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The Influence of NiTi File Design Features on the Apically Extruded Debris During Endodontic Treatment
A concise reviews

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Abstract

Expelling debris and irrigating solution during cleaning and shaping is an inevitable incidence during endodontic treatment. Any irritation of the periapical area can initiate a flareup situation which can affect the prognosis of endodontic treatment. Thus, Controlling the amount of apically extruded debris increases the success rate of endodontic treatment. Furthermore, the incidence of flare-ups during endodontic treatment can be reduced by selecting the NiTi file system with the lowest apically extruded debris. Despite the advances in endodontic file design that aims to conservatively prepare the apical third of root canals, extruding debris toward the apex is still a non-eliminated issue with all instrumentation systems. The purpose of this review is to identify the effect of each design characteristic on the amount of debris expelled beyond the apical foramen. The strategy of this review focused on reviewing specific electronic databases, time, keywords, and standardized methods. Literature reviewing included studies from almost 20 years ago and up to 2022. In conclusion, the design of the NiTi endodontic file has a significant impact on the amount of apically extruded debris.

Keywords: NiTi endodontic file; Apically extruded debris; Design features; Endodontic treatment.

1. Introduction

Shaping and cleaning are the most critical steps in root canal therapy. The main objective of these steps is to eliminate irritants and bacterial by-products as much as possible and create a continuously tapered funnel-shaped canal that will act as a matrix in which the obturating material will be accommodated(E. Schäfer et al., 2006).

Dentinal shavings, microorganisms, pulp tissue, and irrigation solutions may be pushed apically instead of flushed coronally during the shaping procedure. Debris extruded apically during instrumentation, defined as a "worm of necrotic debris," which can cause an inflammatory reaction without bacterial contamination (Seltzer and Naidorf, 2004). Moreover, when contaminated debris is pushed apically, disrupting the existing microbial balance, an immunological response will be provoked to regain the previous equilibrium (Singbal et al., 2017). Clinically, apical extrusion of debris results in the formation of an immune complex, consequently leading to flare-ups, which affects the prognosis of root canal therapy (Tanalp, 2022). Gaining an insight into the mechanical properties of NiTi endodontic files and understanding what happens when the file is cutting through a canal wall is highly emphasized to make a better decision for a successful root canal treatment (Agarwal S, 2018). In apical extrusion research, the endodontic equipment and irrigation systems are continually being examined for their potential to create flare-up situations by extruding debris and bacterial products toward the apical (Tanalp, 2022). This parameter is continuously evaluated with the advent of endodontic file systems. This review aims to explore the influence of file design characteristics on the amount of debris extruded apically.

2. Reviewing methodology

Four different electronic databases were employed (PubMed, Elsevier, Google Scholar, and Scopus). This review included dentistry research papers as well as endodontic articles. Only publications written in English were chosen. Literature reviewing included studies from almost 20 years ago and up to 2022. Research articles that used human teeth, working length, standardization of apical foramen size, randomization, blinding to reduce bias, and Myers and Montgomery methods were included. The keywords that were used included (Apically extruded debris, endodontic treatment, NiTi file design, Cross-section, Tip, Taper, Helical angle, Flute dimensions, Pitch, and Core size). After the search was completed, the titles were evaluated, and only papers that did fit the inclusion criteria were considered.

3. Mechanical factors

Apical extrusion of debris is a multifactorial problem. Mechanical factors that are related to the instruments used during cleaning and shaping have been well studied and mentioned in the literature, such as endodontic file design, file number, and kinematics (Nevares et al., 2015). In addition, the number of contributing physical factors, such as apical foramen size, working length, root curvature, and the design of the coronal access cavity, also has been considered to affect the amount of apically expelled debris (Tanalp, 2022) According to the literature, the mechanical properties of the endodontic file are governed significantly by microscopic variations of its design. Thus, cutting efficiency, flexibility, and torsional strength dictate how the file behaves inside the canal (Edgar Schäfer, 2001). Chip space and cleanliness of the canal were directly linked to the cutting efficiency of the endodontic file in multiple studies (Bürklein and Schäfer, 2012; Kim et al., 2009; Melo et al., 2008) . Several studies have concluded that file design can be considered an influential factor in the amount of apically extruded debris (Caviedes-Bucheli et al., 2016; Kharouf et al., 2022; Koçak et al., 2013). Although, a study in which Reciproc instruments (VDW, Munich, Germany) were compared to evaluate the blue heat treatment revealed a positive influence of more flexible alloy on the amount of apically extruded debris (Doğanay Yıldız and Arslan, 2019) .

3.1 Cross Section

It is the configuration of the endodontic file when viewed from a cross-sectional plane. This design element has significantly influenced the file's behavior (Zhang et al., 2010). A recent study by Kharouf et al. (Kharouf et al., 2022) evaluated apically extruded debris using different files' geometry, in which the amount of debris was significantly higher in ProTaper Next (Dentsply-Maillefer, Switzerland) and WaveOne (Dentsply-Maillefer, Switzerland) that both demonstrate a rectangular cross-section; compared to One Curve (MicroMega, France) and One Reci (MicroMega, France) that have S-shaped and triple helix cross-sections respectively. They concluded that the main parameter determining the amount of debris pushed apically was the cross-section of the file. Another study by Amaral et al., that compared two reciprocating systems with similar S-shaped cross-sections and resulted in no significant difference between them (Amaral et al., 2019).

Moreover, a study by Santa-Rosa et al., that suggested as the cross-sectional area of a file decreases, its cutting efficiency increases. It was attributed to the increase in free space available between the file and canal walls, allowing debris to be flushed coronally while reducing the amount of apical propagation of debris (Santa-Rosa et al., 2018). Previous research has revealed that modifying the cross-section of endodontic files from square to triangular or rhomboid shape increased their cutting efficacy and flexibility which can influence the amount of debris produced during shaping (Edgar Schäfer, 1999). Furthermore, in 2001, a study done by Edger et al. explained that the change in file behavior is interrelated to changing its cross-section surface area (Edgar Schäfer, 2001).

3.2 Tip

The tip can be defined as the guiding part of the instrument, which leads the file through the canal. It could be active or passive, depending on whether it has a cutting or non-cutting end. Concurrently, endodontic files possess non-cutting tips to enhance the centering ability of the file and reduce the risk of transportation or ledge formation (Agarwal S, 2018). Previously, manual preparation using stainless-steel instruments with active cutting tips was associated with a substantial amount of debris (Caviedes-Bucheli et al., 2016). Apical extrusion of debris has been correlated to the design of the tip, as mentioned in a comparative study between One Shape (Micromega, France) with three-point contact at the tip of alternating triangular cross-section and Neo-Niti (Neolix, France) with the rounded gothic tip of a rectangular cross-section. One shape has extruded significantly more debris than the Neo-Niti system (Singbal et al., 2017) . Moreover, a study concluded that increasing the diameter of the instrument's tip results in more debris pushed beyond the apical foramen (Marchiori et al., 2021).

3.3 Taper

It is defined as the percentage of an increase in the instrument's diameter in each millimeter along its working part. Traditionally ISO hand instruments have had a standard 2% taper, indicating that the instrument diameter increases by 0.02 mm for every millimeter of its active part (Agarwal S, 2018). However, a modification in Niti files has increased taper ranging from 0.04 mm to 0.12 mm, and it can further be distinguished between having a constant or variable taper along their shank (Arias and Peters, 2022).

The increase in the taper of the endodontic instrument has been made possible due to the flexibility of Niti alloy compared to standard stiffer stainless-steel files. This paradigm shift in taper took place in the first generation of Niti systems, which continued in the second generation by adopting an alternating taper along the same file allowing it to prepare the canal asymmetrically as in the ProTaper file system (Arias and Peters, 2022). In a previous in-vitro study, the larger taper at the tip of the ProTaper Universal system of F2 file with 0.08 taper at its apical 3 mm has been suggested as an explanation of the increase of the amount of the apically extruded debris when compared to ProTaper Next system of X2 file with 0.06 taper at the same apical 3 mm (Capar et al., 2014) . Another study by Frota et al., in which the amount of apical debris and deformation of apical foramen was evaluated using different reciprocating systems; concluded that taper and alloy can be considered to influence the amount of debris and deformation beyond the apex (Frota et al., 2018). However, other studies revealed that increased taper may not affect the amount of apically extruded debris (Al Omari et al., 2022; Mustafa et al., 2021) .

3.4 Helical Angle

It is defined as the angle produced between the cutting edges and the instrument's long axis; additionally, the helical angle has a complex interrelationship with the cross-section and the number of flutes. All these factors combined will determine the cutting ability of the endodontic instrument, in addition to its metallurgy and debris removal capacity (Sch~ifer et al., 1999).

Maintaining a constant helical angle results in the accumulation of debris, while varying the flute angle along the same file facilitates debris removal coronally, and it is also suggested to prevent the file from being sucked inside the canal (Koch K, 2002). This knowledge allowed the production of files with constant taper while alternating their helical angle, such as K3 (Kerr, USA), resulting in a superior debris removal capability and less screwing-in effect

(Agarwal S, 2018). In addition, the RaCe file (FKG, Switzerland) has been designed uniquely to have an alternating helical angle by using spiraled and non-spiraled parts along the active length of file (Koch K, 2002). Alternating the helical angle was also a parameter suggested explaining the results obtained by comparing the Neolix Niti file with One shape. In this study, the better performance of the Neolix file was attributed to its variable helical angle versus the constant helical angle of the One Shape file (Singbal et al., 2017).

3.5 Flute Dimensions

It is the engraved part that represents the file's non-working surfaces, and these grooves determine the shape of the file's working surface (Grande et al., 2005). The characteristics of the flute dimensions, width, and length influence the file-cutting efficiency and debris accommodation capacity (Elmsallati et al., 2009). A previous study has concluded that flute length affects the capability of a file to eliminate debris, stating that short-pitch designs were associated with a decreased amount of debris extruded apically (Capar et al., 2014).

The HyFlex EDM (Figure 1) by (Coltene, Germany) has been assumed to cause more debris to extrude toward the apex when compared to ProTaper Next system (Figure 2); its unwinding feature causes its flute dimensions to change to a longer flute (Mustafa et al., 2021). Other studies have implied that fluting volume, determined by the flute's pitch and depth, can have a decisive factor in the extrusion of debris throughout increasing the capability of the flute to accommodate more debris (Diemer and Calas, 2004; Singbal et al., 2017).

A previous study had emphasized the influence of flute design over the file's behavior and stated that it could exceed in importance the cross-section of the file as a detrimental factor of the cutting efficacy and debris removal capability. The researcher has further explained that decreasing the number of flutes per millimeter will increase the space available to collect debris between the flutes, resulting in a better chance to avoid pushing debris apically and enhanced cutting efficacy (Felt et al., 1982). Research by Tanalp et al. indicated that the flute design of ProTaper is not effective in preventing the extrusion of debris beyond the canal (Tanalp et al., 2006).

3.6 Pitch

It is the distance between two adjacent leading edges along the working surface of the instrument (Jordan et al., 2021). Modifying this feature from constant into alternating threads along different parts of the instruments has been attempted to reduce the tendency of the file to be pulled down inside canal (Agarwal S, 2018). In addition, a study evaluated the effect of varying pitch length on the behavior of file, and the conclusion revealed that increasing the pitch length would result in less tendency to screwing-in (Diemer and Calas, 2004). The authors of other studies have further explained that if the screwing-in of the file is profound, this will increase the file’s propagation beyond the apex (J. H. Ha et al., 2015).

Moreover, the screwing-in effect may lead to an accidental extension of the file beyond the apical foramen, which can further increase the tendency to apical extrusion of debris beyond the canal (J.-H. Ha et al., 2016). The screwing-in forces of ProTaper Next and ProTaper Universal have been evaluated, and the forces associated with the latter demonstrated more screwing-in forces than the ProTaper Next system. This behavior has been attributed to metallurgy, cross-section, and pitch length of the different files tested, while motion has not been proven to significantly affect screwing in forces in this study (J.-H. Ha et al., 2016). Improving pitch and flute angle have been reported to enhance debris removability (Liang and Yue, 2022).

3.7 Core size

It is defined as the central, circular section of the file which is surrounded by the depth of the flutes circumferentially (Arias and Peters, 2022). Files with a slender central-core have been considered to increase file flexibility and increase safety and reducing unwanted over-instrumentation of the apical area (J.-H. Ha et al., 2016; Liang and Yue, 2022). A previous study has concluded that the superior shaping ability of XP-endo Shaper (FKJ, Switzerland) has been attributed to its nominal size with a thin adaptive core which might played a vital parameter in enhancing cleanliness than the other two solid core files tested (WaveOne Gold, HyFlex EDM) (Azim et al., 2018). In another study, BioRaCe (FKJ, Switzerland) compared with ProTaper Universal, the former extruded statistically the least amount of apical debris. The results were attributed to the smaller core size and non-convex cross-section of the BioRace system (Tasdemir et al., 2010). More over, in a study by Eliasz et al., a similar amount of debris extrusion resulted from ProTaper Next and WaveOne Gold (Figure 3) which was attributed to the similar cross sectional design of the two systems which in turn affect the diameter of files' core (Eliasz et al., 2021) . Contrstly, A previous study has concluded that ProTaper Next extruded significantly more debris apically than both WaveOne Gold and Twisted File Adaptive systems, and the results were attributed to the reciprocation motion (Dincer et al., 2017).

4. Conclusion

The design of the NiTi endodontic file has a significant impact on the amount of apically extruded debris.

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Conflict of Interest:

The authors declare that there was no conflict of interest.

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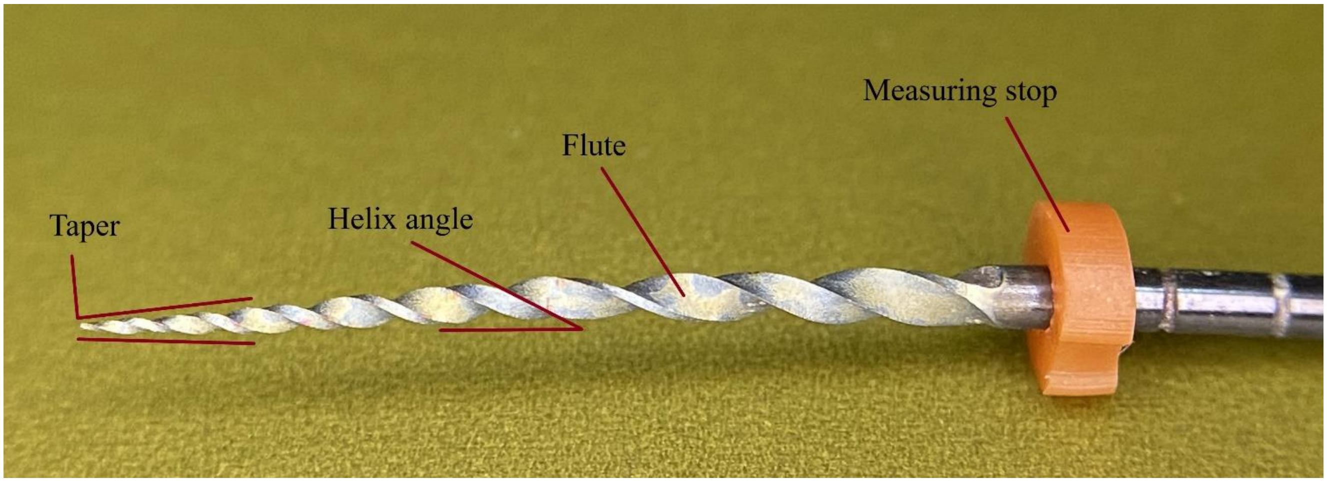

Figure 0. The HyFlex EDM file design.

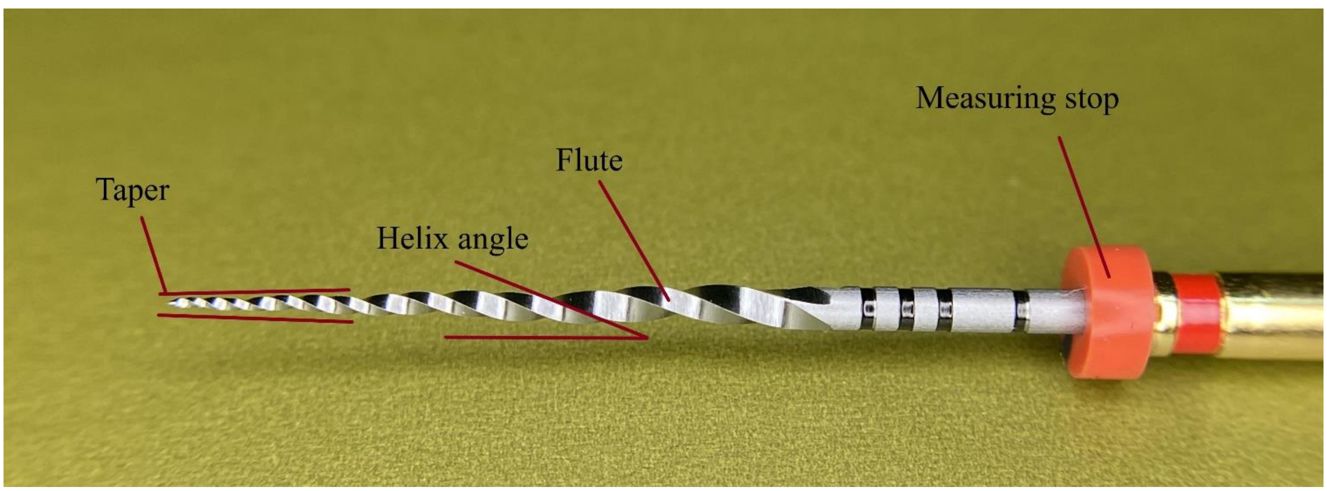

Figure 2. The ProTaper Next file design.

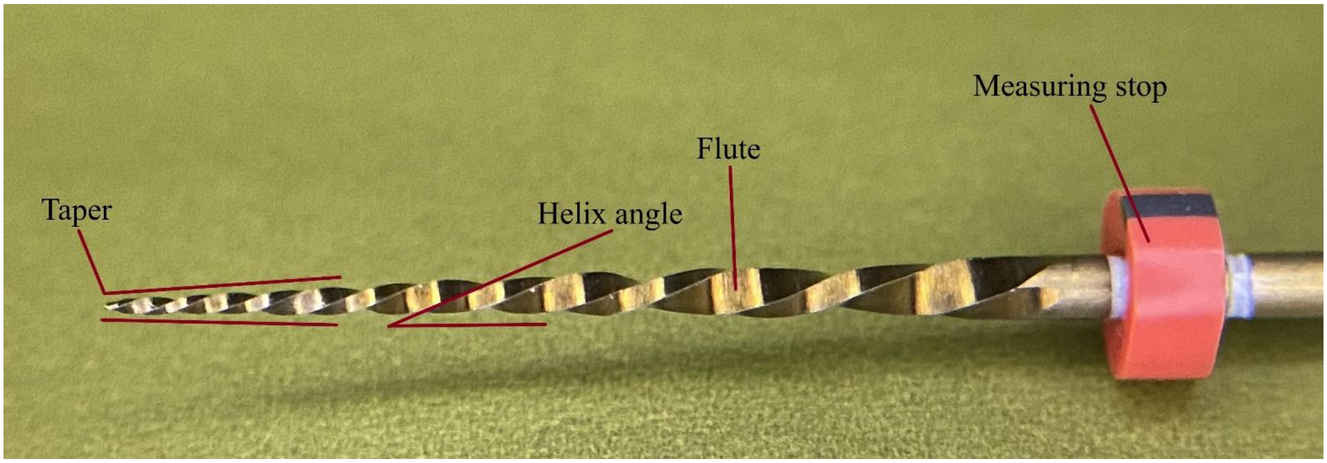

Figure 3. The WaveOne Gold file design