at apical third, which is non-significant. However, the reason for this minor variation in stress could be due to the asymmetrical triple helix design which might have lowered the value of stress which can be justified by a study executed by Diemer et al[85] , it was concluded that these type of cross-section tend to produce a smaller amount of axial stress compared to instruments with symmetrical instruments to ensure instrument safety.An equivalent study was accomplished by Hashem et al(2012) to demonstrate that the asymmetric design of an instrument helps to enable snake like movement of file inside the canal leading to lesser generation of stress.[92]

In addition to above mentioned reason another reason for this slight difference in values of stress could be due to the vaguely larger tip diameter (0.26) of Trunatomy files in relation to that of 2shape files (0.25).

It is to be noted that value of stress at the coronal level was different, Trunatomy files produced a stress of 453.59 MPa and 2shape files generated a stress of 456.59 MPa, it should be taken into consideration. At this level Trunatomy files exerted less stress compared to 2shape files, the justification for it can be ascribed to the regressive taper of Trunatomy files.

On the other hand F360 files had produced maximum amount of stress generation (460.92 MPa) among all the other tested groups; apical - 463.59 MPa, middle- 460.59 MPa, coronal- 458.59

MPa. The reason could be due to its S shaped cross-section, Parashos et al stated that the fracture rate of this type of cross section is more compared to the fixed taper triangle [23].

The justification for this increased value of stress could be due to its manufacturing, All the above three mentioned tested files are thermomechanical heat treated whereas f360 files are developed from conventional superelastic NiTi alloy. It is mentioned in the literature that the Af temperature for most conventional superelastic NiTi files is at or below room temperature. As a result of which these conventional NiTi files remains in an austenite phase throughout clinical use. These files display resistance against torsional stress but do not show resistance against cyclic stress. According to Vaudt J et al, upon instrumentation when they tend to regain its shape during instrumentation, they produce uneven stress on curved root canal wall. [93,94,95]

After doing the statistical analysis it was found that the amount of stress generated by all four tested novel NiTi was not significant. The stress was found to be least at the coronal part of root canal followed by middle part, the stress was found to be maximum at the apical area. Overall, the mean of stress generation was found to be maximum for Group C i.e., 460.92 and minimum for group B i.e., 454.02.

The value of mean stress at the coronal level was found to be maximum for group C-458.59 followed by Group D-456.59 and group A-453.59. The least amount of stress was generated by Group B-452.35

The mean stress level at the middle part of the root canal was intermediatory, it was minimum for Group B -453.35and maximum for group C-460.59; for group A-458.59 and group D-457.59. The stress was found to be maximum at the apical portion of the root canal, the maximum stress was produced by Group C-463.59, followed by group D-458.59 and group A-461.59 and the minimum stress was generated by Group B-456.35.
Here, a simulated root canal was used, which was in accordance with the study carried out by Chevalier et al. This method does not rely on an externally applied force, as was the case in earlier studies for producing stress, and it relates both bending and torsion to create a combined loading and to provide a fixed deflection at 45 degrees.

The explanation for the rise in stress from the middle to the apical area after the virtual instrumentation in this investigation may be related to a reduction in the radius of curvature of the root canal model. In this investigation, root radii of 6 mm were chosen with moderate curvature in accordance with the classification by Balani et al. [97] (Small radius -r 4 mm: Severe curvature, Intermediary radius -r > 4 and r 8 mm: Moderate curve, large radius r > 8 mm: mild curvature). In their research, Necchi et al. and Petrini et al. [98,99] employed comparable radii.

The pressure applied by the file tip from the restoring force of the instrument, followed by curvature areas that were subjected to a higher level of stress throughout shaping of the simulated root canal due to the flexure of the files at the site of curved area and due to its narrower dimensions, may be the cause of the increased value of Von Mises stress at the apex. As opposed to the region of the canal that is the widest and showing the least Von Mises stress.

Within the constraints of this research According to the standards of this in vitro investigation, the XP Endoshaper files produced the least stress and F360 files produced maximum stress when compared to other evaluated groups on the dentinal wall of a simulated root canal. The findings of this study indicate that post-machining thermomechanical heat treatment of endodontic files may be a more effective method than conventional NiTi files for reducing the risk of instrument breakage due to stress during the shaping of curved root canals. Because of this, producers continue to try to alter the mechanical behavior of endodontic files in order to increase clinical effectiveness and tool safety.

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ANNEXURE-I

Babu Banarasi Das University
Babu Banarasi Das College of Dental Sciences,
BBD City, Faizabad Road, Lucknow – 226028 (INDIA)

Dr. Lakshmi Bala
Professor and Head Biochemistry and
Member-Secretary, Institutional Ethics Committee

Communication of the Decision of the VIIIth Institutional Ethics Sub-Committee

IEC Code: 31 **BBDCODS/03/2020**

Title of the Project: Comparative evaluation of stress distribution against root canal wall at three different levels by using trunatomy, 2Shape, XP endo shaper, F360 files- A finite element analysis: An in vitro study.

Principal Investigator: Dr Rimjhim Singh **Department:** Conservative Dentistry and Endodontic

Name and Address of the Institution: BBD College of Dental Sciences Lucknow.

Type of Submission: New, MDS Project Protocol

Dear Dr Rimjhim Singh,

The Institutional Ethics Sub-Committee meeting comprising following four members was held on 07th April, 2022.

1.	Dr. Lakshmi Bala Member Secretary	Prof. and Head, Department of Biochemistry, BBDCODS, Lucknow
2.	Dr. Amrit Tandan Member	Prof. & Head, Department of Prosthodontics and Crown & Bridge, BBDCODS, Lucknow
3.	Dr. Rana Pratap Maurya Member	Reader, Department of Orthodontics, BBDCODS, Lucknow
4.	Dr. Akanksha Bhatt Member	Reader, Department of Conservative Dentistry & Endodontics, BBDCODS, Lucknow

The committee reviewed and discussed your submitted documents of the current MDS Project Protocol in the meeting.
The comments were communicated to PI thereafter it was revised.

Decisions: The committee approved the above protocol from ethics point of view.

Forwarded by:

Lakshmi Bala

(Dr. Lakshmi Bala)
Member-Secretary
IEC

Member-Secretary
Institutional Ethic Committee
BBD College of Dental Sciences
BBD University
Faizabad Road, Lucknow-226028

(Dr. Puneet Ahuja)
Principal
BBDCODS

PRINCIPAL
Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow-226028

ANNEXURE-II

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES
(FACULTY OF BBD UNIVERSITY), LUCKNOW

INSTITUTIONAL RES EARCH COMMITTEE APPROVAL

The project titled **"Comparative Evaluation of Stress Distribution Against Root Canal Wall at Three Different Levels by Using Trunatomy, 2 Shape, XP Endo Shaper, F360 Files- A Finite Element Analysis: An In Vitro Study"** submitted by **Dr Rimjhim Singh** Post graduate student from the **Department of Conservative Dentistry and Endodontics** as part of MDS Curriculum for the academic year 2020-2023 with the accompanying proforma was reviewed by the Institutional Research Committee present on **11th October 2021** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.

Prof. Vandana A Pant
Co-Chairperson

Prof. B. Rajkumar
Chairperson

ANNEXURE-III

eurofins | Spectro

Format No: ES/F/02
Issue No 03, Issue Date 01-11-2022
Rev. No 00, Rev. Date: __-__-____

TEST REPORT

Test Report Issued To:

MOHD. SAIF RAIS

88/99,
CHAMANGANJ,
KANPUR, UTTAR PRADESH - 208001,
INDIA

Test Report No: K230105002/K230105002-10
Issue Date: 14-Jan-2023
Sample Booking/Receipt Date: 05-Jan-2023
Test Start Date: 11-Jan-2023
Test Completion Date: 14-Jan-2023

Customer Relationship Number 71974

Sample Description :
ROTARY FILE- 01

Customer Reference No :
DATED 05.01.2023

Kind Attention : MOHD. SAIF RAIS
E-Mail : saif.rais12@gmail.com
Contact No: 8564036818

Sample Condition : Good
Sample Quantity (Approx) : 1 - Nos
Sample Size (Approx) : " - "

SAMPLE NOT DRAWN BY OUR LABORATORY. THE RESULTS RELATE ONLY TO THE ITEMS TESTED

Digitally signed by PRAVEEN SINGH
Date: 2023.01.14 12:10:12 +05:30
Report Issued By

Authenticity of report can be verified by mail at verification@spectrolab.in
This is a Digitally Signed Report and hence doesn't require Physical Signature.

Legal Entity: Spectro Analytical Labs Private Limited (formerly Spectro Analytical Labs Limited), CIN : U74220DL1999PTC092698
(part of Eurofins Scientific SE)
E-41, Okhla Industrial Area, Phase-II, New Delhi-110020 (India)
+91-11-40522000, 41611000 | www.spectro.in | care@spectro.in

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Page 1 of 3

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Format No: ES/F/02
Issue No: 03, Issue Date: 01-11-2022
Rev. No: 00, Rev. Date: __-__-____

Report No. K230105002/K230105002-10

TEST REPORT

Discipline-Chemical
Group -Metal and alloys

ID No –K230105002-1

Density Test Result			
S. No	**Test Name**	**Result**	**Test Method**
1.	Density, gm/cc at 35 ° C	6.44	IS:5642-1991

ANNEXURE-III

eurofins | Spectro

Format No: ES/F/02
Issue No:03, Issue Date:01-11-2022
Rev. No:00, Rev. Date: __-__-____

TEST REPORT

Test Report Issued To:

MOHD. SAIF RAIS

88/99,
CHAMANGANJ,
KANPUR, UTTAR PRADESH - 208001,
INDIA

Test Report No:	K230105002/K230105002-20
Issue Date:	14-Jan-2023
Sample Booking/Receipt Date:	05-Jan-2023
Test Start Date:	11-Jan-2023
Test Completion Date:	14-Jan-2023

Customer Relationship Number 71974

Sample Description :
ROTARY FILE- 02 (ZIG ZAG BLUE)

Customer Reference No :
DATED 05.01.2023

Kind Attention : MOHD. SAIF RAIS
E-Mail : saif.rais12@gmail.com
Contact No: 8564036818

Sample Condition : Good
Sample Quantity (Approx) : 1 - Nos
Sample Size (Approx) : " - "

SAMPLE NOT DRAWN BY OUR LABORATORY. THE RESULTS RELATE ONLY TO THE ITEMS TESTED

Digitally signed by PRAVEEN SINGH
Date: 2023.01.14 12:14:15 +05:30
Report Issued By

Authencity of report can be verified by mail at verification@spectrolab.in
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Format No: ES/F/02
Issue No: 03, Issue Date: 01-11-2022
Rev. No: 00, Rev. Date: __-__-____
Report No. K230105002/K230105002-20

TEST REPORT

Discipline-Chemical	
Group	-Metal and alloys

ID No –K230105002-2

Density Test Result			
S. No	**Test Name**	**Result**	**Test Method**
1.	Density, gm/cc at 35 ° C	6.45	IS:5642-1991

ANNEXURE-IV

Formulas used in statistical analysis.

Mean

$$\overline{X} = \frac{\Sigma X}{N}$$

Where:

$\overline{X}$ = the data set mean

$\sum$ = the sum of

X = the scores in the distribution

N = the number of scores in the distribution

Range

$$range = X_{highest} - X_{lowest}$$

Where:

$X_{highest}$ = largest score

X_{lowest} = smallest score

Variance

$$SD^2 = \frac{\Sigma(X - \overline{X})^2}{N}$$

The simplified variance formula

$$SD^2 = \frac{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}{N}$$

Where:

SD^2 = the variance

$\sum$ = the sum of

X = the obtained score

$\overline{X}$ = the mean score of the data

N = the number of scores

Standard Deviation (N)

$$SD = \sqrt{\frac{\Sigma(X-\overline{X})^2}{N}}$$

The simplified standard deviation formula

$$SD = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}{N}}$$

Where:

SD = the standard deviation

$\sum$ = the sum of

X = the obtained score

$\overline{X}$ = the mean score of the data

N = the number of scores

One Way ANOVA

The formula for the one-way **ANOVA** *F*-test statistic is

$$F = \frac{\text{between-group variability}}{\text{within-group variability}}.$$

The between-group variability" is.

$$\sum_{i=1}^{K} n_i(\bar{Y}_{i\cdot} - \bar{Y})^2/(K-1)$$

where Y_i denotes the sample mean in the i^{th} group, n_i is the number of observations in the i^{th} group, $\bar{Y}$ denotes the overall mean of the data, and K denotes the number of groups.

The "within-group variability" is.

$$\sum_{i=1}^{K}\sum_{j=1}^{n_i}(Y_{ij} - \bar{Y}_{i\cdot})^2/(N-K),$$

where Y_{ij} is the j^{th} observation in the i^{th} out of K groups and N is the overall sample size.

Post Hoc Tukey Test

Tukey's range test, also known as the Tukey's test, Tukey method, Tukey's honest significance test, or Tukey's HSD (honestly significant difference) test,[1] is a single-step multiple comparison procedure and statistical test. It can be used on raw data or in conjunction with an ANOVA (post-hoc analysis) to find means that are significantly different from each other. Named after John Tukey, it compares all possible pairs of means, and is based on a studentized range distribution (q) (this distribution is similar to the distribution of t from the t-test. Tukey's test compares the means of every treatment to the means of every other treatment; that is, it applies simultaneously to the set of all pairwise comparisons $\mu_i - \mu_j$ and identifies any difference between two means that is greater than the expected standard error.Tukey's test is based on a formula very similar to that of the t-test. In fact, Tukey's test is essentially a t-test, except that it corrects for family-wise error rate.

The formula for Tukey's test is:

$$q_s = \frac{Y_A - Y_B}{SE},$$

where Y_A is the larger of the two means being compared, Y_B is the smaller of the two means being compared, and SE is the standard error of the sum of the means. This q_s value can then be compared to a q value from the studentized range distribution. If the q_s value is *larger* than the critical value obtained from the distribution, the two means are said to be significantly different at level.

ANNEXURE -VI

Master Chart

GP	MIDDLE	APICAL	CORONAL
GP A	459.18	462.18	457.18
GP A	458.91	461.91	456.91
GP A	456.72	459.72	454.72
GP A	460.47	463.47	458.47
GP A	462.19	465.19	460.19
GP A	459.86	462.86	457.86
GP A	459.49	462.49	457.49
GP A	456.08	459.08	454.08
GP A	457.63	460.63	455.63
GP A	458.14	461.14	456.14
GP A	457.61	460.61	455.61
GP A	455.04	458.04	453.04
GP A	458.44	461.44	456.44
GP A	459.79	462.79	457.79
GP A	459.24	462.24	457.24
GP B	451.81	454.81	449.81
GP B	452.23	455.23	450.23
GP B	452.43	455.43	450.43
GP B	452.62	455.62	450.62
GP B	452.82	455.82	450.82
GP B	453.01	456.01	451.01
GP B	453.19	456.19	451.19
GP B	453.38	456.38	451.38
GP B	453.56	456.56	451.56
GP B	453.73	456.73	451.73
GP B	453.91	456.91	451.91
GP B	454.08	457.08	452.08
GP B	454.24	457.24	452.24
GP B	454.41	457.41	452.41
GP B	454.84	457.84	452.84
GP C	461.18	464.18	459.18
GP C	460.91	463.91	458.91

GP C	458.72	461.72	456.72
GP C	462.47	465.47	460.47
GP C	464.19	467.19	462.19
GP C	461.86	464.86	459.86
GP C	461.49	464.49	459.49
GP C	458.08	461.08	456.08
GP C	459.63	462.63	457.63
GP C	460.14	463.14	458.14
GP C	459.61	462.61	457.61
GP C	457.04	460.04	455.04
GP C	460.44	463.44	458.44
GP C	461.79	464.79	459.79
GP C	461.24	464.24	459.24
GP D	456.18	459.18	454.18
GP D	455.91	458.91	453.91
GP D	453.72	456.72	451.72
GP D	457.47	460.47	455.47
GP D	459.19	462.19	457.19
GP D	456.86	459.86	454.86
GP D	456.49	459.49	454.49
GP D	453.08	456.08	451.08
GP D	454.63	457.63	452.63
GP D	455.14	458.14	453.14
GP D	454.61	457.61	452.61
GP D	452.04	455.04	450.04
GP D	455.44	458.44	453.44
GP D	456.79	459.79	454.79
GP D	456.24	459.24	454.24

ANNEXURE-V

Ouriginal

Document Information

Analyzed document	RIMJHIM SINGH.docx (D158405481)
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Submitter email	sandeepdubey.mds@bbdu.ac.in
Similarity	0.9%
Analysis address	sandeepdubey.mds.bbduni@analysis.urkund.com

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Entire Document

INTRODUCTION Mechanical preparation of the root canal system is one of the most important steps in root canal treatment procedure as it aids to optimize the shape of the root canal for disinfection and for attaining 3-D obturation. Therefore, for the success of endodontic procedure suitable instruments and precise instrumentation by means of biological and mechanical preparation are of utmost importance. [1] Realizing the importance of mechanical preparation in an endodontic procedure, Edward Maynard in the year 1938 designed the first endodontic instrument preliminary made by the spring of a clock, shortly afterwards the primary endodontic instruments made up from carbon steel were designed. Instrument made from Carbon steel were reported to be stiffer and had a hardness more than dentine but when they were used for instrumentation in curved canals, they tend to cause numerous iatrogenic errors. The most common errors were the deformation of the apical foramen, anatomical deviation of the canal and perforations and they had a major disadvantage of being highly corrosive in nature. To overcome these problems, they were replaced by stainless steel instruments, which are in practice even at present because of the advantages they offer. These instruments are rigid in nature, and they are recognised to have superior strength, good cutting efficiency and they offer little flexibility during instrumentation in curved canals. However, despite having numerous advantages they possess a risk of producing iatrogenic errors.

Sandeep Dubey