Microstructural replication – obturation

S
teven 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 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 (38). 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 (34, 35, 36). 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 (40).

Gutta-percha was introduced to dentistry by Edwin Truman in 1847 (41). The concept of thermolabile vertical condensation of gutta-percha was originally described by Dr J R Bilany in 1927 (42). The defining article on obturation remains Dr. Schilder’s classic on filling the root canal space in three dimensions published some 40 years later (43). 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 criticize 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 38 per cent of treatment failures were due to incomplete obturation (44). The corollary is obvious; teeth that are poorly obturated are invariably poorly debrided and disinfect. 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 (45, 46). 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...
is - marketing is inexorably directing science. However, gutta-percha in combination with a myriad of sealers and solvents remains the primary endodontic obturating material. The dominant systems remain carrier-based obturation (Thermplif – 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).

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 and higher bond strength to root canal dentin, reduced periapical inflammation and enhanced fracture resistance of endodontically treated teeth when compared with gutta-percha (46) (Fig 13). Other studies have reported undesirable properties associated with Resilon including low push-out bond strength (48) and low cohesive strength plus stiffness (49). In addition, Resilon could not achieve a complete hermetic apical seal (50). 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 demonstrate a viscoelastic gradient that manifests as a dynamic 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-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 steps required for debridement and disinfection of the root canal space are sequential and interdependent. Aberration of any node in the process impacts upon the others, leading to intragenic 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 per cent of the time (51). Dentin 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 (52). The most predictable method is to regularly use a designated patency file throughout the cleaning and shaping procedure in conjunction with copious irrigation. A Ø.08 K-file passively moved through the apical terminus without widening it is most effective; it will refresh the NaOCl at the terminus as the action of the file going to the point of patency produces a fluid dynamic. Regrettably, loss of working length remains a common adverse event during endodontic therapy, especially among less experienced clinicians. Its major cause is the formation of an apical dentin...
plug. Therefore, establishing apical patency is recommended even during treatment of canals with vital pulps (86).

Historically, numerous techniques have been advocated for canal preparation (balanced force, anti-curvature, double-flare, modified double-flare); however, step-back (98) and crown-down (99) 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 (100).

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 (101). 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) (86, 99). 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 thirds 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 (98). 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 foramenal 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 thermobalve 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 correspond to the length of the apical third of the root canal space. As shown, the .07 taper of the F1 (.20 tip), the .08 taper of the F2 (.30 tip) and 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 system were epi-
cremented. The term “imprinting” of the canal preparation would be logical. Unfortunately, such is not the case.

Figure 16b shows how the use of hand files in the apical third produces the desired apical terminus, the two di-
nal files from the NiTi files. Hand files have a 0.2a ta-
per (along the shaft of the file, 0.02 mm per mm of length – 0.2 mm with 16 mm of files would be measure 52 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 0.2 a or 0.20 per cent taper with no undue disruption of the native anatomy. Schilder’s precept for shaping was to keep the ap-
ical foramen as small as prac-
tically possible. Whatever file shape will ensure the apical terminus and the coronal and middle thirds of the root canal space. There are five finishing files that are adhered to, in almost all ending in the area created will enhance the apical terminus and vectors of compaction and condensation have a greater lateral volume of displacement at the terminus.

FASHIONING A RISK ASSESSMENT ALGORITHM

If the biologic parameters that mandate endodontic success are adhered to, in almost all cases, treatment outcomes will be predictable. The endodontic implant algorithm processes to the array of contributing fac-
sors leading to endodontic failure, in order to determine whether to implement a re-en-
ginered 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 breakdown and associated periapical precariousness of adjacent teeth, the quality and quantity of the bone support and tissue condition, the en-
gineerability of the bone to be built by the tooth or teeth in ques-
tion and assesses the occlusal scheme and the patient’s a-
thetical and functional expectations of treatment.

Thereasons for tooth extrac-
tion may include, but are not
limited to, crown to root ratio, remaining root length, peri-
odontal attachment lev-
els, advanced periodontal per-
odontal health of teeth adjacent to the proposed fixture site and non-restor-
able conditions. In addition, the clinician must consider questionable teeth in need of endodontic treatment, teeth requiring endodontic/periapical amplifications, semi-secions or ad-
vanced periapical procedures with a questionable prognosis and pulpal condition at the gingival margin with roots shorter than 15 mm. These teeth will require endodontic treatment prior to implantation due to the presence of post/cores and crowns; however, their longevity is very much in doubt with these paramete-
rms.

Practitioners are ethically obligated to inform patients of all treatment options. The patient’s attitude, values and expectations are integral to the risk

assessment algorithm. Poor motivation to retain a tooth mandates extraction, not clini-
cal intervention whereas high motivation to retain a tooth mandates clinical intervention or surgery. The process of planning, pres-
etuation and acceptance of dental treatment is always dom-
inated by the dualism of emotion and pragmatism associated with cost. Where it becomes economically or by-side dollar comparison of restoring a natural tooth or placement of a fixed bridge or an endo-
dontic biolopacm of a debilitated tooth.

Far too often the comparati-
ion of purported treatment outcome percentages are based on corporate affilia-
tions, pressures and status. Treatments are simply too narrow a pa-
rameter to suggest comparable alternatives. With the treat-
manship of an experienced endodontist, the very few structurally sound teeth need be removed.

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Fig 16b–Modification of taper in last mm of the apical terminus, exaggerates the “restric-
tion” or minor apical diameter. thermo-light cervical condensation has been shown to enhance survival rates. The effect of the apical termination on the geometric density of the required hermetic apical seal as well as enabling more material to flow into the region to occlude files, canal debris, dents and lateral arborizations.

References