Management of ‘S-shaped’ root canals – technique and case report

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The technical management of roots with S-shaped root canals to achieve both proper shaping and thorough cleaning is difficult and demanding. Little has been written that specifically addresses the clinical challenges encountered in these anatomically irregular roots. The purpose of this article is to detail techniques that can be used to efficiently and safely complete the entire root canal procedure on teeth with S-shaped roots and to amplify this accomplishment using a case report and treatment outcome.

Key words  anatomical irregularities, debridement, shaping, S-shaped canals

Introduction

A wide range of variability in root anatomy is found in certain roots or teeth. In particular, certain roots seem to have a propensity for an ‘S-shape’ configuration. Recent reports indicate that of 1163 roots from 14 different types of teeth (700 total) examined, 17.5% exhibited secondary curvatures that were classified as being S-shaped, with 12.3% of maxillary teeth and 23.3% of mandibular teeth exhibiting this anatomical characteristic. A wide variety of teeth can exhibit S-shaped root anatomies (Fig 1), with one of the most prominent and challenging anatomies being found in maxillary second premolars (Fig 2). The mesial-distal narrowness of these teeth both coronally and apically, along with the propensity for external root invaginations, make enlarging, shaping and debridement and disinfection on this tooth very difficult, even with the use of nickel-titanium (NiTi) hand or rotary instruments.

Very little has been published regarding the specific techniques required to shape, clean and obturate these canals, while preventing deviations from the original canal anatomy, such as straightening the canals, blockages, ledges, zips and strips. More often than not a hybrid technique of canal preparation is necessary and the chosen technique will vary by both the root anatomy and clinician expertise.

The purpose of this technique article and case report is twofold: 1) to describe techniques that can be used to manage S-shaped root canals, and 2) to detail the use of one of these techniques in the management of a maxillary second premolar that has an accentuated S-shape root configuration, along with an assessment of treatment outcomes.
General considerations for techniques used in root canal treatment of teeth with S-shaped root canals

S-shaped, sometimes referred to as bayonet-shaped, canals can be troublesome and challenging because they involve at least two curves, with the apical curve being the most vulnerable to deviations in anatomy, loss of working length and the potential for instrument separation. These double-curved canals (in two dimensions) that often have an additional curve (three dimensions) are usually identified radiographically when they traverse in a mesial-distal direction; however if they transverse in a buccal-lingual direction also (as seen commonly in the mesial roots of mandibular molars), they may be identified with multiple-angled radiographs or when the initial apical file is removed from the canal and it simulates multiple curves. In these situations the additional use of cone-
beam computerised tomography (CBCT) may be of assistance. To manage these root canal systems, the clinician must approach them with knowledge of the anatomical challenges, experience in the use of contemporary and traditional instruments, and a thorough assessment of the case at hand.

Traditional technique – use of stainless steel instruments

When using a traditional approach to the cleaning and shaping of S-shaped root canals with hand stainless steel instruments, the following guidelines or directives should be considered:

- **Visualise** mentally the three-dimensional nature of the S-shaped canal using the radiographic evidence available.
- **Anticipate** the presence of multiple concavities or invaginations along the external surfaces of the root to prevent a strip perforation along with the approximate position of both the curves (Fig 3).
- **Develop** an unrestricted approach to the first or coronal curve by skewing the access preparation to the mesial or distal if necessary (see Fig 4 for skewing concept). This can be done with an Endo Z bur in the crown of the tooth (Dentsply Maillefer, Ballaigues, Switzerland), which should eliminate any potential for gouging tooth structure. This will not permit better access to the altered long axis of the root in the middle and apical portions of the root.
- **Shape** the coronal curve passively as access through this will facilitate the cleaning and shaping of any other curvatures. Irrigate frequently and recapitulate as necessary with small files.
- **Overcurve** the apical 2 to 3 mm of the stainless steel file to maintain the curvature the apical portion of the canal. In this process the master apical file should be in the smaller size range (20 to 25) and smaller file sizes are used in this mid-to-apical region with short-amplitude strokes to manage these anatomical challenges effectively and to prevent stripping, zipping and ledging in the root curvatures (Fig 5). Anticurvature or reverse filing in the coronal curve is used with primary pressure being placed away from the curve of the coronal curvature to prevent stripping. Each case will vary depending on the nature of the curvatures, position of the tooth and skill/experience of the clinician.

If either the loss of working length or deviations in anatomy are identified during the enlarging and shaping, the same principles of error management apply as those with a straightforward canal system. However, focusing on a problem that has occurred in the apical curvature can easily produce an additional problem in the coronal curvature. Thus, careful clinical judgment is necessary when managing.
ing problems in the apical curve. Once enlarging, shaping and cleaning have been completed, NiTi finger or hand compactors are used with either a cold or warm gutta-percha technique to obturate these delicate canal systems. However, in these cases, core-carrier obturators would be ideal.

Contemporary technique – use of NiTi rotary instruments

Initial skewing of the access cavity to the mesial or distal is of benefit for a better entry into the coronal part of the S-shaped curve based on the position of the tooth in the arch. Endo Z burs are especially effective in accomplishing this goal.

When contemplating the use of NiTi rotary instruments in these teeth, both the angle and radius of root curvature are extremely important. The radius of curvature impacts greatly on the cyclic fatigue of engine-driven rotary instruments, because as the radius of curvature decreases, the cycles of NiTi instrument failure also decreases.

From an anatomical perspective for any technique of canal penetration that uses rotary instruments is the recognition that most roots and root canals are 9 to 14 mm from the orifice to the desired apical position and not the full tooth length (Fig 6). This means that when working around multiple curves, the clinician has to only think in terms of achieving penetration of approximately 1/3 of the root length at a time, or, for example, in the case of a root that is only 12 mm long, 4 mm at a time for safe penetration. In severe curves, penetration of only 1, 2 or 3 mm may be indicated. Therefore, penetration of the entire length immediately may not be necessary, however the application of sound principles of crown-down preparation techniques to achieve the desired goal is always essential. Development of a pathway for all instruments requires the initial use of small K-files to determine the degree of patency. However, safe penetration through the first curve (mostly coronal) of the root is essential to open the canal system for further cleaning and shaping. Options for this procedure include hand NiTi shaping instruments (ProTaper S1 and SX) or the use of orifice shapers (both from Dentsply Maillefer), Gates Glidden drills (Dentsply Maillefer), LA Axxess (SybronEndo, Orange, CA, USA), Light-Speed CRX (Discus Dental, Culver City, CA, USA), ultrasonic instruments or larger tapered rotary instruments to open the coronal third to the first curve (Fig 7). These instruments are generally safe to develop the initial coronal canal flare.

Once penetration and shaping to or slightly around the first curve occurs, additional penetration can occur to the second curve or slightly beyond that anatomical challenge, as the coronal pathway should not impact on this procedure. This can be done with small K-files, small variably tapered NiTi instruments or instruments designed for this purpose, such as a rotary PathFile™ in small diameter sizes (0.02) (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA). Once the pathway has been cleared into the third curve, sufficient space has usually been developed to enhance the use of irrigants for tissue dissolution and disinfection, although full penetration of the irrigant may not always occur until larger apical sizes are achieved or there is sufficient coronal flare. However, even
if a small instrument can go around both curves successfully, full canal cleaning and shaping should still be applied using the 1/3 or even ¼ guideline, taking small lengths at a time to minimise or prevent deviations, which can even occur with rotary NiTi instruments; and certainly with stainless steel K-files. Instruments such as the variably tapered S1, SX and S2 of the ProTaper® Universal series (Dentsply Tulsa Dental Specialties) are exceptionally effective in helping to create a tapered pathway with minimal to no deviations in the curves of these canals, due to the location of the cutting on the instrument (primarily coronal), with the non-cutting apical portion serving as a pathfinder.

As long as smaller tapered, rotary instruments, such as a 0.02 or 0.04 are used with minimal pressure in the canal to minimise cyclic fatigue, their application in the canal, taking one curve at a time, is usually successful. In some cases where the curvatures are not extreme (> 20 to 30 degrees), these instruments may work well shaping the entire curved system, as long as they do not go beyond a size of a No. 25. Beyond that size, deviations are likely, especially as the taper increases.

Some of the newer rotary NiTi files, such as the Sequence file (Brasseler, Savannah, GA, USA), the Twisted file (SybronEndo), the GTX file and Vortex™ file (Dentsply Tulsa Dental Specialities) and LightSpeed (Discus Dental) may be used effectively in small sizes (15–20) using one to shape the canal over its entire length, or two used incrementally, going around each curved 1 to 2 mm before advancing to the next size. Even these approaches, if used excessively or if used in higher sizes, may create a deviation from the canal anatomy. The use of NiTi rotary instruments may have to be followed by hand small stainless steel files to ensure patency and absence of any ledge formation. If the entire canal is prepared with small NiTi files only (size 20 or less with tapers of 0.04 to 0.06) tapers of these smaller sized instruments may be insufficient to facilitate both canal cleaning and thorough obturation.

Most if not all S-shaped canals will have curvatures in three dimensions, especially in the molar teeth. These variances will not be seen readily on two-dimensional radiographs; however these types of variations must be anticipated as the degree and radii of curvature will impact greatly on the choice of instruments and their usage in each particular situation. For example, one of the most challenging S-shaped root configurations is the mesial-lingual canal of a mandibular molar that curves to the lingual, returns to the buccal, while at the same time curving distally. In this regard separated instruments or blocked/ledged canals are often seen in this root.

Case report – application of contemporary principles in the management of a S-shaped root canal system

A 51-year-old male patient was referred from the undergraduate student clinic at the Universitat Internacional de Catalunya, Barcelona, Spain, to the postgraduate endodontic program with a history of pain during mastication with an associated periapical lesion on the maxillary right second premolar. There were no medical contraindications to dental treatment. The tooth in question had a Class II deep resin restoration that appeared intact. The tooth did not respond to a cold stimulus (Endo-Frost, Roeko, Langenau, Germany); the contralateral tooth served as a control. While the tooth was symptomatic to palpation and to vertical percussion, no sinus tract was found. Periodontal probing was within normal limits and no evidence of occlusal trauma was identified. A preoperative periapical radiograph confirmed the presence of a periapical radiolucent lesion around the apex and the S-shaped root anatomy (Fig 2). A bitewing radiograph was also taken in
order to determine the restorability of the tooth (Fig 8).

The diagnosis was pulpal necrosis with symptomatic apical periodontitis. The patient was thoroughly informed about the high degree of case difficulty and the possible risk of instrument failure or irreversible alteration of the root canal anatomy.

## Root canal treatment

All root canal procedures were performed under local anaesthetic and dental dam isolation. Following initial access opening preparation with a small round diamond bur, margins and the depth of the access were redefined with an Endo-Z bur. A DG-16 endodontic explorer was used to locate the buccal and palatal canals. Subsequently the coronal portions of the canals were gently probed with small K-files (sizes 06 and 08) (Dentsply Maillefer) to establish an initial pathway and patency to the estimated apical terminus of the root canal. In this case it was determined to be at the radiographic apex until a working length was taken. Then the coronal portions of the canals were flared using SX and S1 files (ProTaper Universal, Dentsply Maillefer) (Fig 9). Once the coronal pathway was established, the working length was determined using the Dentaport ZX (J. Morita, Tokyo, Japan) and confirmed radiographically using a size 15 K-file at 23 mm for each canal (Fig 10).

Canal enlargement and shaping was performed using a hybrid technique. Initially the S1 (ProTaper Universal) was used, followed by the S2 and F1. Due to the increase in taper and size of the subsequent finishing files and the abrupt canal curvatures, subsequent enlarging and shaping was accomplished with a ProFile® instrument (#25/.04; Dentsply, Maillefer). During all the enlarging and shaping, the cleaning process was facilitated with sodium hypochlorite (NaOCl 4.2%). Apical patency was maintained with a size 10 K-file.

A final irrigation protocol consisted of sonic activation of the irrigants with the Vibringe® device (Vibringe B.V., Amsterdam, The Netherlands), following the manufacturer’s instructions, using each irrigant with a frequency of 150 MHz. The irrigants used were, in order, 10 ml of 10% citric acid and 10 ml of 4.2% NaOCl. The canals were rinsed with 96% ethanol and dried with assorted paper points (Dentsply, Maillefer).

Prior to obturation, the final canal size was verified, using #25/04 ProFile to the working length in lieu of the ThermaFil verifiers provided by the manufacturer (Dentsply, Maillefer) (Fig 11). ThermaFil core-carriers (size 25) were used for obturation due to the severe curvature. The use of the core-carrier facilitates flow of both sealer and gutta-percha around the curves and enhances obturation in teeth with challenging anatomies. The root canal sealer (AH-plus®; Dentsply, Maillefer) was mixed and applied using a size 25 paper point. The obturators were heated in the ThermaPrep® Oven (Dentsply, Maillefer) and inserted into the canal with a smooth and firm movement without rotation, until the working length was reached. The coronal portion of the carriers was removed with an Endo Z bur and after cleaning the pulp chamber, a thin layer of flowable composite was placed over the carriers to prevent leakage until a coronal restoration was placed. This was covered with Cavit™ (3M ESPE, Seefeld, Germany) as a temporary restoration and a final radiograph was taken to assess the obturation (Fig 12). The tooth was restored with an indirect resin restoration (Adoro, Ivoclar-Vivadent, Schaan, Liechtenstein) providing cuspal coverage to prevent tooth fracture.

At 3-month and 10-month re-examinations, the patient was symptom-free. The 10-month radiograph showed a breakdown of the extruded sealer and the formation of new bone around the root apex (Fig 13).
Discussion

Key to the successful root treatment of teeth with S-shaped roots is the recognition of the challenges that will be encountered in the enlarging, shaping and cleaning of the root canal system in the clinical setting. Heretofore, studies have only focused on these procedures in simulated S-shaped root canal systems\(^9\)-\(^{12}\), with a focus primarily on comparing shaping ability and efficacy of multiple, new and innovative nickel-titanium root canal files. However, while the use of these types of simulated root canal systems may have some validity\(^{13}\) they cannot account for the three-dimensional changes encountered in the human dentition, the ability to assess debridement, and the dissimilar nature of the model’s material from root canal dentine. While the intricacies of canal management must ultimately be demonstrated on human teeth, the use of a hybrid technique was identified as being the best when using the models, integrating instruments from varying manufacturers that had different cross sections,
greater flexibility and reduced tapers. On human teeth, a recent study showed that combining different file systems did not lead to increased levels of apical (canal) transportation and that this approach may actually be a valid alternative to achieving larger apical diameters without a higher risk of procedural errors. Furthermore, with larger apical sizes and the use of devices that agitate the irrigant, canal cleanliness may be enhanced.

Concern has been expressed in related literature as to how large the apical preparation must be to 1) enable the instrument to contact the walls circumferentially and clean the dentine, and 2) permit the flow of irrigant effectively into the apical few millimetres to enhance the removal of debris and bacteria. Historically there have been recommendations to prepare the apical extent of the canal to a size 25 to 35. However histological studies indicate that 15 to 30% of the root canal walls remain untouched by instruments when using these recommended sizes. Apical preparations to larger sizes have shown better debridement and dentine wall contact, however they also risk perforations or lacerations of the apical foramen or for that matter even small apical fractures. Even with the use of a rotary instrument in curved canals, as much as 25% of the apical wall may be untouched, even up to an apical size of 45, and in some teeth in particular, excessively large sizes may be necessary, which are not compatible with the external root anatomy.

The application of rotary instruments in curved canals has proven to be successful as compared to stainless steel hand instruments; however, the ability of the rotary instrument to provide better cleaning has not been substantiated. In fact, with the contemporary clinical guideline of an apical size of #20/.06 or even #40/.06, debris still remains, although the larger sizes have significantly less debris. With an increase in taper, even the smaller sizes, such as #20/.10 may be as clean as a #40/.10, but debris still remains.

There also appears to be an impetus for larger apical preparations based on better irrigant penetration (minimum of a #30/.06) and better apical cleaning and therefore better management of bacterial populations apically. In fact, larger apical sizes have been identified as being more effective in bacterial elimination in simple root canal systems. However the significance of the extent of the apical preparation in specific clinical situations has not been clarified, such as canal systems with highly irregular branching. Furthermore, studies have indicated that unwarranted or excessively large apical enlargement may not be necessary in the presence of suitable coronal tapers for the efficient irrigation of the canal system. However, when viewed from an outcomes standpoint, there does not appear to be an ideal canal size or taper that influences ultimate success.

The proper use of a gutta-percha core-carrier would seem to be highly desirable for thorough canal obturation. This method would allow for the flow, movement and more thorough distribution of both sealer and thermally-softened gutta-percha easily around the multiple curves, while at the same time penetrating any lateral communications and dentinal tubules following smear layer removal.

Management of these types of anatomical shapes by the skilled and experienced clinician may be an everyday challenge for which they have already developed a successful, technical approach. However for the less experienced, this type of anatomical configuration can be most perplexing and can lead ultimately to a number of problems if not approached in a knowledgeable and confident manner. Knowledge of three-dimensional anatomy, the use of the CBCT when available, and practice on extracted teeth will help the practitioner to achieve positive outcomes when faced with this clinical challenge.
References


