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 - micro-structural replication.

Perhaps the most significant example of negative space recovery is Michelangelo’s statue 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 pathologic 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 (39). Until recently, in vitro testing (dye leakage, fluid transport, bacterial 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 (64, 51, 38). 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 (39). 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 (50).

Gutta-percha was introduced to dentistry by Edwin Truman in 1847 (34). The concept of thermolabile vertical condensation of gutta-percha was originally described by Dr J R Blaney in 1927 (35). The defining article on obturation remains Dr. Schilder’s classic on filling the root canal space in three dimensions published some 40 years later (30). 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 disinfected. 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 (30, 40). 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 hallmark-marked 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-
The steps required for debridement and disinfection of the root canal space are sequential and interdependent. Alteration of any node in the process impacts upon the others, leading to intracanal damage and potentially treatment outcome failure. The most common distortion of native anatomy is ledging; canal curvature exceeding 20° was shown to produce ledging of mandibular molars in a cohort of undergraduate students 56% of the time (40). Dental chips pushed apically by instrumentation incorporated with fragments of pulp tissue will compact into the apical third and the foramen area causing blockage, altering the working length due to the loss of patency (Figs 14a, 14b).

Apical patency is a technique in which the minor apical diameter of the canal is maintained free of debris by recapitulation with a small file through the apical foramen (49). The most predictable method is to regularly use a designated patency file throughout the cleaning and shaping procedure in conjunction with copious irrigation. A #0.08 K-file passively moved through the apical terminus without widening it is most effective; it will refresh the NaOCl file going to the point of patency and Promote regeneration, a “smart” nano-material that can adapt to the ever-changing microenvironment of the canal system is essential, but to date, remains elusive.

All polymers demonstrate melt temperature and flow rate. Both gutta-percha and Resilon demonstrate a viscoelastic gradient that manifests as a dynamic rheological hysteresis 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-transformation diagram of any molding compound can be constructed. In the thermoplastic world of today, this has engendered an increase in the weight of the mass of obturating material and an improvement in the bacterial seal. This applies to carrier based obturation techniques, Continuous Wave Compaction Technique and Obtura III obturation without cone placement.

Instrumentation

The working length has two reference points, cervical 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.

Resilon (RealSeal – Sybron Endo Corp., Orange, CA) is 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 resistance to root canal dentin (44) and enhanced fracture resistance (44). 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 microenvironment of the canal system is essential, but to date, remains elusive.

All polymers demonstrate melt temperature and flow rate. Both gutta-percha and Resilon remain the primary endodontic obturating material. The dominant systems remain carrier-based obturation (Thermofill – Tulsa Dental Specialties, Tulsa, OK), Continuous Wave Compaction Technique (Elements Obturation – Sybron Endo, Orange CA and Thermoplastic Injection (Obtura III Max – Obtura Spartan, Earth City MO).
plug. Therefore, establishing apical patency is recommended even during treatment of canals with vital pulps (\textsuperscript{[15]}).

Historically, numerous techniques have been advocated for canal preparation (balanced force, anti-curvature, double-flare, modified double-flare); however, step-back \textsuperscript{[16]} and crown-down \textsuperscript{[17]} 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, instrumental 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 \textsuperscript{[18]}.

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 \textsuperscript{[19]}. 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 \textsuperscript{15}) \textsuperscript{[20, 21]}. 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 zone 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 shape 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 \textsuperscript{[22]}. 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 zone 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 \textsuperscript{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 corresponded to the length of the apical third of the root canal space. As shown, the .25 taper of the F1 (.20 tip), the .08 taper of the F2 (.05 taper at the .09 taper of the F3 (.50 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 canal were epi-
phelial and did not consist of the three “imprinting” of the canal preparation would be logical. Un-
Fortunately, such is not the case 18.

Figure 16b shows how the use of hand files in the apical third, in conjunction with the ini-
tially shape created by the NiTi files. Hand files have a #20 ta-
er (along the shaft of the file, 0.02 mm diameter, 0.02 mm per mm of length - 20 file with 16 mm of flutes would be measure 32 mm at the coro-
nal end of the flutes). In the example shown, a #20 file is positioned at the minor apical diameter. Careful positioning of a series of files within the last mm can produce a 2 mm or per 20 per cent taper with no undisputed resolution of the native anatomy. Solicited preliminary shaping was to keep the api-
cal foramen as small as prac-
tically possible. Whatever file 

Fig 16b - Modification of taper in last mm of the apical terminus, exaggerates the “resorci-
tion” or minor apical diameter. Thermal-taper coronal condensation has been shown to enhance survival of the post-treatment. The effect of the apical foramen on the geometry of the root canal and the use of hand files in the apical third, in conjunction with the ini-
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Fig 16a - The Pre-Taper lased canal system comprises two shaping files that address the planes of geometry of the curved and middle thirds of the root canal space. There are fin leaching files that include tip sizes, 20, 25, 30, 40 and 50. Tapers range from 0.4 to 0.9 through the files. A thorough 
understanding of the merits is essential for the preparation of hand and rotary files to intra-
tional morphology of the root canal space and the attainment of minimal iatrogenic impact.

References

