# A COMPARATIVE STUDY ON FINITE ELEMENT MODELS OF HERO, PROTAPER, MTWO & QUANTEC ENDODONTIC FILE SEGMENTS

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**Abstract:** Endodontic files are used for shaping and cleaning purpose during the root canal treatment of infected tooth. These files are made from nickel-titanium orthodontic wire alloy that has high strength and more flexibility as compared to stainless steel. The aim of present research work is to study flexibility of Hero, ProTaper, Mtwo and Quantec endodontic file segments when they are subjected to torsion and bending loads and to identify most flexible endodontic file. Non linear material behaviour is considered during the analysis. Various results are obtained in form of equivalent von-Mises stress, which are presented in the form of contours and charts. Discussion is presented on suitability of cross section under bending and torsional loads and effect on flexibility of endodontic file.

**Keywords:** Endodontic files, Root canal treatment, finite element method, Nitinol

**Introduction:** Endodontic files are surgical instruments used by dentist while performing root canal treatment. These tools are particularly used to clean and shape the root canal of infected tooth. These files are made from nickel-titanium orthodontic wire alloy which facilitates instrumentation of curved canal. Nickel-titanium (NiTi) rotary instruments have become a mainstay in clinical endodontics because of their exceptional ability to shape root canals with fewer procedural complications. NiTi has high strength and is very flexible, but firm enough to resist excessive bending and torsion as compared to stainless steel. Literature shows that the files made from NiTi are more flexible than stainless steel. The flexibility of endodontic files not only depends on the material but also on the geometry. There are various NiTi files available that are made from different cross sections.

Finite Element Method is widely used to analyze the behavior of endodontic files subjected to various loading conditions. A study by N. Raj Vikram [1] illustrates that a variety of sophisticated procedures and equipment are used in the field of dentistry, which are based on basic concepts of engineering. The finite element analysis shows areas of internal stress concentration and consequently predictions can be made of possible failure. A study by Wakabayashi [2] illustrates that the nonlinear Finite Element analysis has become an increasingly powerful approach to predict stress and strain within structures in a realistic situation that cannot be solved by conventional linear static models. Further development of the nonlinear FEM solutions is encouraged to gain a wide range of mechanical solutions that would be beneficial for dental and oral health science.

Several researchers have analyzed various file systems and compared these files based on results obtained using finite element method. Walia and others [3] presented the investigation of the bending and torsional properties of Nitinol root canal files. It was observed that the Nitinol files have two to three times more elastic flexibility in bending and torsion, as well as superior resistance to torsional fracture, compared with stainless steel files manufactured by the same process. A study by Berutti et al. [4]

shows comparison of ProTaper and ProFile endodontic file system using finite element procedure. The ProFile model was found to be more elastic than the ProTaper model. Under equal loads, the ProTaper model showed lower and better distributed stresses than the ProFile model. A study by Diogo Montalv [5] compares two NiTi rotary instruments with similar geometries and equal cross sections, ProFile GT (GT) and a GT Series X (GTX). It was found that GTX file is more flexible and capable of stress relief at the most critical section as compared to GT file.

Khapre et al. [6] compared two endodontic file systems namely ProTaper and Twisted using finite element approach. Full length models were analyzed under similar loading conditions and it was found that twisted file model shows greater displacement as compared to ProTaper file model. Force-displacement curve also showed that the Twisted file model is more flexible than the ProTaper file model. Another study by Khapre [7] presents comparison of three file segment namely Hero, ProTaper and Mtwo file systems. Finite element study carried out on these three file models shows that the Mtwo file system is the most flexible file as compared to Hero and ProTaper file system.

The aim of this study is to compare four file systems namely Hero, ProTaper, Mtwo and Quantec using finite element analysis. It also aims at discovering the most flexible file among four files under consideration based on finite element analysis.

**Table 1: Geometric properties of endodontic file system**

| Geometric Properties | Hero | ProTaper | Mtwo | Quantec |
|---|---|---|---|---|
| Area ($mm^2$) | 0.088977 | 0.090798 | 0.0723 | 0.060709 |
| Length of file (mm) | 1.8 | 1.8 | 1.8 | 1.8 |
| Volume (mm^3) | 0.16023 | 0.16342 | 0.12913 | 0.10947 |
| Outer Radius (mm) | 0.2 | 0.2 | 0.2 | 0.2 |
| Core Radius (mm) | 0.1439 | 0.1551 | 0.1118 | 0.12247 |
| Nodes | 3358 | 3312 | 2159 | 19118 |
| Elements | 2610 | 2632 | 396 | 4005 |
| Mass Moment of Inertia Ix | 2.8233e-013 | 2.8799e-013 | 2.2555-013 | 0.19897 |
| Mass Moment of Inertia Iy | 2.8233e-013 | 2.8799e-013 | 2.2556-013 | 0.19895 |
| Mass Moment of Inertia Iz | 1.4784e-014 | 1.5163e-014 | 1.0099-014 | 1.1056e-002 |

**Finite element analysis**

Initially four cross sections of Hero, ProTaper, Mtwo and Quantec endodontic files are created in form of sketch in ANSYS modeler feature. These cross sections (shown in Figure 1) are taken from literature [7] and created such that they can be inscribed in a circle of 0.4 mm diameter. These sketches are then converted to 3D model using sweep command. In this process, the sketch is extruded over the length of 1.8 mm with full 360° rotation. These models are then imported to Design Simulation feature of ANSYS where they are discretized using 3D element to generate finite element model. Medium size mesh is used while generating finite element model. Geometric properties of these finite element models are shown in Table 1.

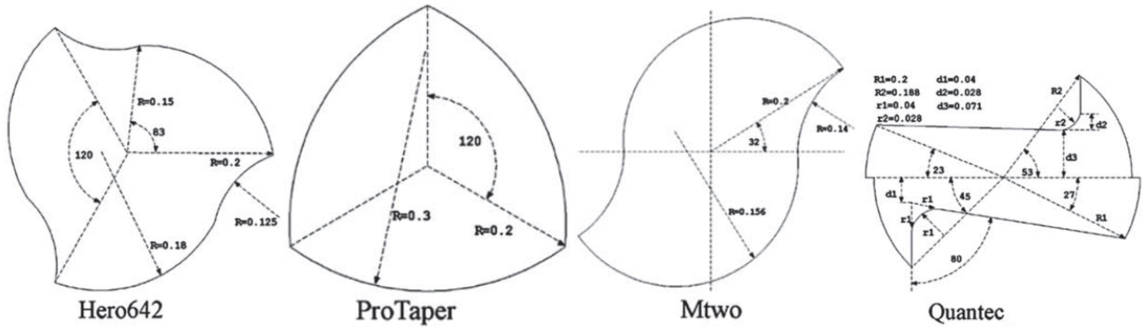
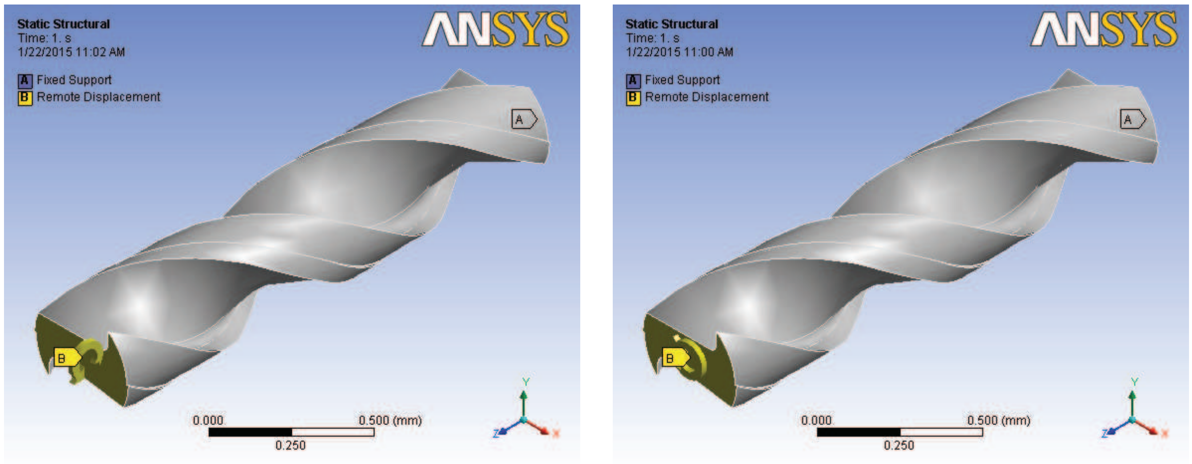


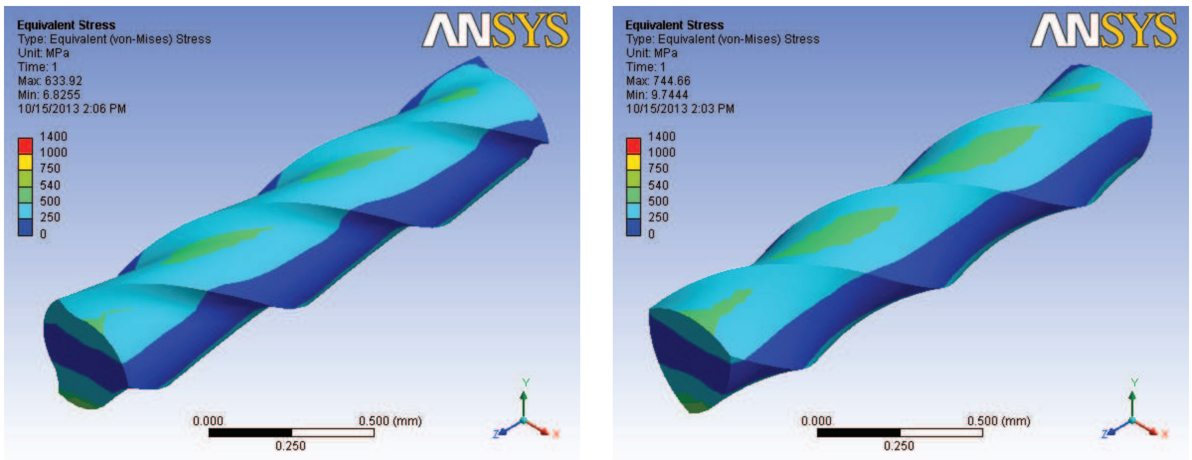
Figure 1: Cross sections of endodontic files



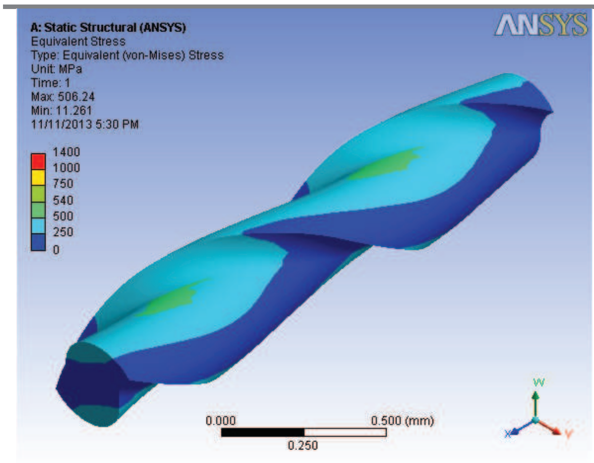
(a) Bending load (b) Torsional load

Figure 2: Bending and Torsional loads on Quantic Endodontic file

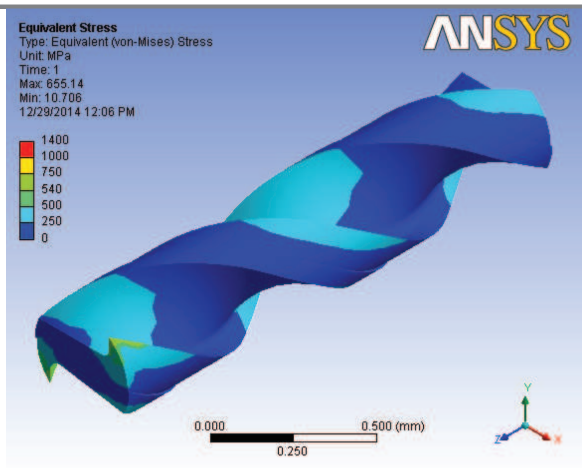
Finite element analysis is carried out on these models for bending and torsional loading. Bending effect is simulated by applying rotation of 20° about x axis at one end and other end is kept fixed. Similarly, torsional effect is simulated by applying 20° rotation about z axis at one and other end is kept fixed (see Figure 2). Non-linear material effect is considered by providing multilinear stress-strain curve of NiTi. Results of simulation are plotted in form of equivalent von-Mises stress for all finite element models under torsional and bending loading conditions. The distribution of stress in bending is shown in Figure 3 and stress distribution in torsion is shown in Figure 4.



(a) (b)

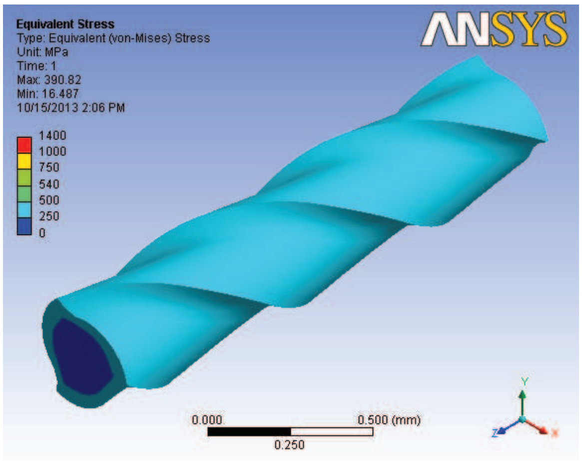



(c)

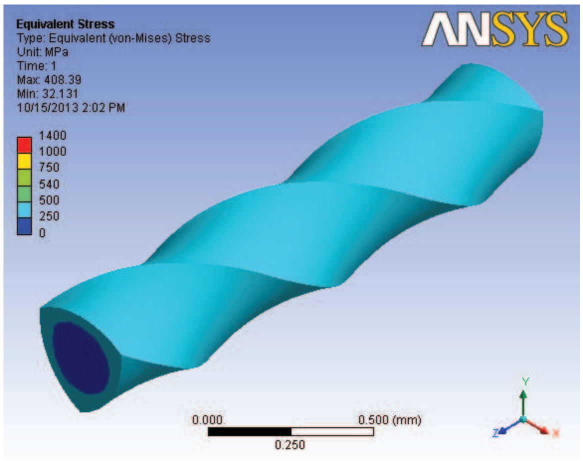



(d)

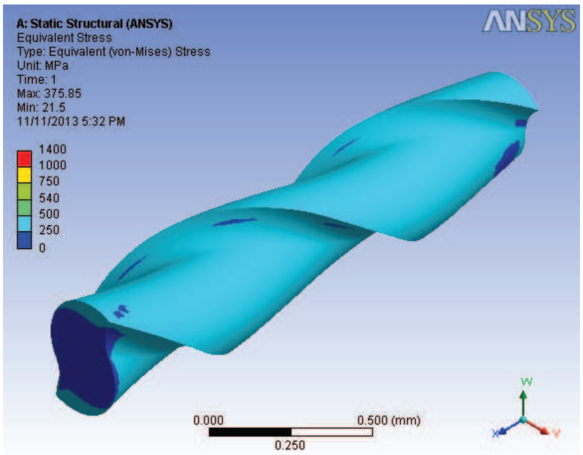
Figure 3: Von-Mises stresses in (a) Hero File (b) ProTaper (c) Mtwo (d) Quantec model subjected to bending (rotation about x = 20°)



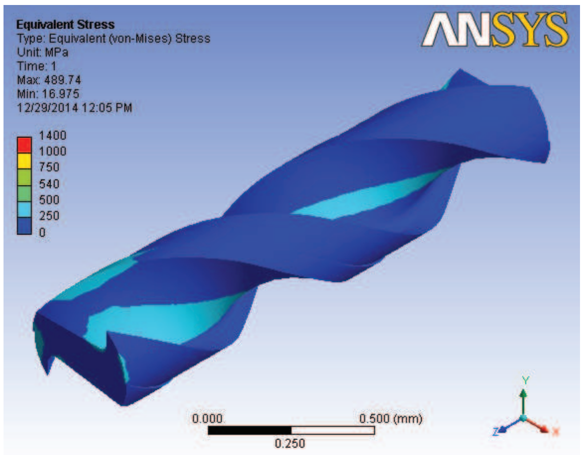

(a)




(b)




(c)




(d)

Figure 4: Von-Mises stresses in (a) Hero File (b) ProTaper (c) Mtwo (d) Quantec model subjected to torsion (rotation about z = 20°)

Transient analysis is also carried out to measure the rigidity of these file models. In this case, all file models are subjected to transient torsional loading at one end and other end is kept fixed. Reaction at supporting end is measured in terms of moments and rigidity is calculated at every time step. Figure 5 shows graph plotted between moment and rigidity for four file models.

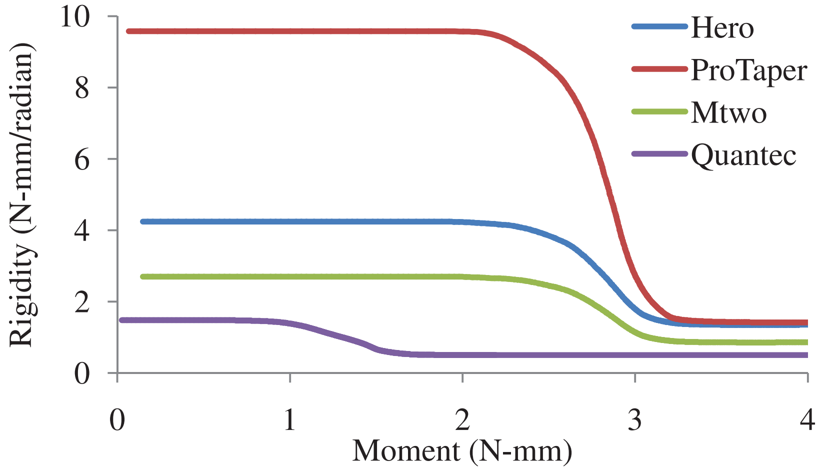



Figure 5: Rigidity Curve

**Discussion :** From Table 1, it can be seen that Quantec file model has lowest cross sectional area and volume as compared to other file models. It was also observed that other geometric properties like core radius and mass moment of inertia is also less for Quantec file model as compared to all models. When these models were subjected to rotation of 20° along x-direction (bending), the value of maximum von-Mises stress are generated in Hero, ProTaper, Mtwo and Quantec are 633.92 MPa, 744.66 MPa, 506.24 MPa and 655.14 MPa respectively (Figure 3). In case of torsional loading (Figure 4), these values are found to be 390.82 MPa, 408.39 MPa 375.85 MPa and 489.74 MPa respectively for Hero, ProTaper, Mtwo and Quantec file models. These stress values indicates that the Quantec file model is subjected to greater stresses when subjected to bending and torsional loads as compared to other file models. Smaller cross sectional area and lesser moment of inertia is mainly responsible for higher values of stresses in Quantec file model. It was also observed that the material of Quantec file model is in the martensitic stage resulting in higher deformation. This clearly indicates that Quantec file model is more flexible as compared to other file models.

Rigidity curve shown in Figure 5 clearly indicates that the Quantec file model exhibits lowest rigidity and ProTaper file models shows highest rigidity. This also confirms that the Quantec file model is the most flexible file model. It can also be seen that the Mtwo file model has slightly higher rigidity as compared to Quantec file model.

**Conclusion**Finite element analysis on four endodontic file segments is carried out and results are presented in this study. Based on results, following conclusions may be drawn.

1. From the stress distribution diagrams (Figure 3 and 4) of file segment, it can be observe that von-Misses stress distribution is complex when these models are subjected to bending as well as torsional loads.
2. From Figure 3 it was observed that, the stress in the flute regions are on higher side and their magnitude is 540MPa which indicates that the material is in martensitic phase under bending loads
3. From Figure 4, under torsional loads it can be observed that the stress is below 500Mpa hence the material of file is in austenitic phase. It was also observed that the stresses

are less at the central region that gradually increases towards exterior surface of file.

4. From the rigidity curve (Figure 5), the mmaximum rigidity of ProTaper, Heroshaper, Mtwo and Quantec endodontic file can be observed at 9.7, 4.22, 2.72 and 1.48 N-mm/rad respectively. Hence ProTaper is most rigid file and Quantec is most flexible file.
5. Rigidity curve shows horizontal behavior when in austenitic phase then sudden drop in rigidity is observed, this phase is the transition phase. Further the curve shows horizontal behaviour which indicates martensitic phase of the NiTi.
6. Based on the result obtained from finite element analysis, it can be concluded that the Quantec file model is most flexible as compared to Hero, ProTaper and Mtwo file model.

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