THREE-DIMENSIONAL OBTURATION OF THE ROOT CANAL SYSTEM*

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** Portions of this article have been updated since its original publication to properly reflect Dr. Ruddle's current supplies and/or equipment utilized (July 2006).*

Pulpal injury frequently leads to irreversible inflammatory conditions that can proceed to ischemia, infarction, necrosis and pulp death. This phenomenon originates in a space exhibiting infinite geometrical configurations and intricacies along its length *(Figures 1, 2)*.[1] Root canal "systems" commonly contain branches that communicate with the attachment apparatus furcally, laterally, and often terminate apically into multiple portals of exit *(Figures 3-8)*.[2] Consequently, any opening from the root canal system to the periodontal ligament space should be thought of as a portal of exit through which potential endodontic breakdown products may pass.

Improvement in the diagnosis and treatment of lesions of endodontic origin occurs with the recognition of the interrelationships that exist between pulpal disease flow and the egress of irritants along these anatomical pathways. It is fundamental to associate radiographic lesions of endodontic origin as arising secondary to pulpal breakdown and forming adjacent to the portals of exit *(Figures 4-6, 9, 10)*.[3]

Clearly, the healing capacity of endodontic lesions is dependent on many variables including diagnosis, complete access, and the utilization of concepts and techniques directed toward three-dimensional cleaning, shaping and obturation of the root canal system.[4-6]

The purpose of this article is to describe an obturation technique that is safe, easy to use, and routinely fills root canal systems in three dimensions.[7] The obturation technique that will be described is the vertical compaction of warm gutta percha.

Figure 1. Post-op film of a mandibular first molar depicting a three-dimensionally packed root canal system. Observe the anastomosing systems in the mesial root and the multiple apical portals of exit associated with each root.

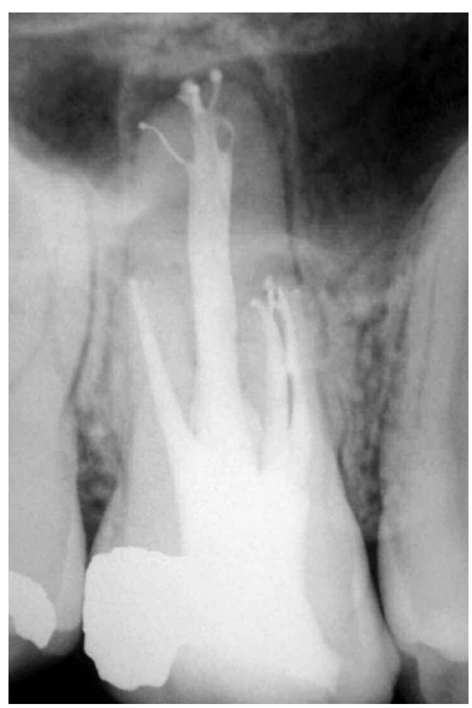

Figure 2. Post-op film of a maxillary first molar revealing three-dimensional compaction of complex canal systems. Note the MB root containing two anastomosing canal systems and the multiple portals of exit associated with all apices.

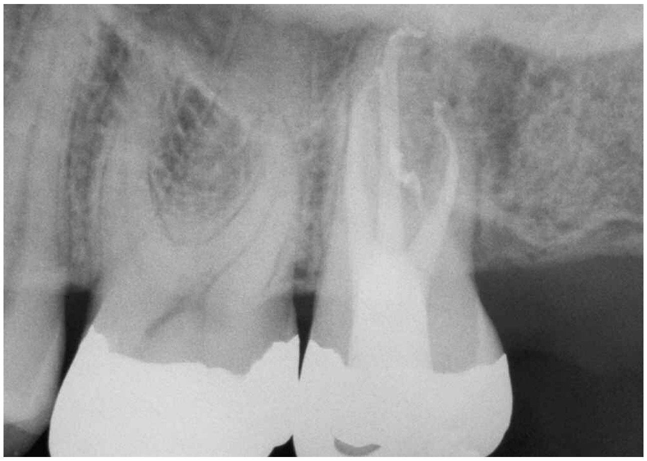

Figure 3. Post-op film of a maxillary second molar demonstrates the shape and flow of the packed root canal system. Note the treated furcal canal and apical recurvature of the distal-buccal system.

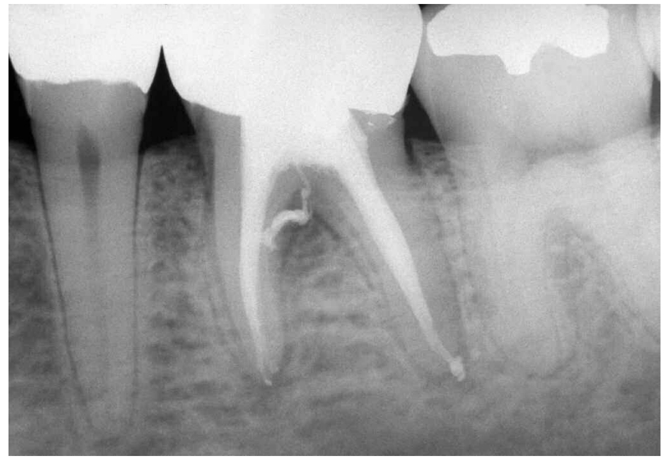

Figure 4. Post-op film of a mandibular first molar demonstrates the periodontal importance of treating lesions of endodontic origin. The pulpal floor was packed with warm gutta percha/sealer.

Figure 5a. Pre-op film of a maxillary first bicuspid. Note the large lateral root lesion and the presence of a traced fistula. Pulp testing confirms a lesion of endodontic origin.

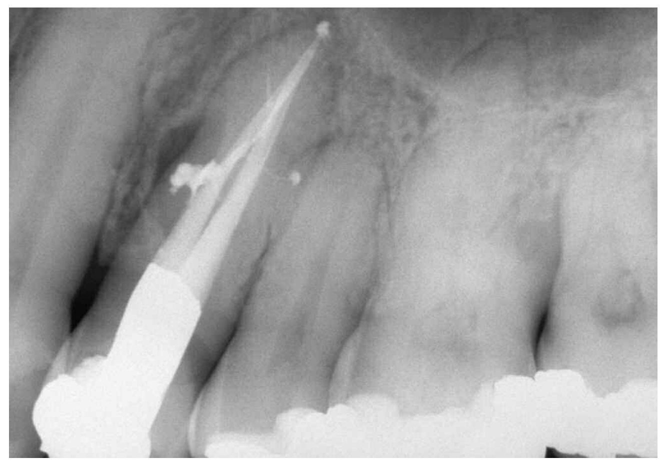

Figure 5b. Three-year recall demonstrates excellent apical and lateral ossification. Note the shape and flow of the merging buccal and lingual systems containing several lateral canals. Surplus material has not impeded healing.

Figure 6a. Post-op film of a maxillary first bicuspid demonstrating a significant distal crestal lesion. Note the dense compaction obtained by the Schilder warm gutta-percha technique and the five treated apical and lateral portals of exit.

Figure 6b. Six-month review demonstrates good progressive apical and lateral bone fill.

Cleaning and Shaping Objectives

Central to successful endodontics is knowledge, respect, and appreciation for root canal system anatomy and to careful, thoughtful, meticulously performed cleaning and shaping procedures.[8]

Cleaning removes all the pulp, breakdown products, and microbes whereas shaping is the development of a logical cavity preparation that is specific for each root. Shaping accomplishes two major goals.

First, shaping facilitates cleaning by progressively removing restrictive dentin in a predetermined design, significantly enhancing the ease, effectiveness, and control of canal preparation and complete penetration of irrigation throughout the root canal system. Second, shaping allows a graded series of pluggers to work deep within the root canal system unimpeded by dentinal walls so that warm gutta percha can be easily compacted.[9]

The endodontic breakthrough occurs when it is understood that unshaped canals cannot be cleaned. A three-dimensional fill of any root canal system requires the performance of cleaning and shaping procedures that produce a canal preparation that any dentist can effectively obturate. It is axiomatic that well-shaped canals will become consistently well-filled canals.

Figure 7. *Post-op film of a mandibular second bicuspid reveals "the pack" and depicts completed treatment of the primary system containing three apical portals of exit.*

Figure 8. *Post-op film of a maxillary first molar. Note the dramatic curvatures of the mesiobuccal (MB) root canal system in the apical third. The MB system bifurcates apically then terminates in four apical portals of exit.*

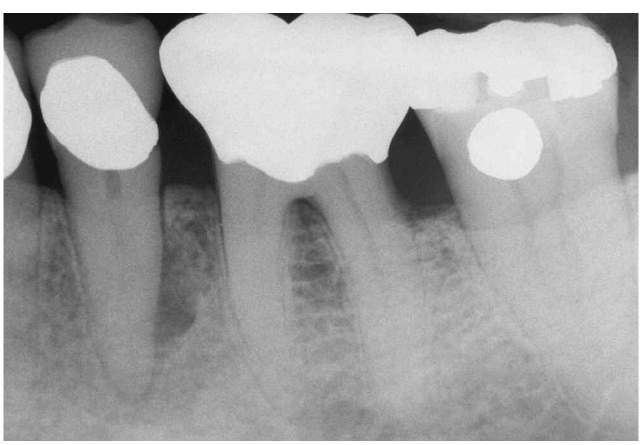

Figure 9a. *Pre-op film of a mandibular second bicuspid depicting a large middle one-third lateral root lesion of endodontic origin.*

Figure 9b. *Radiographic review reveals a dense three-dimensional fill, endodontic elimination of three significant portals of exit, and the inevitability for osseous repair in spite of surplus material after filling.*

Current Obturation Techniques

Dramatic improvements in endodontic therapy have occurred on multiple fronts. Perhaps the most intriguing advancement for many dentists is the observation of obturation potentials of various techniques. Justifiably, practitioners are constantly searching for three-dimensional obturation techniques that are safe, predictable and expeditious.

Many of these obturation techniques are potentially more three-dimensional than the older time-honored lateral condensation techniques.[10] A few of these three-dimensional obturation techniques, however, have clinical disadvantages such as dimensional changes, lack of control and alteration of the physical properties of gutta percha.

In the early 1960s, Dr. Herbert Schilder ingeniously created the warm gutta percha with vertical condensation technique. Thirty years later, significant numbers of well-trained dentists continue to select this obturation technique because it is simple, efficient, effective, and routinely fills root canals in three dimensions. Furthermore, this technique is easily reversible in case the clinician needs to remove gutta percha for any reason.

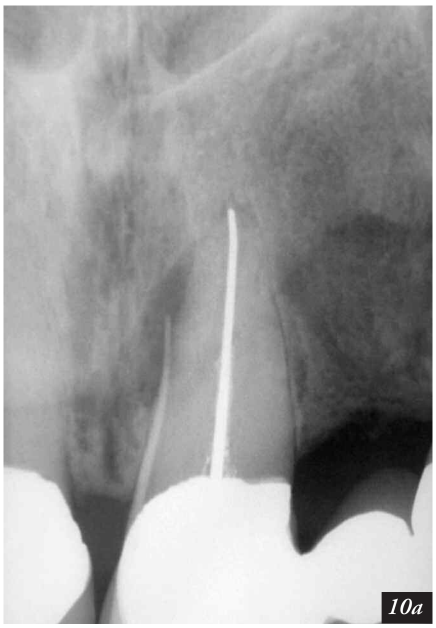

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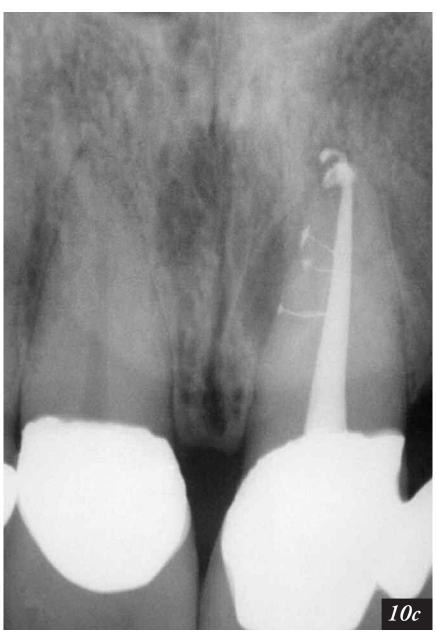
Figure 10a. *Pre-op film depicting a maxillary central incisor bridge abutment. A gutta percha point traces a fistulous tract to a large lateral root lesion. The canal is considerably underfilled and slightly overextended.*

Figure 10b. *A working film during the downpack reveals apical corkage and three packed lateral canals. Note the mass of gutta percha is apical to the most coronally positioned lateral canal.*



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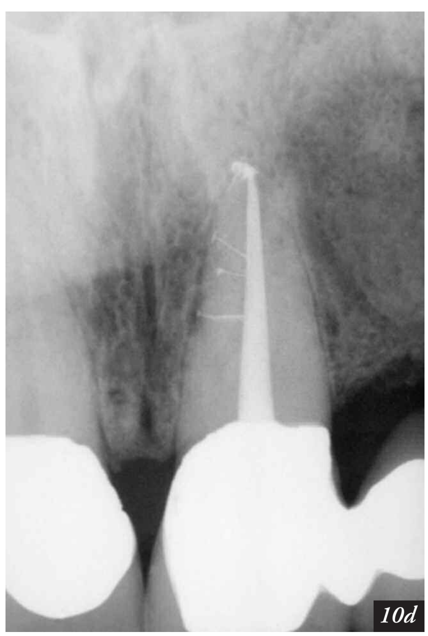

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Figure 10c. *Following the backpack a post-op film reveals a densely packed root canal system.*

Figure 10d. *Five-year review demonstrates the importance of three-dimensional endodontic treatment and excellent progressive healing.*

Physical Properties of Gutta Percha

The physical and thermomolecular properties of gutta percha are well understood and have been described previously.[11-15] Gutta percha is a long chain hydrocarbon and is an isoprene unit of naturally obtained rubber. Heated thermal conductivity through gutta percha occurs over a range of 4-5mm. Gutta percha need only be elevated in temperature 3-8°C above body temperature or 40-45°C, to become sufficiently moldable so that it can be easily compacted into the infinite geometric configurations of the root canal system. Repeated gutta percha heatings slowly increases and progressively transfers heat through the length of the gutta percha master cone, transforming it from a semi-rigid to a moldable state.

Vertical condensation and effective adaptation of thermo-softened gutta percha occurs over a range of 4-5mm. Vertically condensing gutta percha as it cools slightly from a maximum of 45°C to body temperature (37°C) produces an optimally adapted, dimensionally stable material.

To consistently meet these obturation objectives, any syringeable gutta percha technique must include intermittant vertical compactions of injected thermosoftened gutta percha every 4-5mm to discourage shrinkage and loss of volume.

Cone Fit

After optimal canal preparation and appropriate drying techniques, a non-standardized cone of gutta percha is selected that closely resembles the dimension of the cleaned and shaped canal. The greater taper of these master cones, as compared to the standardized gutta percha, ensures more effective obturation (as will be understood subsequently). Generally, a "fine medium" or "medium" non-standardized master cone is selected and fitted so that the rate of taper of the master cone is less than, but parallels, the rate of taper of the prepared canal; the master cone can be inserted to full working length, not further, and upon removal it should exhibit apical tugback *(Figure 11)*.

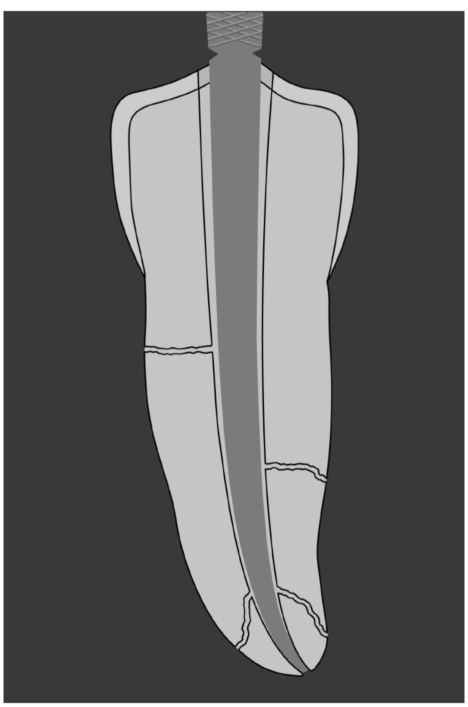


Figure 11. *A non-standardized gutta percha master cone is selected and adjusted so it is loose in the coronal and middle one-thirds, fits to the canal terminus, and is snug in its apical extent.*

Master cones can be further customized by using heat, glass slabs, or cold rolling with a spatula. A diagnostic film should confirm the master cone's position and all the operative steps to date. The master cone is then cut back 0.5-1.0mm from the canal terminus or consistent drying point. It is simple to fit a master cone into a well-prepared canal and, when properly performed, ensures that obturation is controlled, complete and quick.

In irregularly shaped orifices/canals, a supplemental point, typically of size fine medium or medium, should be placed lateral to the master cone to enhance compaction.

Sealer

Kerr Pulp Canal Sealer EWT *(Kerr/Schein)* is the sealer of choice in this technique for a number of reasons:

1. Flow, lubrication, and viscosity.
2. Virtually inert in the periapical tissue.
3. Virtually non-resorbable.
4. Sets in the presence of heat.
5. Zinc oxide and eugenol combine to form zinc eugenate, a prostaglandin inhibitor. Prostaglandins are a known pain mediator.

Kerr pulp canal sealer sets and is essentially inert within 15-30 minutes, thus significantly reducing the inflammatory responses noted with sealers that take 24-36 hours to set. The amount of sealer used in the warm gutta percha with vertical condensation technique is minimal in that only a thin film occupies the dentin/gutta percha interface. A thin sealer film has been shown to be significantly less predisposed to wash out.[16]

Initially, most obturation techniques rely on sealer pools to fill the space between the gutta percha cones and the gutta percha dentin interface. Over time these lakes of cement readily undergo dissolution and shrinkage.

Armamentarium

PLUGGERS

Dentsply Maillefer manufactures a set of Schilder pluggers used to pack thermo-softened gutta percha into the root canal system. There are nine instruments in the set and the series ranges from the smallest plugger, size 8, and increases by half sizes to the largest plugger size 12. The smallest (size 8) plugger is 0.4mm in diameter at its working end, the 8-1/2 size plugger is 0.5 mm, and so on. I recommend the posterior set of pluggers because they are designed for easy use on posterior teeth.

Additionally, the pluggers have reference lines at 5mm intervals so the clinician will always know the depth of the plugger.

Rubber stops can be placed on the pluggers to further orient the clinician to the desired depth of placement. Generally, three pluggers are used for any one root canal preparation. Clinicians should select pluggers whose diameter is just slightly less than the canal preparation at any given level. The diameter of the largest plugger selected must work passively, unimpeded by dentinal walls, over a range of a few millimeters in the coronal one-third ***(Figure 12)***. A smaller diameter plugger is chosen that can work passively but effectively in the middle one-third ***(Figure 13)***, and a small plugger is selected that can work easily to within 4-5mm from the canal terminus ***(Figure 14)***.

The pluggers selected must be pre-fit before packing so the clinician knows with confidence that when a plugger meets resistance it is on thermosoftened gutta percha and not unyielding dentinal walls.

HEAT SOURCE

There are several heating units designed to thermosoften gutta percha. I prefer the 5004 Touch 'N Heat *(Kerr/Schein)* for a variety of reasons. This small and highly efficient unit can be set at the desired temperature so the clinician can start the heat carrier by merely touching a designated area on the probe. Almost instantly, the carrier becomes red hot, transferring heat into the gutta percha. Because of the thermomolecular properties of gutta percha, heat will transfer about 4-5mm along the master cone from the point of heat contact.[11,15] Thermosoftened gutta percha has compaction potential.

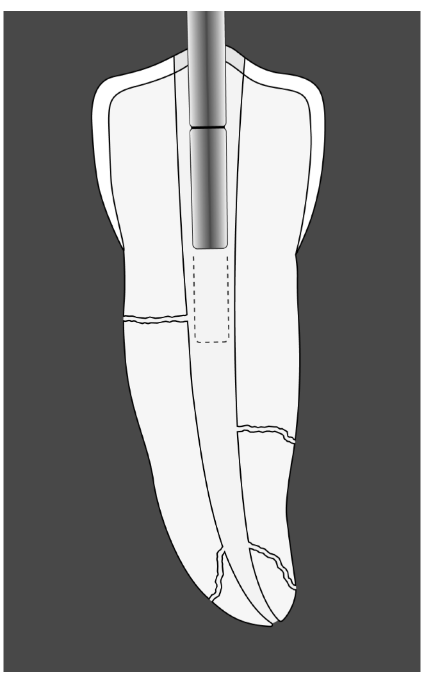


Figure 12. *A large size plugger is selected such that it will work passively and effectively over a range of a few millimeters in the coronal one-third.*

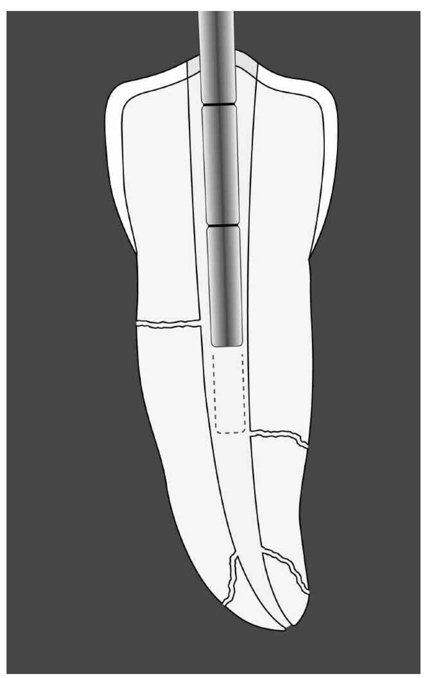


Figure 13. *A smaller size plugger is selected such that it will work passively and effectively over a range of a few millimeters in the middle one-third.*

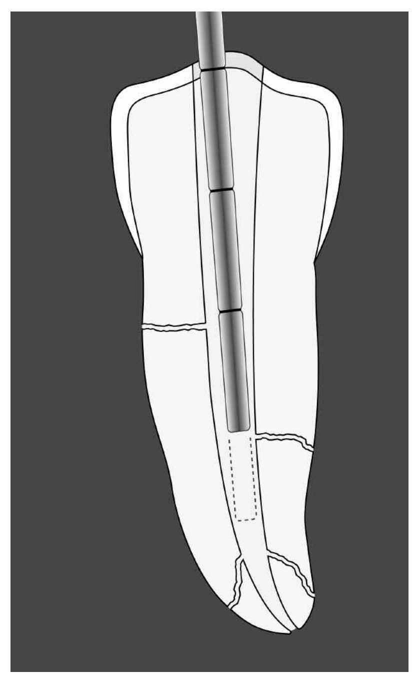


Figure 14. *A smallest size plugger is selected that will work passively and effectively over a range of a few millimeters to within 4-5mm of the canal terminus.*

GUTTA PERCHA DELIVERY SYSTEM

As will be discussed shortly, following the downpack and corking the apical one-third, the most efficient way to back-pack the root canal system is to use the Calamus Flow gutta percha delivery system *(Dentsply Tulsa Dental)*. This well-designed and engineered system allows the clinician to select the appropriate temperature and flow rate to uniformly place heated aliquots of gutta percha against the previously corked apex. These thermosoftened segments are readily compacted into the root canal system in an apical to coronal direction.

Sealer and Master Cone Placement

The amount of Kerr pulp canal sealer used is typically one small bead of cement carried into the carefully dried canal preparation with the last working file that can fit to the canal terminus. The file carrying the sealer is placed into the preparation to full length and gently worked in short up and down circumferential strokes so that the cement is streaked along the canal walls.

Additionally, the pre-fitted master cone is lightly buttered with cement in its apical one-third and the cone is slowly and carefully teased to place to prevent cement from being displaced periapically. We are now ready to pack.

Vertical Condensation of Warm Gutta Percha

The objective of this obturation technique is to continuously and progressively carry a wave of warm gutta percha along the length of the master cone starting coronally and ending in apical corkage. The vertical compaction of warm gutta percha is conducted in a heat-sustained compaction cycle and is performed in the following manner.

DOWNPACK

Following sealer placement and master cone insertion, the heat carrier is started and the non-useful portion of the cone is seared off and removed either at the CEJ in single rooted teeth or at the orifice level in multi-rooted teeth ***(Figure 15)***. Heat will transfer through the master cone and supplemental points, if used, about 4-5mm. The apical extent of the largest prefit plugger is lightly coated with dental cement powder to prevent adhesion to the tacky gutta percha and to vertically pack the thermosoftened mass apically ***(Figure 16)***.

To capture the maximum cushion of warm gutta percha, the plugger is stepped circumferentially around the canal while plugging apically with firm, short strokes. This cycle is completed by a sustained firm apical push held for a few seconds. Tactilely, the operator will feel the thermosoftened mass of gutta percha begin to stiffen as it cools during continuous vertical condensation. The apical and automatic lateral movement of thermo-softened gutta percha three-dimensionally adapts to the preparation over a range of 4-5mm and is termed a wave of condensation.

Compacting thermosoftened gutta percha apically moves this mass into narrowing cross-sectional diameters of the preparation, creating a piston effect on the entrapped cement, which produces significant sealer hydraulics. It should be noted that the master gutta percha cone has not yet been heat-altered in the middle and apical one-thirds. This completes the first heating and compaction cycle.

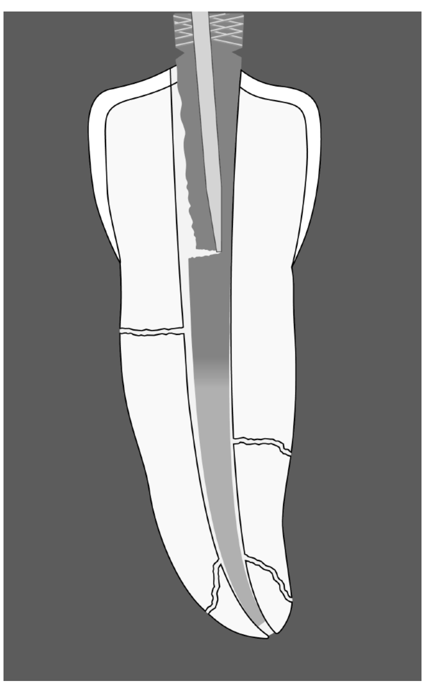


Figure 15. *The heat carrier is activated and the non-useful portion of the master cone is seared off with the tip of the carrier at the level of the CEJ in single-rooted teeth. Note the limited transfer of heat through the gutta percha.*

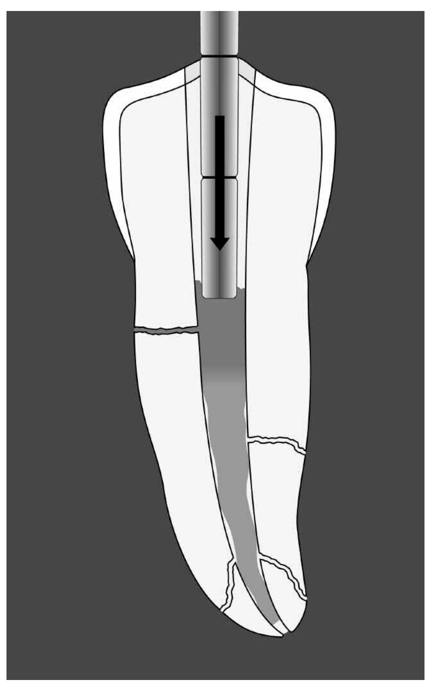


Figure 16. *The large prefit plugger generates the first wave of condensation and compacts warm gutta percha vertically and automatically laterally into the root canal system.*

Immediately, the probe of the Touch 'N Heat unit is introduced into the orifice, started, and allowed to plunge 3-4mm into the coronal most extent of the gutta percha *(Figure 17)*.

The heat-activating element is released and the clinician pauses momentarily, allowing the instrument tip to begin cooling. The heat carrier is then removed along with an adhered bite of gutta percha *(Figure 18)*.

Two important events have occurred. The first result of this action is the progressive apical transfer of heat along the master cone another 4-5mm. The second result of removing a bite of gutta percha is that a smaller prefit plugger can be placed progressively deeper into the root canal preparation where it can vertically pack warm gutta percha. Again, gutta percha will three-dimensionally fill the preparation laterally and in depth over a range of 4-5mm, producing a second wave of condensation, piston effect, and resultant sealer hydraulics *(Figure 19)*. The downpack continues in a heat-sustained compaction cycle.

Through heating, gutta percha removal and vertical condensation of warm gutta percha, the cycle continues, usually about three to four times, depending on root length, until the smallest prefit plugger approaches the apical one-third and can be placed within 4-5mm of the canal terminus.

Following the final heating and gutta percha removal cycle *(Figure 20)*, the transfer of heat is progressive into the apical one-third of the gutta percha master cone, reaching a maximum temperature of about 45°C. The smallest prefit plugger need not be placed closer than 4-5mm of the canal terminus and can predictably deliver a thermosoftened wave of gutta percha into the narrowing cross-sectioned diameters of the canal, resulting in apical corkage *(Figure 21)*.

The plugger action is firm, short, vertical strokes capturing the maximum cushion of rubber. A sustained vertical push on the plugger will produce the final wave of condensation. Stepping the plugger circumferentially along the canal perimeter while plugging apically during the gutta percha cooling cycle will effectively offset any potential for shrinkage and allow for controlled predictable apical corkage.[11] A periapical working film taken during or at the conclusion of the downpack frequently reveals filled lateral canals coronal to the apical mass of gutta percha *(Figure 10b)*. The material in the previously cleaned lateral canals is either gutta percha, sealer, or a combination of both.

BACKPACK

The downpack is completed, and if a post is desirable to facilitate prosthetic dentistry, then post selection and placement can ensue. Otherwise, reverse filling the canal is recommended so as not to leave dead space radicularly. The backpack technique that is the most effective and efficient involves using the Calamus Flow gutta percha delivery system.

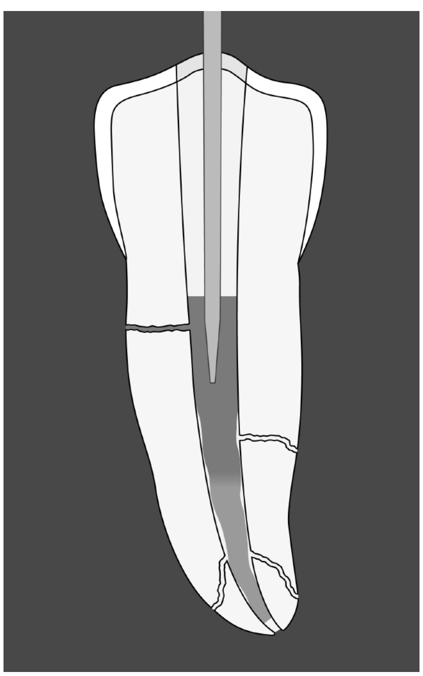


Figure 17. *The heat carrier is started, is almost instantly red-hot, and is allowed to plunge about 3-4mm into the gutta percha coronally. Note the progressive apical transfer of heat through the gutta percha master cone.*

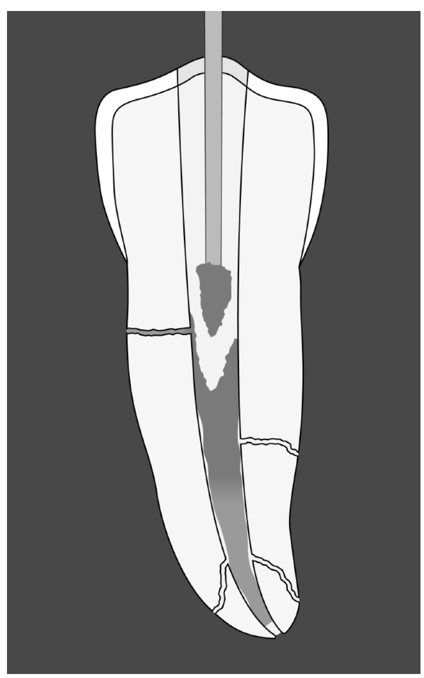


Figure 18. *The heat carrier is deactivated and after hesitating momentarily, the cooling instrument is removed along with a bite of gutta percha.*

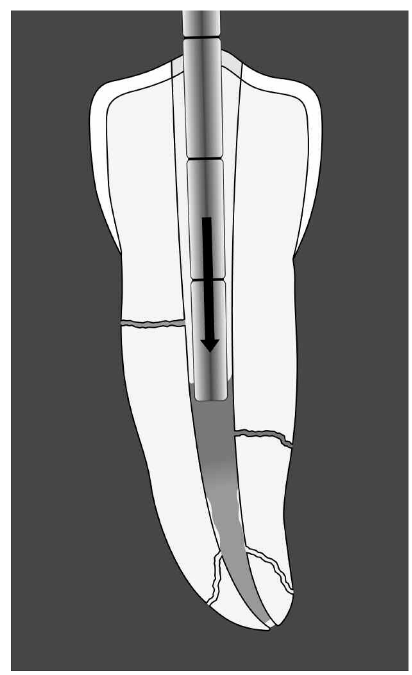
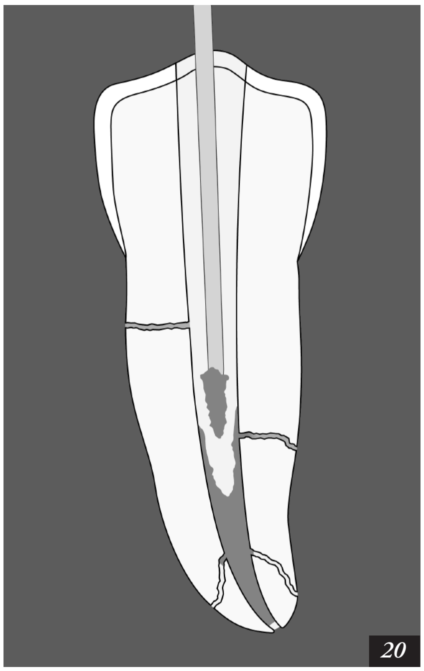


Figure 19. *A smaller prefit plugger captures the maximum cushion of rubber and carries a wave of warm gutta percha into the narrowing cross-sectional diameters of the preparation. This second wave of condensation fills the system three-dimensionally over a range of 4-5mm.*

The tip of the hot Calamus Flow needle is inserted into the canal until it comes into contact with previously packed gutta percha apically.

Holding the Calamus Flow handpiece lightly, the operator depresses the activation cuff dispensing a controlled 4-5mm segment of uniformly thermosoftened gutta percha against the previously corked apical one-third ***(Figure 22)***.

Properly performed, the operator will feel the Calamus Flow handpiece backing out of the canal easily and progressively when placing small aliquots of warm gutta percha. The smallest prefit plugger is used in short vertical strokes and is stepped circumferentially around the preparation enabling the clinician to capture a maximum cushion of rubber generating a reverse wave of condensation ***(Figure 23)***.



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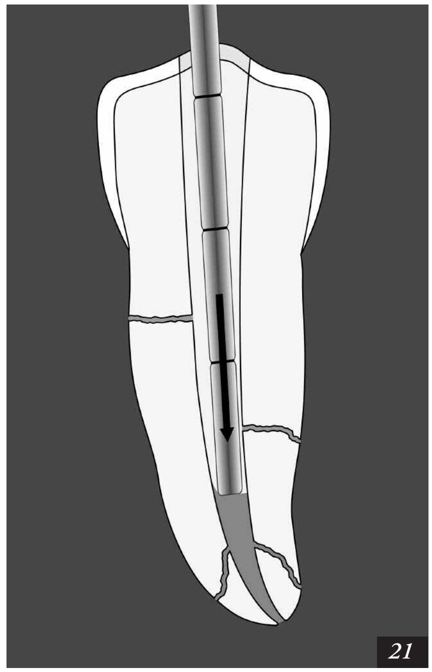

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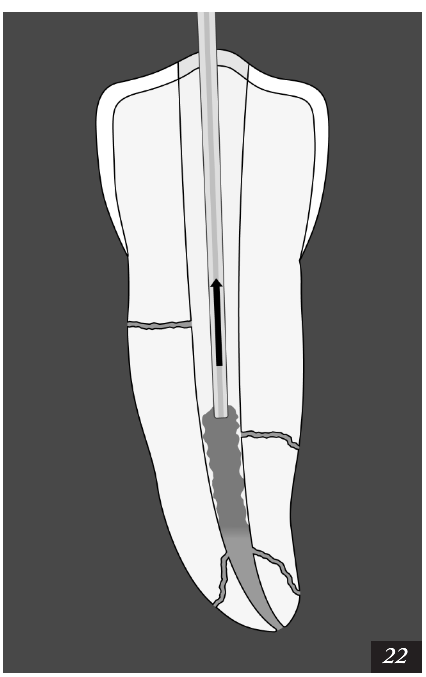
Figure 20. *The heat carrier is started, plunges another 3-4mm into the gutta percha, is deactivated, and, after a moment of hesitation, it is removed along with another bite of gutta percha. Note the complete transfer of heat apically throughout the length of the master cone.*

Figure 21. *The smallest prefit plugger effectively creates the final wave of condensation and delivers warm gutta percha into multiple portals of exit, resulting in apical corkage.*



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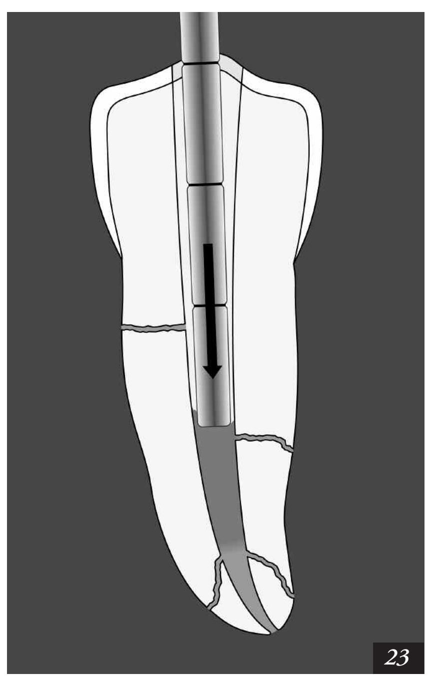

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Figure 22. *The Calamus Flow is used to place a 4-5mm segment of warm gutta percha. Initially the needle is positioned against the previously packed gutta percha apically. Dispensing properly will allow the handpiece to back out of the canal.*

Figure 23. *A prefit plugger three-dimensionally packs thermosoftened gutta percha generating a reverse wave of condensation. Stepping the plugger circumferentially around the canal preparation while using short firm strokes eliminates space and will ensure a dense solid core of gutta percha.*

Through a series of gutta percha placements and vertical condensations the canal is filled in a reverse manner *(Figures 24-26)*.

The pulp chamber floor of multi-rooted teeth should be covered with a thin layer of sealer and gutta percha should be dispensed into the chamber floor. Using an appropriate plugger, the thermosoftened gutta percha is plugged vertically, allowing for the obturation of furcal canals *(Figure 4)*.

At this stage, a radiograph should be taken to confirm that the root canal system is densely obturated to the canal terminus. Frequently, a sealer puff will be noticed adjacent to the portals of exit, which ensures that the root canal system has been eliminated in its entirety. Because of a well-fitted master cone, sealer puffs will generally be larger laterally and smaller or nonexistent apically. Surplus sealer is thoroughly excavated from the pulp chamber with xylol or chloroform to prevent residual sealer from infiltrating the dentinal tubules where longitudinal crown darkening could result. The clinical crown can now be restored in the appropriate manner.

Conclusion

The dental profession and general public have become increasingly interested in retaining endodontically involved teeth and annually millions of teeth are being saved due to better trained general dentists and specialists alike.

The degree of endodontic success is directly proportional to a clinician's knowledge of, appreciation of, and respect for the root canal system anatomy and the techniques selected when performing treatment. As the health of the attachment apparatus of endodontically-treated teeth is fully understood and appreciated, the naturally retained root will be recognized as the "ultimate implant". Properly performed endodontic therapy is the cornerstone of restorative and reconstructive dentistry. ▲

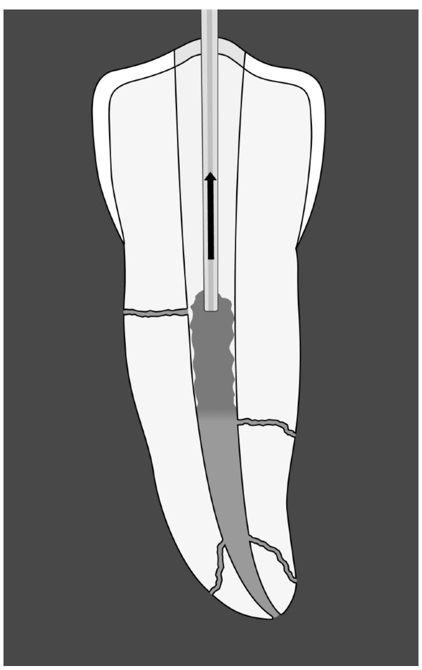

Figure 24. *Another uniformly heated aliquot of gutta percha is placed. Again the needle is positioned against the previously packed gutta percha apically and while dispensing, the handpiece will back out of the canal.*

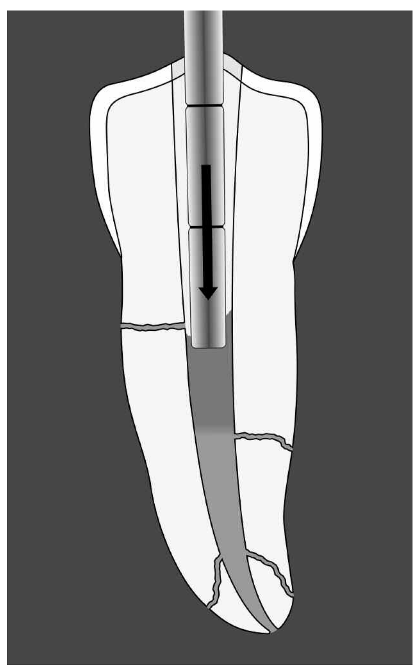

Figure 25. *A larger prefit plugger generates another reverse wave of condensation, three-dimensionally filling the canal with warm gutta percha laterally and in depth over a range of 4-5mm.*

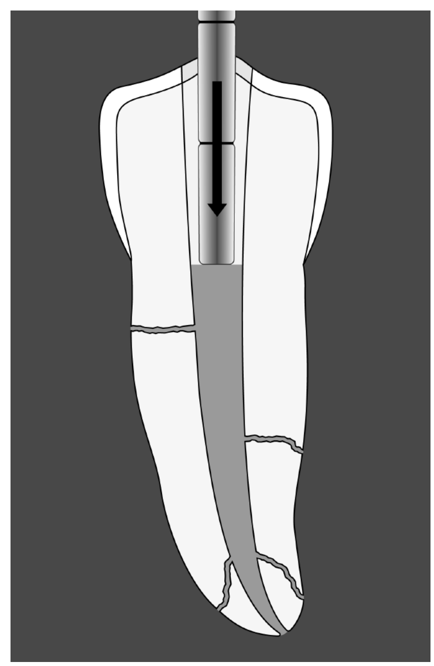

Figure 26. *Following the final placement of warm rubber, the largest prefit plugger delivers the thermosoftened gutta percha three-dimensionally against the walls of the preparation and completes the backpacking phase.*

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