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Vertical Compaction of Warm Gutta Percha

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The objective of nonsurgical endodontic treatment is the total debridement of the root canal system followed by three-dimensional obturation of the remaining endodontic space. Numerous clinical and histologic studies confirm the frequent existence of side branching, delta formation, and multiple canals in individual roots.¹⁻³ Clinical success is enhanced by adopting techniques that maximize the potential for debriding and totally obturating root canal systems effectively and consistently.

Most reliable endodontic techniques have been built upon the triad of root canal *instrumentation, sterilization, and filling*. Modern endodontics, recognizing to a greater extent the biologic and anatomic problems to be dealt with, has gradually modified the triad to *cleaning and shaping, mechanical sterilization, and three-dimensional obturation*.^{4,5} This more sophisticated appreciation of the biologic and mechanical issues involved in endodontic treatment has produced increasingly more satisfactory treatment results.

Improved success rates in endodontic treatment resulting from better cleaning and shaping and more effective obturation of root canal systems have, indeed, altered the dental profession's entire view of periapical pathosis and the healing capacity of lesions of endodontic origin.

Apical lesions of endodontic origin, which in past years would be treated surgically, are now being treated successfully nonsurgically. The misguided fear of apical epithelium, chronic lesions, fistulous tracts, and so on has receded during the past two decades with gradual improvement in clinical techniques.

Cleaning and shaping are perhaps the sine qua non of good endodontic technique. The concept embodies two important objectives. *Cleaning* requires the removal of all organic substrate from the root canal system. This includes necrotic tissue, pulp remnants, and associated microbes. *Shaping* requires the development of a logical cavity form that any dental practitioner can fill effectively. Equally important, when properly accomplished, shaping facilitates cleaning. It is impossible to thoroughly debride an unshaped canal.^{4,5}

When thorough debridement is achieved, mechanical sterilization is concomitantly accomplished by the physical removal of microbes along with

the underlying organic substrate. This greatly reduces the need for drugs in modern endodontics.

Essentially, therefore, after proper diagnosis and treatment planning, clinical endodontics can be thought of as a rather precise extension of operative dentistry. It may be viewed as a cavity concept with certain biologically and anatomically imposed modifications. In restorative dentistry, dentists seek to clean out carious lesions and to prepare logical cavity forms (see G. V. Black⁶) to receive three-dimensional, hopefully hermetically sealed, restorations. The carious lesions are most often located in the coronal part of the tooth, and the process of caries removal hopefully removes all organisms related to the process of decay. It follows that most dental restorations are also coronal or at the cervical part of root surfaces.

It should take little adjustment for the dental profession to shed the limitations imposed by earlier endodontic concepts and techniques and to sense the parallel with operative dentistry. In endodontics, the major problem is necrotic and/or potentially necrotic material in roots and root canal systems.

CLEANING AND SHAPING OF THE ROOT CANAL

The cavity form required, therefore, for effective removal of substrate and for predictable three-dimensional obturation is one that extends from the apical foramen to the coronal access cavity. For the purpose of describing the technique of vertical compaction of warm gutta percha, a few of the more salient mechanical objectives of this root canal cavity design should be recalled. The exact techniques recommended by the author for cleaning and shaping have been described in detail elsewhere.^{4, 5}

A well-shaped root canal is one that presents a gradually tapering cone, the narrowest part of which is directed apically and the widest part of which is directed coronally. The development of the cone will require the operator to carefully prepare the apical few millimeters so as to ensure that each internal cross-section of the prepared canal is wider as one withdraws from the apex into the canal itself.

Additionally, respect must be maintained for the natural curvatures of roots and root canals. A well-shaped canal will take into account these normal and frequent turns and will exhibit *flow*. That is, the prepared conical shape will occur in multiple planes, depending upon the normal curvature of the original canal. The lesson here is to learn to shape around canals in such a way that they then are straightened in their coronal and middle thirds but *never* in their apical third. This is easily learned. A well-shaped canal requires that its apical foramina not be transported by tearing, ripping, perforating, or blocking — all common mistakes when "instrumentation" alone is considered.

Lastly, the apical foramen should be kept as small as is practical and not be enlarged needlessly beyond its original size. For purposes of compacting warm gutta percha, 0.2 to 0.25 mm might be considered a minimal dimension for easily practicing the technique.^{4, 5}

At this point a word should be said about the instruments used for the cleaning and shaping of the root canal system. Complete cleaning and shaping are achieved with three hand instruments — barbed broaches,

reamers, and files — aided at times by engine-driven Gates-Glidden drills. All cleaning and shaping procedures are accompanied by copious irrigation.

Barbed broaches are made by gouging or cutting spurs from the round shaft of the instrument. Because of the inherent fragility of this instrument, it must be used with extreme caution and must be discarded after use. Since the function of the broach is to remove pulp tissue, and not merely to rearrange it, a broach of the proper size should be selected. This would mean that the broach would be wide enough to engage and remove the pulp, but not so wide as to make binding contact with the walls of the canal. A barbed broach should not be used in calcified canals or around curves. A broach should not be used more than two thirds into the canal.

Reamers and files are manufactured by twisting square or triangular shafts of metal on their long axes, thereby translating the vertical "edges" into partially horizontal cutting blades. The cutting edges of files are oriented in a more horizontal direction and are closer together than the cutting edges of reamers, so files are most effective when used in a push-pull motion in the canal. To accomplish thorough cleaning and shaping with a file, this must be done around the entire circumference of the canal wall and throughout the entire length. The reamer, on the other hand, has cutting edges that are oriented more vertically, so it is used in a rotary motion. Because of this rotary motion used with reamers and because the edges are spaced farther apart than files, reamers tend to remove debris upon withdrawal and therefore do not build up the accumulation of dentinal filings in a canal that files do. Because of the rotary motion employed with reamers, they should not be used around curves since they will tend to straighten a curve, creating a "whiplash" effect.

Gates-Glidden drills are small, flame-shaped rotary cutting instruments with long shafts for use with contra-angles. They are designed to cut without pressure, on the belly of the instrument, and to break near the contra-angle if unwarranted force is applied during use. This allows for easy removal from the canal in the event of breakage. Gates-Glidden drills are not used as pathfinders and are used only to enlarge the orifice of the canal. They are not used in canals that do not accept them freely and are not for use in the body of the canal itself.

The point of termination of the root canal filling has been the subject of discussion for decades. The so-called apical foramen rarely ends at the geometric apex of the root. Nor, on the other hand, is it routinely located far from the root apex. In the clinical descriptions to follow, instrumentation to the "apex" signifies placement of reamers and/or files to the radiographic apex or to a point only a fraction of a millimeter short of the radiographic apex.

The following descriptions presuppose appropriate pretreatment when necessary, proper placement of the rubber dam, sterilization of the field and of all instruments to be placed in the canal, and normal access cavity development.

Cleaning and shaping of the root canal system for the warm gutta percha technique are accomplished by serial reaming and filing and constant recapitulation rather than by sequential placement of all instruments to the apical end of the canal preparation. Serial reaming and filing connote the fact that instruments of greater width are used short of the apex in series to make room for reception and directed use of finer instruments apically. Recapitulation refers to the repeated reintroduction and reapplication of instruments

previously used throughout the cleaning and shaping process in order to create well-designed, smooth, unclogged, evenly tapered, and unstepped root canal preparations.

After access preparation, the chamber is irrigated with sodium hypochlorite and a barbed broach is used to remove additional debris or remaining pulp tissue. The canal is irrigated after using the broach, prior to probing to the apex with the initial trial instrument. A #1 file is most routinely used for the trial length determination radiograph. An appropriately larger instrument may be employed if a #1 file would be so loose as to be displaced while the radiograph is being taken. If the initial instrument is at the radiographic apex, this length is recorded and transferred to the next several instruments. If the initial instrument is short of the apex, the canal is irrigated, appropriate adjustment is made on the length, a #1 instrument is inserted to the new length, and another radiograph is taken. If the initial instrument is beyond the apex, a new length is determined, the canal is again irrigated, and a #2 file is placed to the new length. A radiograph is taken to confirm the accuracy of this length.

A word about "working length" is in order at this point. As the body of the canal is enlarged to accept larger instruments, the canal becomes less curved and therefore the actual length between the point of reference and the apex will tend to become shorter. This must be remembered throughout the cleaning and shaping procedure and adjustments made. This can be accomplished only by taking additional radiographs during the shaping of the canal to confirm the accuracy of the distance to the apex.

The #1 file will act as much as a pathfinder as a file and will rarely produce enough shavings to require the use of a reamer to remove debris. The #2 file, with appropriate intentional deflection, is advanced apically and worked in and out repeatedly with 0.5 mm strokes until it fits loosely in the canal. After irrigation it is followed by a #2 reamer to remove debris. Owing to the rotary motion used with reamers, they must not be used around sharp curves. When the #2 instrument fits loosely, a suitably deflected #3 file is positioned apically, and is used in a push-pull motion until it fits loosely. A #3 reamer is used after irrigation to remove the shavings left by the file. This process is continued with increasingly larger instruments and frequent irrigation until the apical portion of the canal has been satisfactorily cleaned.

A film is taken of the last file that was placed to the apex, and the length is adjusted accordingly. The next size reamer is inserted and is given only a half turn when it first makes contact with the canal walls. This should occur before the full "working length" is reached. The reamer is withdrawn without any attempt to force it further apically. The stop on the instrument should be adjusted to this depth of penetration for future reference. The canal is irrigated, the next larger reamer is inserted to the point where it first contacts the walls, and the procedure is repeated. This is repeated with the next size reamer, each time adjusting the stop on the instrument to indicate the point of penetration, as this will occur short of the working length. The funneling procedure has now begun as the body of the canal is being tapered and widened so that it neither restricts nor directs advancing instruments in paths unrelated to the critical apical portion of the canal.

After irrigation, recapitulate for the first time. Replace to the apex the last instrument that was radiographed at the apex. Irrigate and reapply every reamer in the series previously used. In most cases, without additional pressure, each reamer can be advanced closer to the apex before contacting

the walls of the canal and receiving its half turn. After initial recapitulation and additional irrigation, the use of a Gates-Glidden drill at the entrance to the root canal will unify the access preparation with the canal walls shaped by the serial reaming and filing, allowing the operator to place instruments in the canal without misdirection or interference from coronal tooth structure or from coronal or middle third canal walls. The elimination of such interference is critical to successful manipulation of the apical instruments. The Gates-Glidden drill is inserted only a few millimeters into the canal and never into the middle third of the canal. The point of the drill makes no contact whatsoever, as the cutting is done entirely at the belly of the drill. This must be followed by copious irrigation. Additional recapitulation is done, as described previously, and at this point the operator may decide to increase the size of the apex by one file. An additional film is taken to confirm accurate length and the canal is copiously irrigated, dried, and sealed.

When skill has been developed in properly shaping root canals, obturation becomes a relatively simple and satisfying experience.

OBTURATION TECHNIQUES

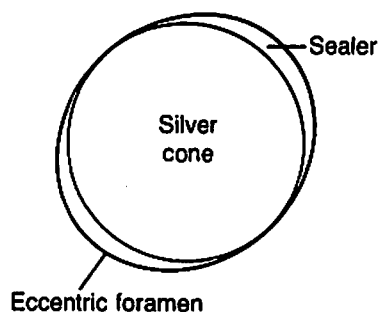
The objective of obturation in endodontics should be to seal permanently as much of the cleaned and shaped root canal system as is possible. Ample evidence exists that the thoroughness with which the root canal system is sealed is a major determinant in endodontic success.⁷ Generally, it has been accepted that the most desirable root canal filling consists of a dimensionally stable, nonresorbable solid cone assisted by a sealer or cement.⁸ Ideally, the sealer should constitute only a small fraction of the obturating material in order to reduce the possibility of dissolution and dimensional instability associated with most pastes and polymer fillings.⁹

Miscellaneous Techniques

Many techniques have been employed to meet these objectives. They can all be expected to produce a certain degree of clinical success. Eucherpercha, chloropercha, and chlororosen techniques utilize the solubility of gutta percha in chloroform and in certain essential oils to produce a physically plastic mixture that, with lateral condensation, can be expected to replicate reasonably well the internal anatomy of the root canal system. Indeed, when these techniques are carried out faithfully, it may be demonstrated that a number of accessory canals are filled as well. Several problems of the technique include the difficulty of curtailing the apical movement of the chemically softened material, the potential irritant effects of the chloroform on the periapical tissues, and the measurable shrinkage that occurs when the chloroform or essential oil volatilizes after treatment.⁴

Silver points in conjunction with sealer have in the past enjoyed great popularity as a root canal filling material. Silver points have the advantage of being able to negotiate narrow and severely curved canals. Their radiopacity is impressive, and when handled well, they are able to seal the apices of many root canals. Unfortunately, because silver points are pre-formed, they are unable to adapt to the intricacies of most root canal systems. Also, when apical foramina are ovoid, it is impossible to seal canals without relying

Figure 3-1 Variation in shape between round silver cone and eccentric foramen. The apical seal in such a case depends more on the sealer than on the silver cone itself. Dissolution of sealer may, over a period of time, lead to leakage and clinical failure of the case.



heavily on cement, since a round silver cone may bind on two points only, without completely obturating an eccentrically shaped foramen (Fig. 3-1). Experience over a number of years has demonstrated a large number of failures when cement has washed out, resulting in seepage not only apically but also along the entire body of the silver cone as well.

Lateral condensation of gutta percha in conjunction with nonsolvent cement has long been taught and utilized for root canal filling. The objective is to press gutta percha cones laterally against each other and against the dentinal walls of the canal so as to produce a dense and well-adapted filling. Tactilely, the illusion of a homogeneous mass is created. Unfortunately, the gutta percha cones never merge into a homogeneous mass after this technique (as does occur with gutta percha solvent techniques).⁷ Rather, the cones glide and slip over each other until they are frozen in a sea of cement as the sealer sets in the later stages of the condensation procedure (Fig. 3-2).

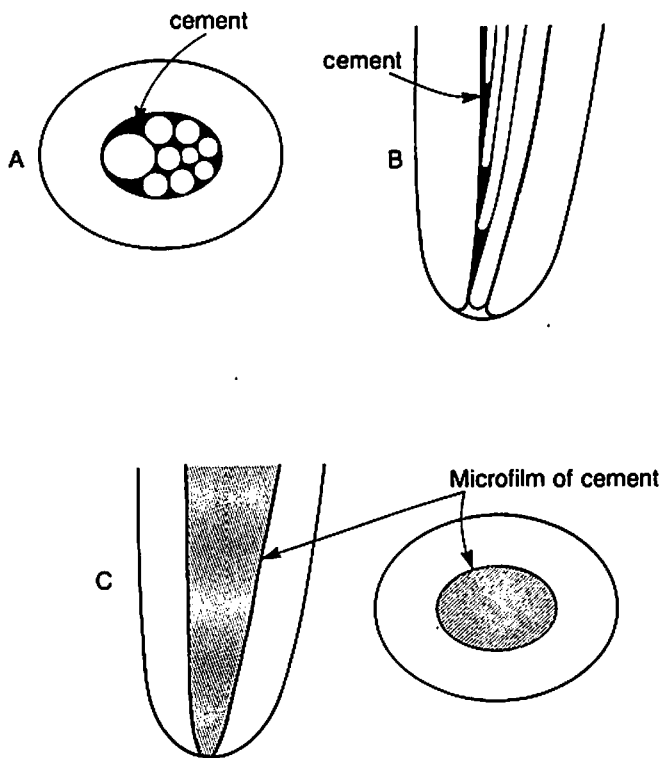


Figure 3-2 A, Cross-section of middle third of root demonstrating primary and auxiliary cones. Gutta percha cones frozen in a sea of cement. B, Longitudinal section of apical portion of root demonstrating primary and auxiliary cones. Gutta percha cones never merge into a homogeneous mass. C, Warm gutta percha with vertical compaction. Gutta percha becomes a homogeneous mass, filling prepared root canal from wall to wall with only a microfilm of intervening sealer.

This leads to undesirably large amounts of cement in the final filling. Also, little improvement over the initial fit of the master gutta percha cone apically is possible if condensation is, *in fact*, lateral and primarily in the middle and cervical thirds of the canal. Recent evidence indicates that an apical seal with "lateral condensation" is enhanced when the spreader is utilized very close to the apex. In these instances, the spreader is acting essentially as a vertical compactor.¹⁰

In reality, heat transfer instruments are rarely carried very deeply into canals except in anterior teeth. Most molar root canals presumably filled by lateral condensation have actually been filled by the method of a single gutta percha cone generously engulfed in sealer. The introduction of finger pluggers provides a reasonable means for operators to try to deal with this problem.

Root canal fillings consisting solely of pastes have been used for over a century and persist to this day. Their appeal is twofold. First, they may be vehicles for pharmacologic agents or they may be pharmacologic agents themselves. Examples would be Sargenti's paraformaldehyde paste and Wycoff's iodoform paste. The list is endless, and pastes with exotic chemical potentiality are still being introduced today. The second appeal of these materials, a deceptive one that is shared by a plethora of newly introduced techniques and materials, is that they can be extruded into canals that have been inadequately cleaned and shaped or that have not been cleaned and shaped at all.

Although a certain degree of success can be achieved with paste fillings, no amount of chemical disinfection will neutralize a grossly contaminated root canal system. On the other hand, modern endodontics shows that a thoroughly debrided canal requires little in the way of pharmacologic assistance. Pharmacologic pastes are an anachronism whose promise of simplicity assures their retention in the dental armamentarium in spite of the unpredictability of the results they provide.

Technique of Vertical Compaction of Warm Gutta Percha

Vertical compaction of warm gutta percha combines reasonable ease with maximal effectiveness in consistently sealing simple root canals and complex root canal systems. Fortunately, gutta percha can be softened not only by chemical action, but also by heat. This fact, combined with improved methods of cleaning and shaping, permits root canal systems to be filled more rationally than was previously possible.

The method of vertical compaction of warm gutta percha depends, to a considerable extent, on the ability to place vertical compactors directly into root canals, much as amalgam pluggers can be placed into coronal cavity preparations. Gradual changes in the shape of prepared root canals make this possible.^{4,5} These changes in canal preparation, however, were at least as much a response to the need for total cleaning and substrate removal as to the requirements of vertical compaction.

A happy solution has occurred. Better prepared canals are cleaner; cleaner canals contain fewer microbes and less toxic substrate¹¹; better shaping has led to better cleaning and fortuitously now allows for the facile placement of instruments to easily compact the slightly softened gutta percha directly into the deepest part of root canal preparations.

In essence, one accomplishes an accurate penetration into the root

canal system, including significant accessory canals. With this technique, accessory canals are routinely observed to be filled in the cervical and middle thirds of roots as well as in apical bifidities, trifidities, and delta formations.⁷ On occasion, auxiliary canals leading to the base of infrabony pockets and into previously resistant bifurcation and trifurcation lesions are also filled. In a sample of more than 10,000 patients treated with this technique in the Endodontic Clinic of the Goldman School of Graduate Dentistry at Boston University, *40 per cent of the patients* exhibited demonstrably filled accessory canals on postoperative radiographic examination.¹² These figures are consistent and have been repeated year after year with only minor variation by many operators accurately employing the technique.

The technique involves the prefitting of appropriate gutta percha pluggers into the prepared root canal, the selection and preparation of a master gutta percha cone, the placement of the master cone into the canal with a small amount of sealer, the controlled softening of the gutta percha with a heat transfer instrument, and the gradual vertical compaction of the softened gutta percha into the space of the cleaned and shaped root canal system. Ideally, a microfilm of cement should surround the final gutta percha filling.⁹ Vertical compaction produces dense homogeneous gutta percha fillings with minimal cement content. All significant portals of exit are permanently sealed.⁷

The technique is predicated on capturing the maximum cushion of softened gutta percha with appropriate pluggers and moving the entrapped material toward the apex. At no time in this technique do the pluggers contact the dentin walls of the canal preparation. To do so is directly antithetical to the basis of the technique because a plugger wedged into the canal preparation *cannot possibly compact the gutta percha* apical to it (or ahead of it, or apically, or in the apical part of the canal). Vertical pressure is also essential to compaction of the mass in order to compensate for potential contraction as the material returns to body temperature. Any thermoplastic technique that does not include vertical compaction will result in gradual reduction in volume of the original root canal filling.¹³

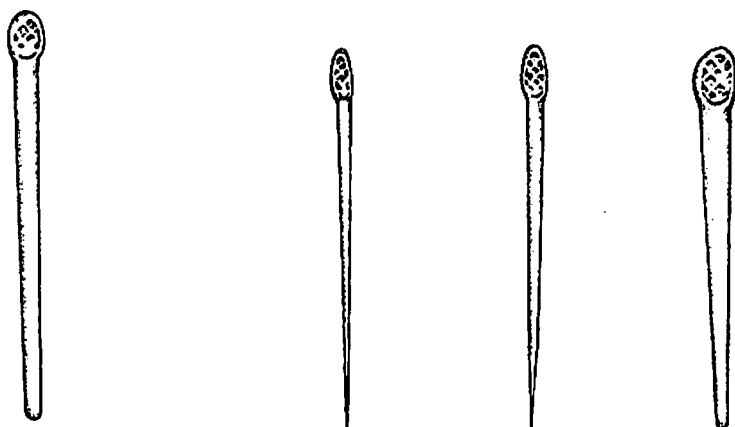
The technique is quite simple but should be carried out exactly if optimum results are to be achieved in each case. The armamentarium consists of a series of pluggers, or compactors, and a heat transfer instrument. The pluggers are marked with 5 mm serrations so that the depth at which they are used within the prepared root canal can be known to the operator at all times. Two lengths are available. The shorter instruments have approximately 23 mm of working length and were designed primarily for use in anterior teeth. In clinical practice, however, most root canal systems can be obturated effectively with the shorter series of pluggers, the longer ones being reserved for unusually long cuspids or incisors. The angle of the plugging end to the shaft is the same for all instruments and has been designed so that the shorter series fits equally well into posterior and anterior teeth.

Heat transfer instruments resemble spreaders in that they are slender and taper to a point. However, they are *never* used with pressure or placed in contact with dentin. They are designed to deliver heat to gutta percha in the root canal. The metal in the working ends has been carefully adjusted so that the instruments can be used repeatedly for up to a year without oxidation.

When necessary, the working end can be unscrewed from the shaft and inexpensively replaced.

The pluggers (both the short series and the long series) are available in a graded series of working end diameters, ranging from 0.4 to 1.5 mm.* The instruments are also labeled in conventional numerology from #8 to #12 by half sizes so that a #8 corresponds to 0.4 mm, #8½ corresponds to 0.5 mm, and so on. Thus, a wide variety of plugging diameters is available to accommodate to root canals of any width. It should be understood, however, that no more than two to four pluggers are necessary for effective obturation of any one canal.

The gutta percha cones that are most suitable for this technique are those in the tapered series (fine, medium-fine, medium and so on) rather than those in the so-called standardized series (20, 25, 30, and so on) (Fig. 3-3).



Standardized gutta percha cone

Tapered series of gutta percha cones

Figure 3-3 Standardized gutta percha cone, and tapered series of gutta percha cones.

Although the quality of the compounded gutta percha is the same for both the tapered and standardized series of gutta percha cones in any brand, the standardized series is inconvenient to use because it does not provide sufficient bulk of gutta percha to effectively obtain an impression of the root canal system. The author prefers to use Mynol gutta percha cones† with this technique, but Healthco‡ and Hygienic gutta percha cones§ are acceptable substitutes.

As has been suggested above, a minimal amount of cement is desirable to ensure maximum sealing of the canal system. Scanning electron microscopic evidence shows that, in spite of the wall-to-wall nature of gutta percha in a three-dimensionally obturated canal, the gutta percha is at no time chemically bound to the dentin surface. The amount of cement used should be kept to a minimum because previous investigations have demonstrated that excessive amounts of cement are prone both to dissolution and to shrinkage over a period of time.¹¹ For a variety of reasons, the author

*Ransom and Randolph, Toledo, Ohio.

†Mynol Chemical Co., Broomall, Pa.

‡Healthco Inc., Boston, Mass.

§Hygienic Dental Manufacturing Co., Akron, Ohio.

prefers to use Kerr Sealer* with this technique. Any one of a wide number of nonirritating sealers with which the operator feels comfortable may be used with this technique since the cement will constitute only a microfilm around the completed gutta percha filling when the technique is carried out properly.

The small amount of cement that is used in this technique is placed into the prepared canal with a lentulo paste filler. Although these instruments have been designed to fit into contra-angles, they should be used only by hand in this technique. It is dangerous and inadvisable to spin any cement into a prepared root canal by means of a dental engine.

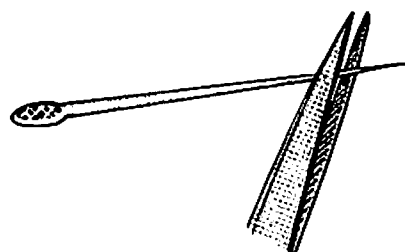
Until recently, the heat for this technique was provided with a heat transfer instrument and a Bunsen burner flame. This remains a convenient means for obtaining heat for those dentists who have safely mounted natural gas Bunsen burners. Alcohol burners provide inadequate heat, and portable "butane" heaters burn excessively hot and can be a risk when employed in a dental office. Presently, a number of cleverly designed flameless heat sources are available that effectively heat a heat transfer instrument. The author prefers to use the metal point heater distributed by the Analytic Technology Corporation, Redmond, Wash. This device heats the tip of a heat transfer instrument to cherry red in a second, while the device itself stays at room temperature, producing no heat whatsoever in itself or in the dental operatory. In addition, electrically controlled heat transfer instruments are available, but wires are required from the electric source to the back of the instrument. The technique is essentially the same regardless of the operator's choice of heat source.

The master gutta percha cone should be selected carefully. Preparation of the cone is the starting point for a good root canal system obturation. Most gutta percha cones that appear to bind on initial placement into the root canal system *do not* bind apically but, in reality, bind laterally somewhere short of the root apex. This well-known fact makes it desirable, therefore, to cut off an appropriate portion of the original cone in order to maximize apical gutta percha bulk (Fig. 3-4). It also requires that apical gutta percha be compacted effectively to fully seal the canal, an objective that is more easily achieved with vertical compaction than with lateral condensation.

The gutta percha cones most frequently used as master cones for well-prepared canals are usually fine-medium, medium, or large for anterior teeth and fine-medium and medium for posterior teeth. Any choice, of course, may be suitable in any individual canal, and it should be borne in mind that canals that have been well-cleaned and well-shaped will easily receive these cones. Fine gutta percha cones are rarely required, and

*Kerr Co., Romulus, Mich.

Figure 3-4 Removal of tip of gutta percha cone. This serves to maximize bulk; to secure apical, rather than mid-root, lateral binding; and to facilitate the ultimate hermetic seal of the apical foramen.



fine-fine cones are never used. When large anterior canals must be filled, it is often desirable to special-roll large or extra-large gutta percha cones in order to reduce their taper slightly.

In all instances, the apical portion of the gutta percha cone should be cut back so that the narrow-pointed end is rejected. This portion of any gutta percha cone is of little value in effectively sealing the canal. By selective removal of varying amounts of the apical tip of a gutta percha cone, any size cone can be easily adjusted to provide a great variety of master cones. During adjustment, the tips of the gutta percha cones are cut off with sterile dental scissors, and the fit is assisted by radiographic control.

The adjusted master cone should be fitted approximately 0.5 to 1 mm short of the radiographic terminus of the canal, should exhibit apical "tug-back," and should provide sufficient bulk for subsequent compaction. "Tug-back" refers to the tactile sensation of apical snugness. (At this time, in tapered canals and ovoid canals, it is sometimes desirable to fit a supplemental cone laterally for added bulk before compaction is begun [Fig. 3-5].) A supplemental cone is usually medium, not fine-fine as in lateral condensation.) The objective of the technique is to compact gutta percha apically rather than to compress cement hydrostatically.

The few pluggers to be used in any individual case are now prefitted into the canal (Fig. 3-6). As has been stated above, the essence of the technique is to capture a maximum cushion of softened gutta percha and to compact it vertically. Accordingly, using a narrow plugger in the wide portion of a canal preparation is ineffective, since such a plugger will penetrate the gutta percha without compacting it effectively (Fig. 3-7). It is equally senseless to use a wide plugger in the narrow portion of a canal preparation, since the plugger will bind against the dentinal walls and be unable to compact the softened material.

For example, it may be determined that #10½, #10, and #9½ pluggers are suitable for obturating a certain prepared root canal system. Accordingly, the instruments should be prefitted into the canal so that the operator becomes familiar and comfortable with each instrument at each level of the canal preparation. Prefitting may indicate to the operator that the #10½

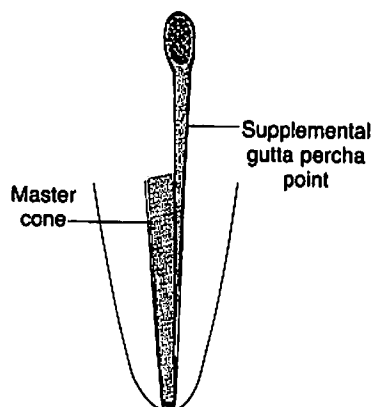


Figure 3-5 Placement of supplemental cone after cementation of master cone but before start of compaction. This is done occasionally, but only when additional bulk of gutta percha is required in the middle and cervical portions of the canal to assure effective obturation of the entire root canal system.

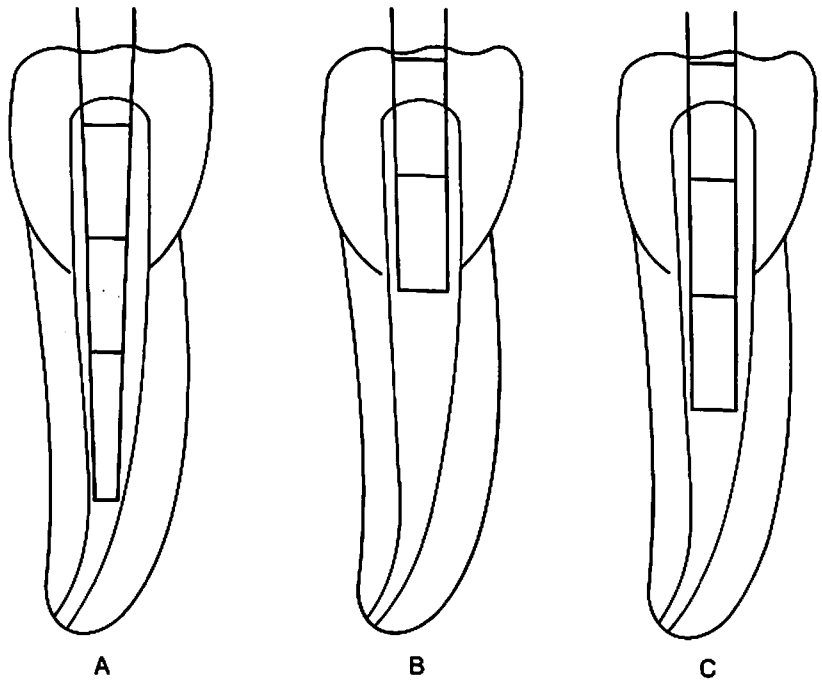
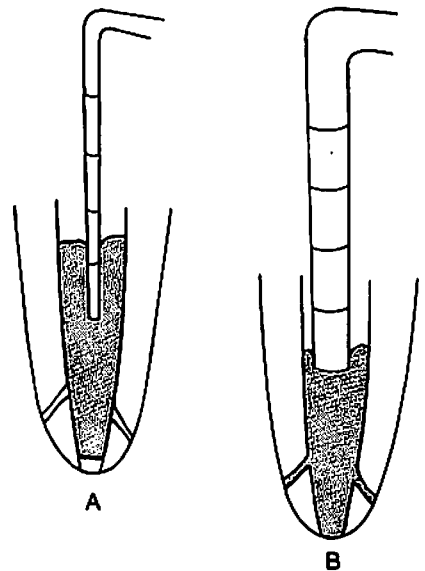


Figure 3-6 Prefitting of pluggers. *A*, The #9½ fits conveniently to the depth of 20 mm. *B*, The #10 fits conveniently to the depth of 15 mm. *C*, The #10½ fits conveniently to the depth of 10 mm.

Figure 3-7 *A*, Small plugger pierces warm gutta percha with little compaction. *B*, Large plugger captures maximum cushion of warm gutta percha, compacting it not only apically, but, without effort, laterally as well.



plugger fits conveniently to the depth of 10 mm, the #10 fits conveniently to the depth of 15 mm, and the #9½ fits conveniently to the depth of 20 mm. In this case, the operator would know that when compaction is being carried out, the #10½ plugger will not be used deeper than 8 mm, the #10 not deeper than 13 mm, and the #9½ not deeper than 18 mm so that good compaction can occur with each instrument. All of these numbers are given for example only and naturally vary from case to case.

The heat transfer instrument of appropriate width is also selected at this time.

The prefitted pluggers and the heat transfer instrument are now arranged conveniently on the dental tray near the selected heat source while the root canal sealer is mixed. Bear in mind, however, that in this technique only the heat transfer instrument is intentionally heated; the pluggers are used at room temperature throughout the compaction procedure. Heating the pluggers intentionally at any time is unnecessary and detrimental to their carefully designed metallurgic properties.

The cement should be mixed routinely according to the directions of the manufacturer and/or any special requirements perceived by the operator. Under most circumstances, the author prefers to increase the powder/liquid ratio of Kerr Sealer slightly to obtain a mixture that, while still fluid, is somewhat denser than the manufacturer's recommendation.

The technique will now be carried out by means of a series of compactions of softened gutta percha with pluggers, reheating by means of a heat transfer instrument, additional compaction with pluggers, reheating, and compaction deeper into the canal. With this process, an exact impres-

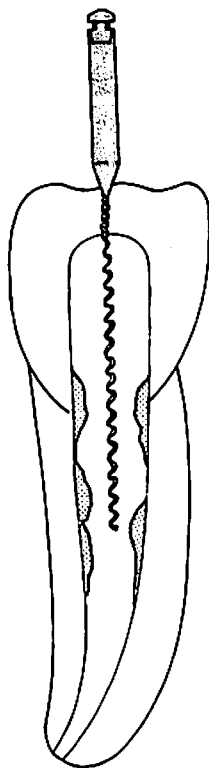


Figure 3-8 A small amount of sealer is placed along walls of canal with hand-held lentulo spiral. The lentulo is placed little more than halfway into the prepared canal.

sion can be taken of the apical half or apical one third of the root canal system.

A small amount of sealer is introduced into the prepared canal by hand with a lentulo spiral filler (Fig. 3-8). Care should be taken to apply the cement evenly along the length of the canal without using too much of the material. The objective is to attain a true gutta percha filling and not one that consists primarily of cement. The apical third of the prepared master cone is coated with cement and is gently reinserted into the root canal until maximum depth has been achieved.

A radiograph taken at this point should indicate that this seemingly tight gutta percha cone is still 0.5 to 1 mm short of the radiographic terminus of the canal. An indication of radiopacity beyond this point, although not serious, signifies either that the master cone was not well fitted originally or that excessive cement has been used.

The portion of the cemented master cone that extends into the access cavity is now removed with a hot spoon excavator. The excavator may be heated with either a Bunsen burner or a metal point heater. The widest prefitted plugger, in this instance the #10½ plugger, is now used to compact the gutta percha into the cervical portion of the canal preparation with a series of 2 or 3 mm vertical strokes (Fig. 3-9).

Compacting strokes in this technique are always short ones, with pressure being applied from the fingers and wrist, never from the arm and shoulder. It is worth repeating that the objective at all times is to capture the maximum cushion of softened material and to gradually move this forward.

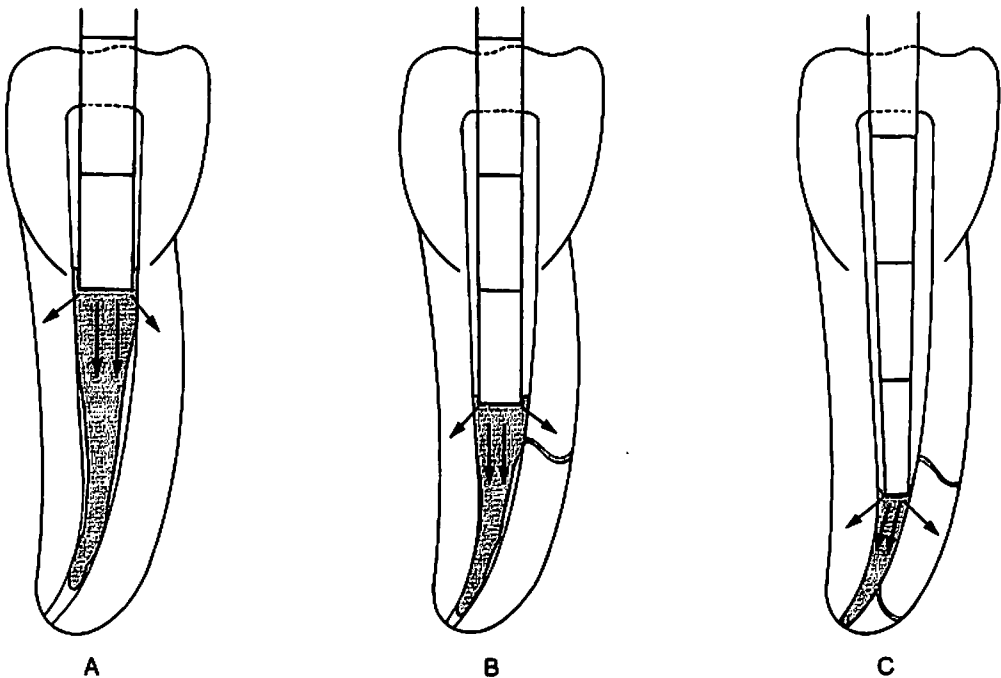


Figure 3-9 Compaction of gutta percha. *A*, The widest prefitted plugger, the #10½, compacting the gutta percha into the cervical portion of the canal. *B*, The #10 plugger capturing the maximal cushion of softened gutta percha in the middle portion of the canal. *C*, The #9½ plugger molding gutta percha into the apical portion of the canal preparation. Note the automatic obturation of significant accessory canals.

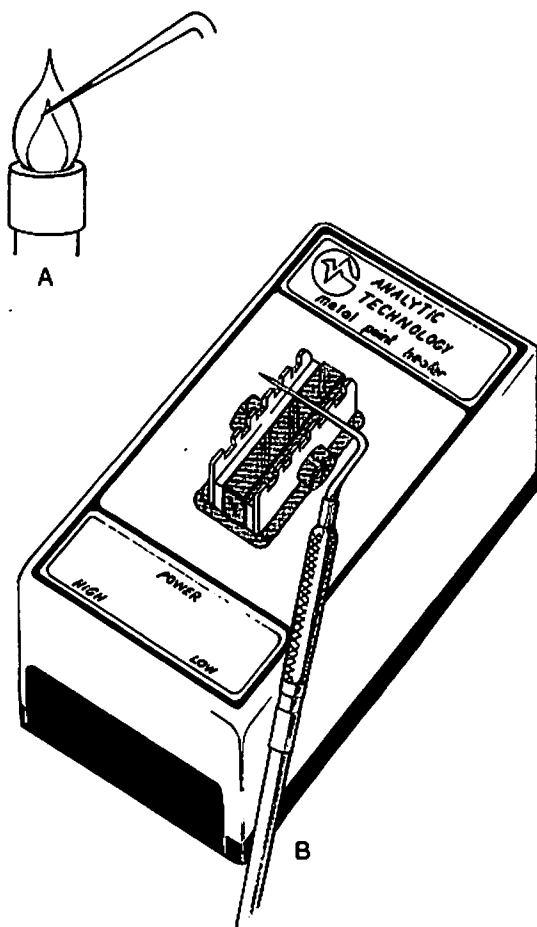


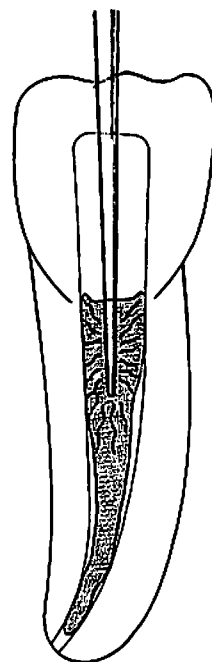
Figure 3-10 A, Heat carrier tip is heated to cherry red in flame. B, Heat carrier is heated with metal point heater.

In actual practice, the plugger is compressed centrally into the mass, moved 2 or 3 mm apically, withdrawn slightly, and reinserted so as to capture any material that has been bypassed by the previous stroke. This process is repeated one or two times before additional heat is added to the gutta percha.

The rhythmic use of the heat transfer instrument and the pluggers is now begun (Fig. 3-10). The heat transfer instrument is heated to cherry red, inserted directly into the central portion of the gutta percha to a depth of 3 or 4 mm only, and quickly withdrawn (Fig. 3-11). It is important that each time the heat transfer instrument is used, it is hot enough to transfer heat to the gutta percha mass and to be withdrawn easily from the gutta percha before it "freezes" on the heat transfer instrument, resulting in inadvertent removal of the gutta percha cone at an early stage of the compaction process. Once compaction has proceeded more deeply into the canal, it is impossible to remove the gutta percha involuntarily in this way.

As the heat transfer instrument is withdrawn, the temperature of the gutta percha is elevated only in the zone immediately surrounding it and apically to the extent of an additional 3 or 4 mm. Gutta percha is not a conductor of heat, but is an insulating material. The elevation of temperature in the apical third of the canal occurs only gradually over a period of several minutes as the cycles of heating and compaction are continued. It is

Figure 3-11 Warming the gutta percha with the heat transfer instrument. The heat transfer instrument is heated cherry red, inserted 3 to 4 mm into the central mass of gutta percha, and withdrawn quickly. The temperature of the gutta percha is elevated only in the zone immediately surrounding the heat transfer instrument and apically, approximately 3 to 4 mm.



erroneous to believe that the temperature of gutta percha in the entire root canal preparation is instantaneously elevated with the first or second application of heat or that the temperature of the gutta percha in the apical third is ever elevated as much as in the cervical and middle thirds of the canal.¹⁴

Thermocouple studies have indicated that the apical gutta percha is moldable at 40 to 44° C. In fact, it is impossible to elevate the temperature in the apical 2 mm more than 9° C above body temperature, even if one attempted to do so deliberately.¹⁴ To return to our example, the heat transfer instrument is removed, and immediately the #10½ plugger repeats the vertical compaction process, being compressed first centrally into the softened mass, brought out slightly to recapture the softened material, and compacting it again once or twice. The plugger is removed; the heat transfer instrument is reheated, reapplied to the approximate depth of 3 or 4 mm, and withdrawn; and compaction with the #10½ plugger is repeated.

Two important things are happening now, which should be noted. One is that the working level of the gutta percha in the root canal preparation seems automatically to be moving deeper into the canal. The other is that the temperature of the apical gutta percha is slowly being elevated a few degrees above body temperature. The apical gutta percha will soon become moldable.

The working level of the gutta percha moves progressively deeper for two reasons. The first is that the softened gutta percha mass, which is being compacted vertically into the conically shaped canal preparation, automatically assumes a lateral component of force. This follows routine laws of physics and requires no lateral direction of the instrument on the part of the operator. The second reason is that, as the process continues and the gutta percha is tightly compressed in the preparation, the dentist may periodically and selectively remove small portions of gutta percha when withdrawing the

heat transfer instrument. In very little time, the compaction process approaches the middle third of the canal preparation.

It soon becomes appropriate to select a plugger of slightly smaller diameter as the narrower portion of the preparation is approached. In the example being used above, the operator would switch from the #10½ plugger to the #10 plugger as the compaction process approaches a depth of 8 mm into the canal. It will be recalled that the #10½ plugger had been prefitted to a maximal depth of 10 mm, a depth at which it was indicated that additional effective compaction would be impossible. The #10 plugger is now best suited for capturing the maximal cushion of softened gutta percha in order to proceed with the effective obturation of the root canal system. The procedure of heating and compacting the gutta percha is repeated as above.

In this process, it is useful to clear as much gutta percha as possible from the sides of the preparation, so that the working level is kept relatively even at the end of each series of vertical compressions. This ensures good compaction of the mass. Also, it will be seen later that there may be minor inconveniences in completing the procedure with total satisfaction if significant amounts of gutta percha and/or cement are bypassed at this stage.

As the rhythmic heating and compaction proceed more deeply into the preparation, the temperature of the gutta percha at the apical end rises slightly above body temperature. Thermocouple studies have identified with precision the levels of temperature encountered at each stage of the technique and at each level in the canal. Thermal profiles may be obtained that accurately describe the manner and rate at which the apical gutta percha is transformed into a semi-rigid and then moldable state (Fig. 3-12). Although these measurements are of considerable interest to researchers, it is important clinically to know three things: (1) the transformation is gradual, (2) the apical gutta percha need be elevated only 3 to 8° C above body temperature in order to be moved, and (3) if additional heat is not intentionally added, the compacted gutta percha will effectively seal the terminus of the root canal preparation, quickly return to body temperature, and resist further movement beyond the terminus of the preparation.¹⁴ Previous correct shaping of the canal preparation makes apical sealing of the root canal system quite simple.

In most instances, the apical portion of the preparation is sealed when compaction is occurring 5 to 7 mm from the apex.¹⁴ This, of course, is an approximation, but provides a clinically useful range for operators who are new to the technique. It is not normally expected that apical movement of the gutta percha will occur when compaction is taking place in the cervical third of the canal, nor should it be necessary to work closer than 5 mm from the apex in routine cases. Somewhere in the 5 to 7 mm +/- range, the apical portion of the canal will be sealed along with, in many cases, one or more accessory canals.

As has been indicated, sealing or "corkage" of the terminus of the canal preparation is most effective in this technique. This is true even when the canal preparation may be inadvertently ovoid or eccentric. Because the apical gutta percha is never molten, apical control is excellent. Variations of this technique that employ overheated and excessively plasticized gutta percha increase the probability of gutta percha extrusion beyond the terminus of the preparation. Likewise, variations of the warm gutta percha technique that do not apply vertical compaction to the softened mass as it

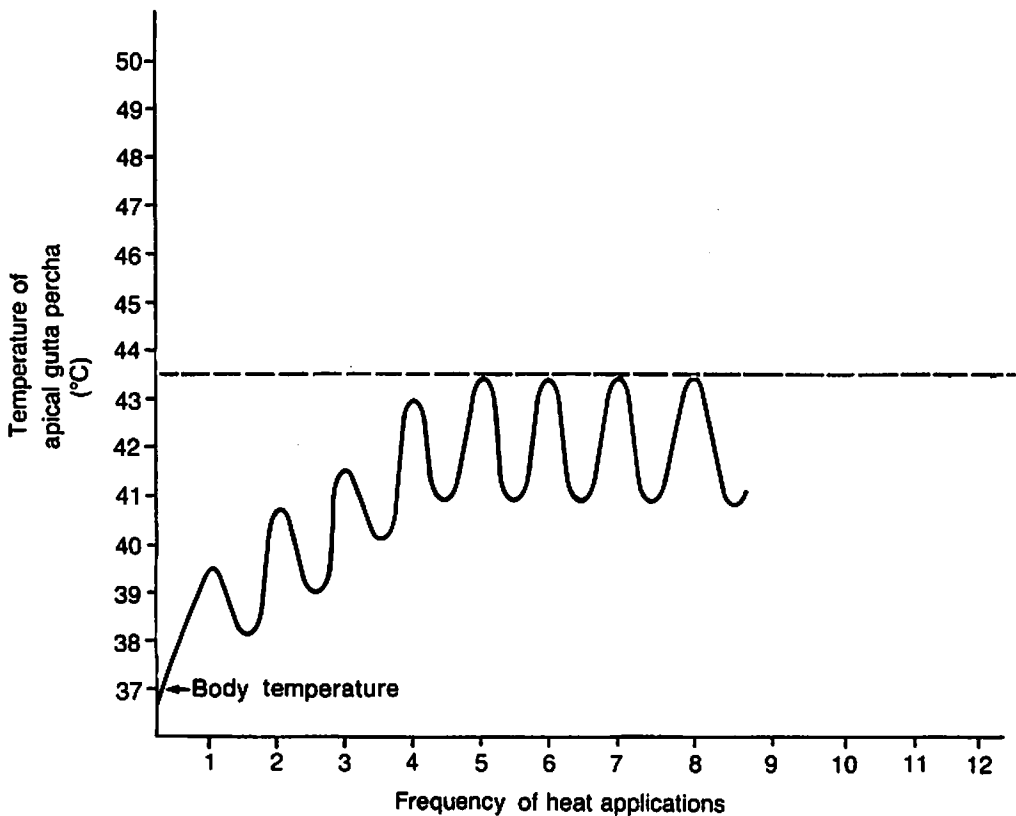


Figure 3-12 Thermal profile of gutta percha in the apical portion of the canal preparation.

cools to body temperature encourage loss of volume of the material in the final filling.¹⁴

When properly employed, the technique may or may not demonstrate radiographically a small amount of cement in apical contact with the periodontal ligament. This is observed more frequently opposite significant accessory canals in the root canal system than at the end of the main canal preparation itself. This material is innocuous. The reader is reminded of the previously reported and now well-known distinction between overfilling and vertical overextension of underfilled root canals.¹⁵ That is, material (silver cones, gutta percha, pastes) may be overextended or extruded beyond a root canal system that has not been filled three-dimensionally or sealed by the material. This constitutes vertical overextension of a root canal system that may nevertheless be both uncleaned and *underfilled*. Under such conditions, seepage of bacterial toxins and proteolytic enzymes from residual organic substrate may be expected to lead to clinical failure. Overfilling, on the other hand, signifies a condition in which the *entire* root canal system has been obturated in three dimensions and surplus material is placed beyond the confines of the root canal system. Human histologic studies and countless clinical cases demonstrate that the excess material is innocuous under these conditions.⁴ What is desirable is three-dimensional filling of the root canal system, a condition infrequently achieved in the past. When three-dimensional obturation is obtained, excess is irrelevant.

To return to our example, with either the #10 plugger or a moment or two later with the #9½ plugger, the apical portion of the gutta percha will be

molded into the terminus of the canal preparation. This, of course, varies from case to case, depending basically upon the length and shape of the preparation. If it were necessary to compact deeper into the canal, in this case deeper than 13 mm, the operator would switch to the #9½ plugger in accordance with the information obtained when the pluggers were prefitted under the principles outlined above.

Dentists learning this technique quickly sense the similarity of compacting gutta percha vertically with condensation of amalgam. Except for the necessity of rhythmically transferring heat to the gutta percha as the compaction proceeds, the two techniques are remarkably similar as far as digital perception is concerned.

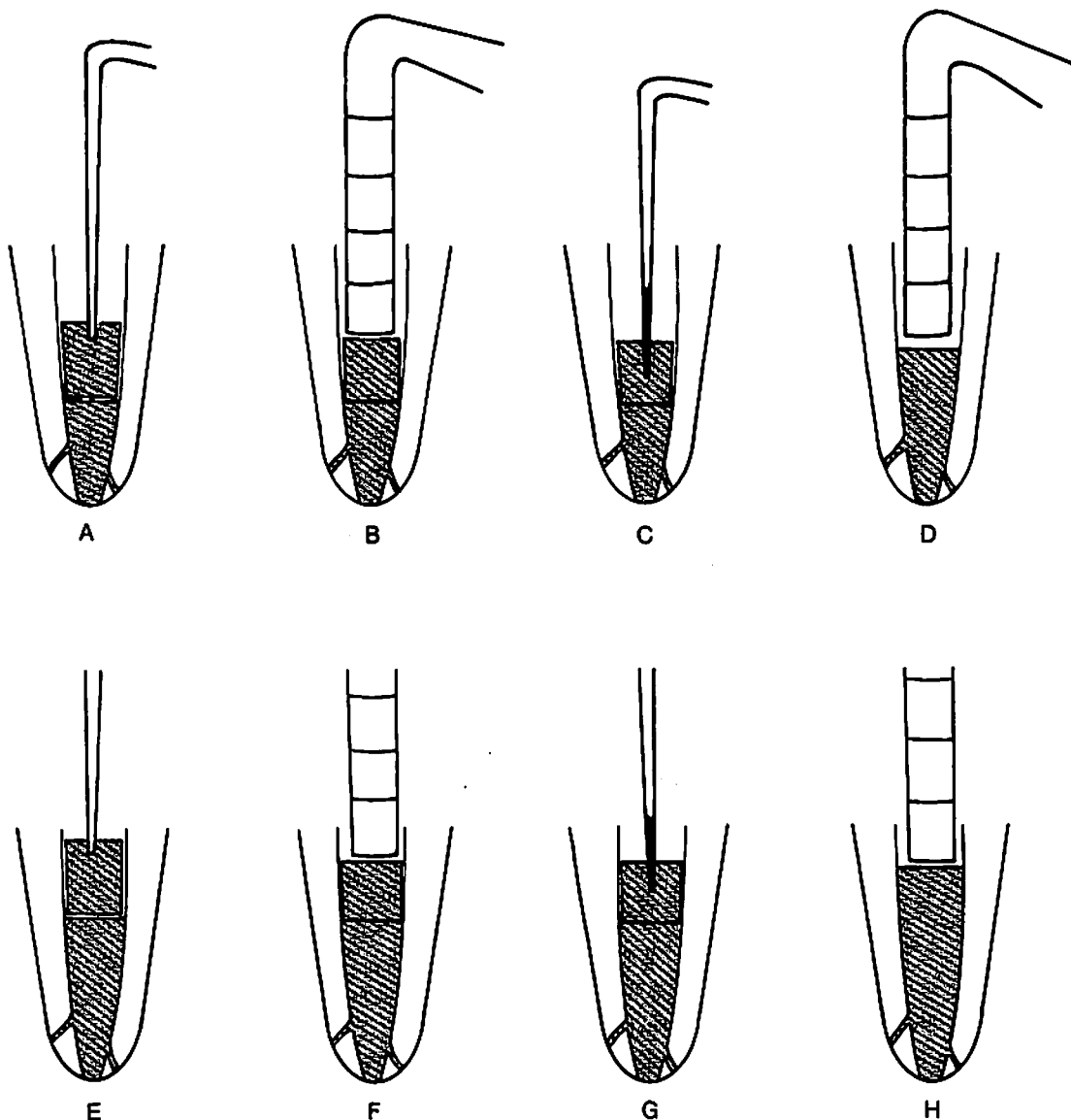


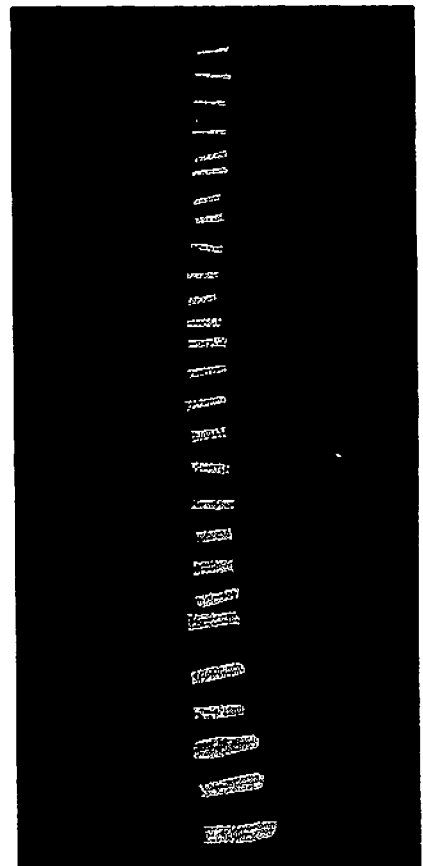
Figure 3-13 Back-packing. A, Carrying gutta percha segment to canal. B, "Cold welding" segment to main mass. C, Heat application. D, Compaction into uniform mass. E, Carrying second gutta percha segment. F, Cold welding. G, Heat application. H, Compaction into uniform mass.

Once the apical portion of the root canal system has been three-dimensionally sealed, the remainder of the canal preparation is obturated quickly by a process known as back-packing.

Back-packing consists of inserting 3 to 4 mm \pm segments of gutta percha, softening them with the heat transfer instrument, and compacting them in a manner similar to that described above (Fig. 3-13). The gutta percha segments are obtained by cutting ordinary gutta percha cones. Anyone interested in practicing this technique should always have available scores of precut gutta percha segments of varying width, although only two to four segments may actually be used for the compaction in any given case. In effect, a wave of heat application and compaction has been rhythmically carried apically into the canal preparation and is now repeated cervically until the preparation is entirely filled.

To facilitate back-packing, it is wise to lay out a selection of these 3 to 4 mm gutta percha segments of varying diameters (Fig. 3-14). Naturally, it is most effective to use relatively narrow segments in the deeper portion of the preparation and wider ones in the wider portion of the preparation. Use of wide gutta percha segments in the deeper portion of the preparation may lead to voids in the final filling that, although of little significance, indicate lack of facility with the technique. Voids may also occur if cement or gutta percha was carelessly left on the walls of the preparation during down-packing (Fig. 3-15). The gutta percha segments may adhere to this lateral residual material before union is established with the mass of gutta percha in

Figure 3-14 Gutta percha segments of varying diameters cut from auxiliary gutta percha cones. Only a few are needed in back-packing any single canal.



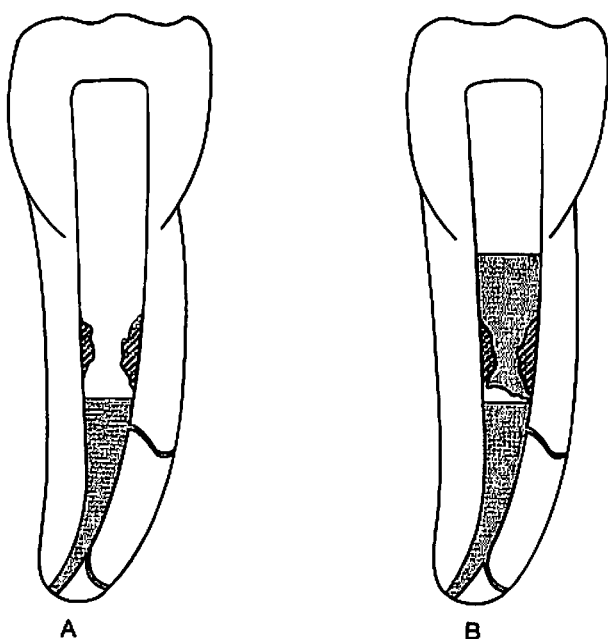


Figure 3-15 A, Cement or gutta percha inadvertently left on walls of preparation during down-packing. B, Possible resulting void.

the deeper portion of the preparation, interfering with the evenness of what should be a quick and smooth back-packing process.

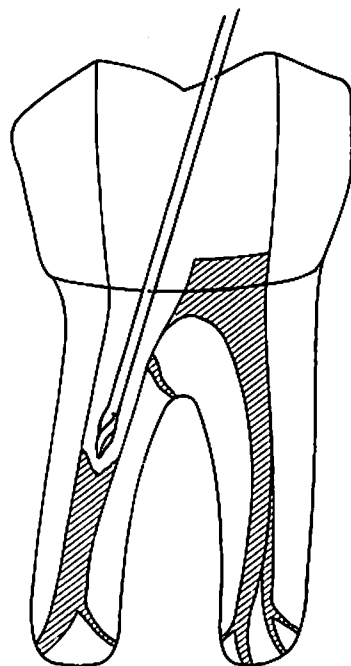
In cases in which post spaces are desired, the operator has the option of terminating the procedure at the point of deepest down-packing or at any point during back-packing. Because of the frequency with which significant accessory canals are observed in the middle and cervical thirds of root canal systems, many operators prefer the second opportunity to obturate these auxiliary canals by completing the back-packing process cervically and removing gutta percha for the post space with a passively rotated Gates-Glidden drill.* Since a vertical wave of compaction has initially occurred along the entire length of the root canal, the ultimate selection of post space preparation in single-canal teeth is optional.

In multi-canal teeth, it is desirable to complete back-packing procedures in all instances so that warm gutta percha may be compacted into the flow of the pulp chamber with appropriately sized amalgam pluggers. This provides an opportunity for filling significant accessory canals in the floors of pulp chambers, leading to bifurcation and trifurcation areas. Heating and compaction are performed as outlined above, but, because of the bulk of the gutta percha involved, hot spoon excavators serve more conveniently as heat transfer instruments. The spoon excavators are heated either in a Bunsen burner flame or with the metal point heater. Therefore, when post spaces are desired in multi-canal teeth, the method of gutta percha removal with the passively rotated Gates-Glidden drill should be employed (Fig. 3-16). In either case, the final result is a root canal preparation filled wall-to-wall with dimensionally stable gutta percha. Recent studies demonstrate the absolute integrity of the remaining gutta percha regardless of what type of post preparation technique is employed.

The techniques described above have been used in clinical practice for

*Union Broach Co., Long Island City, N. Y.

Figure 3-16 Passive rotation of Gates-Glidden drill to provide post space in posterior teeth. Post space is provided in anterior teeth simply by limiting or eliminating back-packing after apical obturation is achieved.



almost two decades. During this time, these techniques have been subjected to exhaustive study, including studies of the thermophysical properties of gutta percha;^{14, 16} scanning electron microscopic studies of uncleaned, cleaned, and obturated root canal systems;^{11, 17} microbiologic and biochemical assays of the organic substrate in uncleaned root canal systems;¹⁸⁻²⁰ serial sectioning of the roots of hundreds of teeth to develop hundreds of thousands of sections for studying the anatomy of root canal systems;^{21, 22} studies of the pressures applied to plugging instruments and to the walls of canal preparations in both lateral condensation and vertical compaction;¹³ studies of dimensional stability of a wide variety of root canal sealers;²³ as well as permeability studies of obturated root canal systems and extensive observation of teeth that were clinically treated in vivo and subsequently extracted for direct observation of the effectiveness of three-dimensional filling, both by scanning electron microscopy and by cleaning processes that allow direct observation of the effectiveness of the obturation procedures.⁷

What one achieves in this technique is an accurate duplication of the prepared root canal with uniformly compacted gutta percha. The amount of root canal sealer used should be minimal, should constitute no more than a microfilm, and should be evenly dispersed around the gutta percha fillings. "Lakes" of sealer, common in lateral condensation procedures, are avoided in this technique. The microfilm of sealer is measurable only in Angstrom units along most of the canal preparation.⁹

Accessory canals are either cleaned by direct entry with reamers and files or debrided by dissolution of substrate with sodium hypochlorite (previously described).¹² They are filled with gutta percha, with a combination of gutta percha and sealer, or with sealer alone.⁷ The accessory canals are effectively filled with gutta percha more often than can be fully appreciated by those unfamiliar with the technique.

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