Deep shape in endodontics

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The goal of endodontic treatment is to prevent or cure, when present, lesions of endodontic origin, at times referred to as apical periodontitis. The role of bacteria in the pathogenesis of endodontic disease is well established, and therefore, it is critical to eradicate these pathogens by employing the highest level of presently developed standards.

This goal is clinically accomplished by shaping, cleaning, and filling root canal systems. These three pillars are often referred to as the endodontic triad or, in modern terms, the endodontic trifecta.

The role of deep shape in endodontic preparations

Grossman (1970) described mechanical cleaning as the most important part of root canal therapy. Later, Byström and Sundqvist (1981) could show the efficacy of mechanical instrumentation alone, without antiseptic irrigants and intracanal dressings, to reduce the bacterial load of infected root canal systems. In 1985, the same authors demonstrated that the best results could be achieved with the combination mechanical debridement/antiseptic irrigation with NaOCl, hence the frequent use of the term 'chemo-mechanical preparation' (Byström and Sundqvist, 1985).

It is biologically sound that sufficient mechanical instrumentation of the root canal system is necessary for debridement of all organic material, including predentine, and to allow the penetration and exchange of the irrigating solutions within the root canal system. The only way to create sufficient space in the apical region, without damaging this critical and delicate anatomic area, is to implement a precise deep shape preparation, ie, maintaining the apical extent of the root canal as small as practical with sufficient taper behind the physiologic terminus to allow the deep placement of the irrigating needle and irrigant agitation.

It is striking to notice that, as early as 2001, the Protaper shaping system (Dentsply Sirona) had heralded finishing files with progressive tapers of 7%, 8%, and 9% in their apical 3mm of root canal preparations to cut a deep shape, followed by regressive tapers up to D16. The increased apical taper also provides access to the apical anatomy by shortening the length of lateral canals, therefore improving access to their cleaning.

The recently launched Protaper Ultimate endodontic shaping system (Dentsply Sirona) keeps the legacy of this iconic feature, with the addition of a more conservative coronal preparation to respect, without compromise, the current minimally invasive endodontic (MIE) (Figure 1) preparation concept and trend.

Indeed, the apical third is considered a critical zone because it is the most difficult part to clean and disinfect (Zahner, 2006). The anatomical complexity of this apical area with fins, isthmuses, and ramifications represents a real niche, harbouring the most harmful microorganisms and biofilms (Arnold, Ricucci and Siqueira, 2013). Therefore, from a biological point of view, it would make sense to create apical preparations with

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larger sizes to optimise debridement and irrigation (Kerekes and Tronstad, 1979).

As early as 1961, Ingle proposed a standardised technique with the then newly launched standardised endodontic instruments for the purpose of filling the apical third of the root canal initially with a silver point but later with a gutta percha cone matching the exact diameter of the last instrument used at the working length.

Increasingly sized reamers were successively used at the same working length to create a wide cylindrical preparation involving the whole canal cross section in order to mechanically clean it and, at the same time, provide a retention form with an apical stop to confine the filling material inside the root canal preparation.

This technique, initially developed by the University of Washington in Seattle, was quickly adopted by many dental schools. This standard was considered the reference technique for many years.

Following Kerekes and Tronstad's (1979) studies, in 1991, Ørstavik, Kerekes and Molven were the first to advocate extensive reaming in the apical region to reduce the endodontic source of bacterial infection. This was confirmed by Dalton and colleagues in 1998, who showed that the bacterial count was reduced with larger instruments sizes. According to Card and colleagues (2002), instrumentation of molars to size 60 and cuspids/bicuspids to size 80 showed that 81.5% of molars and 100% of cuspids/bicuspids were rendered bacteria-free at the end of the first appointment.

In addition to bacterial reduction (Rollison, Barnett and Stevens, 2002), several studies have observed the positive effectiveness of increased apical preparation on the cleanliness of the apical third (Fornari et al, 2010) in respect to a positive outcome for apical periodontitis healing (Souza et al, 2012), but also a negative effect on the sealing ability (Yared and Bou Dagher, 1994) and postoperative pain (Saini, Sangwan and Sangwan, 2016; de Freitas Portela et al, 2021).

The main drawback of larger apical preparations is the increased risk of creating adverse iatrogenic errors, such as ledges, canal transportations, perforations, zipping, and instrument fractures (Ruddle, 1997; Buchanan, 2000), especially in narrow and curved canals. A literature review, while advocating larger apical sizes, warns against procedural errors and asks to balance the degree of enlargement according to the canal anatomy (Baugh and Wallace, 2005).

To overcome these mishaps, Weine and colleagues (1970) advocated a telescopic preparation with enlargement of the apical part of the root canal three sizes larger than the first file that binds at the working length. This statement was clinically random and debatable.

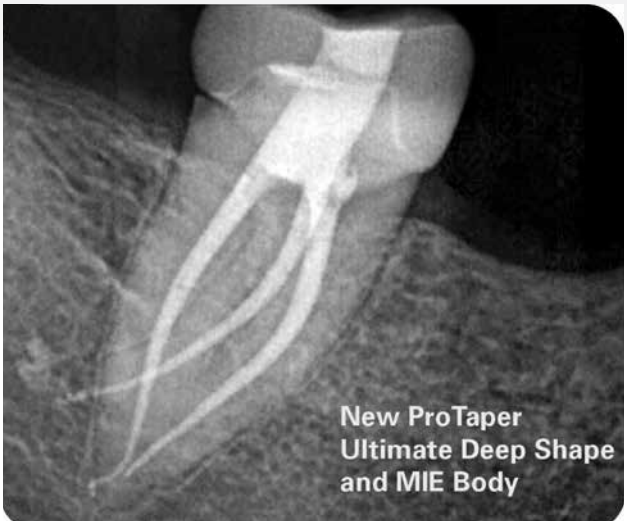

Figure 1: Mandibular molar post-treatment image illustrating the preparation outline form of the new Protaper Ultimate shaping system. Noteworthy is the presence of Protaper's legendary 'deep shape', enabling predictable, easy and affordable 3D cleaning and filling combined with a minimally invasive endodontic (MIE) body

In 1974, Schilder proposed an innovative manual shaping technique based on each individual canal anatomy. Using recapitulations with reamers and utilising the envelope of motion, it was possible to achieve tapered preparations refined in the apical region by designing a deep shape.

Deep shape was clinically confirmed when any given gauging file was snug at length and each consecutive larger K-file uniformly stepped out of the canal on the order of 0.5 to 1.0mm, depending on the anatomy.

The role of deep shape in 3D endodontic cleaning

The deep shape allowed excellent mechanical debridement of the apical third simultaneously with improved apical cleaning due to the deep insertion of the irrigating needle and the creation of a reflux space, enhancing the exchange of irrigants, as well as preparing a funnel shape enabling confined 3D fillings (Figure 2) (Machtou, 1980).

After shaping in vivo, 60 root canals from anterior and posterior teeth and using a radiopaque solution for irrigation, Yana (1989) demonstrated in his master's thesis that the penetration and exchange of irrigant is complete at the end of the preparation only when the deep shape has been built in the apical region.

Figure 2: This eight-image montage demonstrates the clinical outcome values of the 'deep shape' look in endodontic preparations: radiographic evidence of 3D cleaning and filling. It has been called 'the thrill of the fill'. The defining experiential 'moment' in endodontics is the anxious time when waiting for the fill image to come up on their imaging or radiographic system. When the image appears and the anatomy is visibly filled, there is an immediate sense of joy, satisfaction, and clinical triumph. It is a feeling that brings out the child in us and permits us to be fun and productive endodontic clinicians knowing that we can be confident, consistent, and in control of the patient's endodontic outcome!

In the Toronto study – phase four (de Chevigny et al, 2008), which is the only study comparing the Schilder technique to the standardised technique, the healing rate of the Schilder shaping technique with warm vertical compaction of gutta percha was 10% higher than the standardised technique with lateral condensation: 87% versus 77%. The Schilder technique was considered as a measurably improved outcome predictor.

Coldero and colleagues (2002), when assessing the reduction of intracanal bacteria during root canal preparation with and without apical enlargement, reported: 'It may therefore not be necessary to remove dentine in the apical part of the root canal when a suitable coronal taper is achieved to allow satisfactory irrigation of the root canal system with antimicrobial agents.'

According to Albrecht and colleagues (2004): 'When a 0.10 taper can be produced at the apical extent of the root canal, there is no difference in debris removal between a size #40 and a size #20 preparation.'

Khademi and colleagues (2006) have shown on mesiobuccal canals of extracted mandibular molars that the minimum instrumentation size needed for penetration of irrigants to the apical third of the root canal is a #30 file, preferably with an 0.06 taper.

Caron and colleagues (2010), using the Protaper system for shaping difficult molar canals with different irrigation protocols, discovered that very high levels of root canal system cleanliness could be obtained in the apical third after sonic Endoactivator (Dentsply Sirona) activation and manual dynamic activation.

In a digital substraction radiographic ex vivo study, it was shown that cleaning and shaping root canals with Protaper instruments improved penetration and exchange of irrigants (Bronnec, Bouillaguet and Machtou, 2010).

In a second study, the same authors identified that only active irrigation allowed complete irrigant penetration and exchange in curved canals after Protaper shaping (Bronnec, Bouillaguet and Machtou, 2010).

For syringe irrigation alone, the level of the needle tip placement in the canal, which depends on the space allowed by the shaping procedure, was the most dominating factor.

Results from a study by Boutsioukis and colleagues (2010) using an unsteady computational fluid dynamic stressed the impact of an increased taper for improving irrigant replacement and wall shear stress apical to the needle tip while reducing the risk for irrigant extrusion. It was demonstrated that a 30/09 tapered preparation with a Protaper F3 was equivalent to a 60/02 preparation.

The role of deep shape in 3D endodontic filling

The deep shape is also an essential component for sealing the root canal system after shaping. Proper deep shape provides the resistance form to contain the filling inside the

root canal.

In the early 1990s, Yared and Bou Dagher (1994a; 1994b) showed in two studies the benefits of maintaining a small apical size compared to a large one in order to obtain a hermetic seal of the root canal system and avoid extrusion of filling materials.

The deep shape is mandatory for softened gutta percha techniques, such as warm vertical compaction and carrier-based obturation, to allow the capture of apical anatomy, which is an essential prerequisite determinant for predictably successful endodontics (West, 1975).

A micro-computed tomography, studying the influence of apical taper on the quality of thermoplasticised root canal fillings, found that shaping the apical third (last 3mm) of root canals to an 8% taper is necessary to achieve a better sealing ability and thus long-term success for root canal obturations (Zogheib et al, 2012).

The recent availability of bio silicate sealers has updated the use of the single cone technique. But, as opposed to the old, standardised technique (Ingle, 1961), all current canal preparations are performed with tapered instruments. So, to expect a 3D seal, a perfectly matching gutta percha cone is mandatory.

Germain et al (2018) have assessed the influence of root canal taper on the apical adaptability of three root canal sealers and matching GP cones used in a single cone technique by measuring void's volume. In this study, 6% tapered preparations showed significantly less voids compared with a 4% tapered preparation.

In a confocal microscopic evaluation, Eid et al (2021) assessed the impact of warm vertical compaction (WVC) on the sealing ability of calcium silicate-based sealers in comparison with the single cone technique (SCT). WVC allowed better penetration at 1mm and 5mm into the dentinal tubules than the SCT.

After shaping with Protaper Ultimate, whatever the filling technique used, the triple lock fit of the new Dentsply Sirona GP cones provides a better seal over a wider surface distance of the preparation walls.

In conclusion, available reliable data is poor so far to solve the dilemma between apical size and taper after shaping. There are very few randomised controlled clinical trials, and they assess mainly the effect of increased apical size on the outcome of healing radicular periodontitis (Saini, Sangwan and Sangwan, 2016) and postoperative pain (de Freitas Portela et al, 2021; Silva et al, 2013).

The only CONSORT prospective randomised clinical trial assessing, for the first-time, different preparation sizes combined with different apical tapers on the outcome of primary endodontic treatment was released in September 2021 (Fatima et al, 2021).

Based on a thorough literature review and a stringent protocol, the results of this study showed that the minimum apical preparation required to adequately disinfect the canals was 25/0.06 or 30/0.04, which is in accordance with previous studies (Coldero et al, 2002; Albrecht, Baumgartner and Marshall, 2004; Khademi, Yazdizadeh and Feizianfard, 2006).

Deep shape summary

The new Protaper Ultimate shaping system, with a shorter range of instruments, simplifies the shaping procedure and combines a minimally invasive tapered preparation coronally with the predictably successful Protaper deep shape, 3D cleaning, and 3D filling hallmark distinctions.

Optimising the essential elements of design, unique machining, and purpose-specific metallurgy allows the clinician to experience a seamless workflow through slider, shaper, and finisher transitions.

The Protaper success story offers an entirely new performance benchmark, not just for the dentist but also for our most important commodity: the patient.

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This article was originally published in the January/February 2022 issue of Dentistry Today and has been reprinted with permission.

Machtou P, West J, Ruddle CJ (2022) Deep shape in endodontics: significance, rationale, and benefit. Dentistry Today 41(1): 74-77