Untying the Gordian Knot; Part II
Kenneth Serota continues his look at the Endodontic Implant Algorithm

Microstructural replication - obturation

Steven Covey is known for his book *The Seven Habits of Highly Effective People*. The habit most applicable to endodontics is the second one; Begin with the End in Mind. The implication of this vision in regard to idealising the final shape of the root canal system to ensure that the obturation represents a totality is profound. The root canal is negative space and as such recovery of its original unaffected form is the sine qua non of obturation or more descriptively - microstructural replication.

Perhaps the most significant example of negative space recovery is Michelangelo’s statuary for the funerary of Pope Julius II. Four unfinished sculptures speak eloquently to this process: the figure was outlined on the front of the marble block and then Michelangelo worked steadily inwards from this side, in his own words ‘liberating the figure imprisoned in the marble’. This is an exacting description of debridement and instrumentation of the root canal space prior to root filling after a myriad of pathological vectors have destroyed the dental pulp, and altered the morphology/topography of the system (Fig 12).

Incomplete filling of the debrided and sculpted root canal space is one of the major causes of endodontic failure (38). Until recently, in vitro testing (dye leakage, fluid transport, bacte rial penetration, glucose leakage) was used to evaluate the sealing efficacy of endodontic filling materials and techniques by assessing the degree of penetration/absorbance of these tracers (31,32,33). Unfortunately, leakage studies are limited static models that do not simulate the conditions found in the oral cavity (temperature changes, dietary influences, salivary flow). Given the historic dominance of in vitro testing, the clinician must be cautious when extrapolating study findings to the clinical situation, regardless of manufacturer’s claims (38). This reliance on invalid testing protocols diminishes the “mono block” assertions applied to the new generation of adhesive obturating materials proposed as the “replacement material” for gutta-percha (39).

Gutta-percha was introduced to dentistry by Edwin Truman in 1847 (30). The concept of thermolabile vertical condensation of gutta-percha was originally described by Dr J R Bilany in 1927 (30). The defining article on obturation remains Dr. Schilder’s classic on filling the root canal space in three dimensions published some 40 years later (36). Logically, one cannot physically fill the root canal in two dimensions; however, one can fill the root canal space badly in three dimensions. This does not critique Dr Schilder’s exposition, but it does demonstrate that words can easily be misconstrued and alter perspective once they become, as Kipling said, ‘the most powerful drug of mankind’. Ironically, Schilder’s article came seven years prior to his treatise on cleaning and shaping the root canal system, which even to this day remains the iconic standard for the technical imperatives associated with instrumentation.

The Washington Study by Ingle indicated that 58 per cent of treatment failures were due to incomplete obturation (30). The corollary is obvious; teeth that are poorly obturated are invariably poorly debrided and disin fected. Procedural errors such as loss of working length, canal/apical transportation, perforations, loss of coronal seal and vertical root fractures have been shown to adversely affect the integrity of the apical seal (34,35). The Toronto study evaluating success and failure of endodontic treatment at four to six years after completion of treatment showed that teeth treated with a flared canal preparation and vertical condensation of thermolabile gutta-percha had a higher success rate when compared with step-back canal preparation and lateral compaction. Highlighting the vertical condensation of warm gutta-percha obturation technique as a factor influencing success and failure simply confirmed a perspective evident to most endodontists from years of clinical empiricism.

There is a never-ending array of obturation materials, delivery systems and sealers appearing in the marketplace. Each is hallmarkd by proprietary modifications and each is heralded as the most significant iteration in obturation since the previous one; today, we practice with a sad tru-
Resilon (RealSeal - SybronEndo Corp., Orange, CA), a thermoplastic polyurethane was developed as an alternative to gutta-percha. The domi-nant systems remain carrier-based obturation (Thermofil – Tulsa Dental Specialties, Tulsa (OK), Continuous Wave Compac-tion Technique (Elements Ob-turation – Sybron Endo, Orange CA and Thermoplastic Injection (Obtura III Max – Obtura Spar-tan, Earth City MO).

Resilon (RealSeal - SybronEndo Corp., Orange, CA), a high-performance industrial polyurethane was developed as an alternative to gutta-percha. There are scattered studies that show Resilon exhibits less microbial leakage (44) and higher bond strength to root canal dentin (48), reduced periapical inflammation (49) and enhanced fracture resist-

ance of endodontically treated teeth when compared with gutta-percha (45) (Fig 13). Other studies have reported undesirable prop-erties associated with Resilon including low push-out bond strength (46) and low cohesive strength plus stiffness (47). In ad-
dition, Resilon could not achieve a complete hermetic apical seal (47). These results indicate that a more appropriate material for root canal obturation still needs to be developed. There is still no obturation method or material that produces a leakproof seal. A material that is bio-inductive and promotes regeneration, a “smart” nano-material that can adapt to the ever-changing mi-croenvironment of the canal system is essential, but to date, remains elusive.

All polymers demonstrate melt temperature and flow rate. Both gutta-percha and Resi-

lon demonstrate a viscoelastic gradient that manifests as a dy-namic rheological birefringence in the molded state. Dependent upon the molecular weight of the source material (without the opacifiers, waxes and modifiers), gravimetric measurements of the time-temperature-transfor-mation diagram of any molding compound can be constructed. In the thermoplastic world of to-day, this has engendered an in-crease in the weight of the mass of obturating material and an im-provement in the bacterial seal. This applies to carrier based ob-turation techniques, Continuous Wave Compaction Technique and Obtura III obturation with-out cone placement.

Instrumentation

The steps required for debride-ment and disinfection of the root canal space are sequential and interdependent. Aberration of any node in the process impacts upon the others, leading to ia-
trogenic damage and potentially treatment outcome failure. The most common distortion of na-
tive anatomy is ledging; canal curvature exceeding 20° was shown to produce ledging of mandibular molars in a cohort of undergraduate students 56 per cent of the time (46). Denin chips pushed apically by instrumenta-
tion incorporated with fragments of pulp tissue will compact into the apical third and the forame-

Fig 14a - The working length has two reference points, coronal and apical. Failure to maintain patency at the minor apical diameter will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 14b - The volume of irrigant necessary to prevent apical blockage is indeterminant. While NiTi rotary instrumentation has minimized this procedural problem to a significant degree, nonetheless, a slurry of dentin mud is always a risk factor to be monitored.

Fig 15 - Rheology is a science that addresses the deformation and flow of matter. The biochemistry of filling material, its viscosity gradient, the lubricating effect of sealer and file going to the point of patiency will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 16 - The working length has two reference points, coronal and apical. Failure to maintain patency at the minor apical diameter will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 17 - Rheology is a science that addresses the deformation and flow of matter. The biochemistry of filling material, its viscosity gradient, the lubricating effect of sealer and file going to the point of patiency will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 18 - The working length has two reference points, coronal and apical. Failure to maintain patency at the minor apical diameter will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 19 - Rheology is a science that addresses the deformation and flow of matter. The biochemistry of filling material, its viscosity gradient, the lubricating effect of sealer and file going to the point of patiency will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 20 - The working length has two reference points, coronal and apical. Failure to maintain patency at the minor apical diameter will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 21 - Rheology is a science that addresses the deformation and flow of matter. The biochemistry of filling material, its viscosity gradient, the lubricating effect of sealer and file going to the point of patiency will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 22 - The working length has two reference points, coronal and apical. Failure to maintain patency at the minor apical diameter will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 23 - Rheology is a science that addresses the deformation and flow of matter. The biochemistry of filling material, its viscosity gradient, the lubricating effect of sealer and file going to the point of patiency will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.

Fig 24 - The working length has two reference points, coronal and apical. Failure to maintain patency at the minor apical diameter will cause loss of the apical reference point as a result of blockage, or ellipticization of the foramen.
plug. Therefore, establishing apical patency is recommended even during treatment of canals with vital pulps.

Historically, numerous techniques have been advocated for canal preparation (balanced force, anti-curvature, double-flare, modified double-flare); however, step-back \(^{60}\) and crown-down \(^{60}\) are the most universally accepted. Experience has shown that a crown-down preparation will cause fewer procedural errors (apical transportation, elbow formation, ledging, strip perforation, instrument fracture). The preliminary removal of coronal dentin (pre-enlargement - treating the apex last) minimizes blockage and enables an increasing volume of irrigant penetration thereby sustaining working length throughout the procedure \(^{59}\).

The balanced force shaping philosophy is integral to the crown-down approach. Its premise is that instruments are guided by the canal structure when rotational/anti-rotation motion (watch-winding) is used. Changing the direction of rotation controls the probability that instruments will become overstressed and thus ensures that the cutting of structure occurs most efficiently \(^{59}\). Endodontists have long appreciated what the science reported, that the balanced-force hand instrumentation technique produced a cleaner apical portion of the canal than other techniques (Fig 15) \(^{58, 59}\). As will be discussed shortly, this author remains committed to hand filing in order to refine apical third shaping and creating an enhanced apical control cone taper.

Two distinct phases are required for the preparation of canals with nickel titanium (NiTi) rotary files. It is essential, that no matter the protocol used, a reservoir of NaOCl must be maintained and replenished repeatedly in the strategically extended access preparation. The coronal portion of the canal space is explored with small sized K-files to establish a glide path for the rotaries to follow. The taper of NiTi files, regardless of manufacturer, induces a crown-down effect in the straight portion of the canal. After the coronal and middle third segments are opened and repeatedly irrigated with NaOCl, a sequence of small K-files can progress apically, ultimately defining patency, confirming the topography of the accessible canal space and its degree of curvature.

A second “wave” with the NiTi rotaries is then used to effect deep shade approximating the working length and depending upon the configuration of the apical third, to enlarge the terminus to the gauged apical size and initiate the taper of the apical control zone \(^{58}\). This is a basic concept. It is inherent in all templated protocols that each tooth is different and modifications to the process are always necessary as a function of the tooth morphology and type being treated.

The apical control zone is defined as a matrix like region created at the terminus of the apical third of the root canal space. The sones demonstrates an exaggerated taper from the spatial position determined by an electronic foramen locator to be the minor apical diameter. Whether this is linear or a point determination is a function of histopathology. The enhanced taper at the terminus creates a resistance form against the condensation pressures of obturation and acts to prevent excessive extrusion of filling material during thermolabile vertical compaction.

All NiTi systems are modeled upon a single or multiple taper ratio per millimeter of file length. Fig 16a demonstrates the metrics of the F1, F2, F3 finishing files of the ProTaper Universal system (author’s preference). These files demonstrate a common taper in the last four mm of the file, which in the vast majority of situations corresponds to the length of the apical third of the root canal space. As shown, the .08 taper of the F1 (.20 tip), the .08 taper of the F2 (.25 tip) and the .09 taper of the F3 (.30 tip) produce the corresponding diametral dimension indicated each millimeter back from the apical terminus if the crown down protocol built into this multiple taper file system is adhered to. If the shape of the
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internal micro-morphology of the root complex were epi-
merized. Internal micro-morphologic examination of the canal cross-section showed that the thir-
“imprinting” of the canal preparation would be logical. Unfortunately, such is not the case 59.

Figure 16b shows how the use of hand files in the apical third of the root canal system, the mini-
“glide path” function, the minor apical diameter, and the position of the root file will be guided by the tip of the apical foramen as small as prac-
tically possible. Whatever file shape, it is important that the minor apical diameter, in conjunction with file handling, the apical control zone will be maintained in the area where the file will work in the sub-apical region. The file will be removed from the tip of the apical foramen and will follow the “imprinting” created.

The reasons for tooth extrac-

failure, in order to determine whether to implement a re-en-
gineered endodontic approach or to extract and replace the natural tooth with an osseointegrated implant. It finds the greatest common divisor among the degree of coronal breakage, the size of the root canal involved, the adjacent teeth, the quality and quantity of the bone support and tissue condition, the engi-

neering solutions to be born by the tooth or teeth in ques-
tion and assessees the occlusal scheme and the patient’s aes-
thetic and functional expecta-
tions of treatment.

Failing to use internal micro-
morphology of the root canal space and the awareness of minimal cemental impact.

Reference


