Lateral Condensation: An Inside View and the Role of Sealer

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LATERAL CONDENSATION: AN INSIDE VIEW
AND THE ROLE OF SEALER

BY
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DEDICATION

To my parents, whose love and support has enabled me to make it through these long years.
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To Dr Franklin Weine, my friend and teacher, thank you every thing I learned during my residency.

To Dr Leon Lemian, my friend and outstanding teacher.

To all my friends.
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INTRODUCTION

The culminating objective of a successful endodontic treatment is the obliteration of the root canal space and the sealing of the apical foramen at the cementodentinal junction (1), with an inert, dimensionally stable, and biologically compatible material (2).

In order to accomplish this in a wide variety of cases the clinician must be competent with more than one obturating technique. Ingle has reported that almost 60% of endodontic failures are apparently caused by incomplete obliteration of the root canal system (3).

A completely filled root canal accomplishes the following:

1- Prevents percolation of periapical exudate into the canal space by not allowing for tissue exudate to enter an unfilled portion of the canal where it might stagnate and act as a periapical irritant.

2- Prevents reinfection by sealing the root tip from microorganisms present in the periapical tissues or arriving because of a transient bacteremia.

3- Creates a favorable biological environment for the process of tissue healing to take place (4).

Regardless of the technique used to fill the canal, it is very essential to remember that a good access cavity
preparation and thorough canal debridement and preparation are necessary to achieve a successful three-dimensional seal (5). No canal filling technique, no matter how advanced, can make up for errors in or lack of complete canal preparation.

Because of the demands of patients to retain involved teeth, endodontic treatment has become extremely sophisticated to allow for the retention of a wide variety of teeth to be treated and conditions requiring treatment.

If a clinician is married to one simple technique or material, chances then for obtaining this highly desired dense and well-adapted root canal filling in each of these complicated cases is reduced (4).

For many years, gutta-percha has been the most preferred filling material (6). There are a number of various methods of filling employing gutta-percha, i.e.: lateral condensation, vertical condensation of warmed material (sectional or non-sectional), the chemically modified gutta-percha, and most recently, the various injectables.

Although the most widely used technique (6), lateral condensation has its detractors. They state that the gutta-percha in the apical portion of the root canal is never condensed against the dentinal walls and a homogeneous, dense mass of gutta-percha is never obtained (7).

It has been the conclusion of many observers that
the long-term effectiveness of teeth filled by lateral condensation of gutta-percha has been very favorable.

It is the purpose of this thesis to evaluate simulated prepared canals filled with the lateral condensation technique, using the spectrapoint color coded auxiliary cones in association with different types of sealers, by photographing various levels.
REVIEW OF THE LITERATURE

THE HISTORY AND MOLECULAR CHEMISTRY OF GUTTA PERCHA

Prior to the nineteenth century, little had been recorded to demonstrate that dentists removed pulps from root canals and replaced them with filling materials. Fauchard was the first one to mention filling of the root canal space, when he placed lead followed by inserting a pivot (4). Hudson (1783-1833) was recognized by his colleagues to be the originator of canal filling when he used gold to fill root canals (4). Later a wide variety of canal filling materials were utilized until gutta-percha was introduced.

The early history of gutta-percha is obscure. The Malayans and Chinese are said to have used it in a remote and undetermined era long before western civilization had any knowledge of its existence. Gutta-percha, as formerly prepared by the natives of Asia, had a yellowish brown color and a fibrous texture. Even experienced observers mistook it for wood. This why it was called the "playable mazar wood" (8). In the early 1840's the mazar wood was introduced into Europe under the name gutta-percha. The unalterability of gutta-percha in cool salt water led to its use in the insulation of telegraph cables by Ernest Werner von Siemens in 1848. Later on, gutta-percha was
employed in the manufacturing of pipes, surgical instruments, window shades, carpets, gloves, sheathing for ships, and golf balls (8).

The plasticity of gutta-percha at relatively low temperatures 30°C led the industry to abandon this material and rubber soon displaced it. Natural rubber and gutta-percha represent an interesting example of optical isomerism. Gutta-percha is a polymer of isoprene that differs from natural rubber, as it is the Trans-isomer of the polymer, whereas rubber is the Cis-isomer (8) see fig 1.

FIG. 1: Molecular chemistry of gutta-percha
Natural rubber, cis-polyisoprene, exists with its CH2 groups (the chain forming the links of the individual isoprene units) on the same side of the double bond; gutta-percha, trans-polyisoprene, exists with its chain of CH2 groups on the opposite sides of the bond. The trans form of polyisoprene is more linear and crystallizes more readily; consequently gutta-percha is harder, more brittle, and less elastic than natural rubber. Two crystalline forms of trans-polyisoprene exist differing only in single-bond configuration and molecular repeat distance.

If the naturally occurring alpha crystalline gutta-percha is heated above 62°C, it becomes amorphous and melts. If the amorphous material is cooled extremely slowly (0.5°C or less per hour), the alpha form will recrystallize. Routine cooling of the amorphous melted material, however, results in crystallization of the beta form; this occurs in most commercial gutta-percha, which becomes more amorphous when reheated at lower temperatures than does the naturally occurring material (4).

These phase transitions are associated with expansion when the gutta-percha is heated, and shrinkage when the material is cooled, the amount of shrinkage is almost always greater than the expansion (8).

It seems that Dr. Safford G. Perry in 1883 was the first to use gutta-percha as root canal filling material. He used gold wires wrapped with soft gutta-percha (9,10). S.S. White began the manufacturing of gutta-percha points in
Later on gutta-percha became the most preferred filling material and different filling technique using this material were introduced.

Studies of pure gutta-percha are meaningless, because dental gutta-percha contains only a small percentage of gutta-percha. Friedman and Sandrik (11) examined the composition and the mechanical properties of five commercially available gutta-percha endodontic filling materials. They found only about 20% to be pure gutta-percha, whereas from 60% to 75% of the composition is zinc oxide (ZnO) as filler. The remaining constituents are wax or resin to make the point more pliable and/or compactible, and metal sulfates (often barium sulfate-BaSO₄) to lend radiopacity. On an organic versus inorganic basis, gutta-percha cones are only 23.1% organic (gutta-percha and wax) and 76.9% inorganic fillers (ZnO and BaSO₄). In general, the gutta-percha content was found to be inversely proportional to the wax or resin fraction, as was the zinc oxide content to the metal sulfates. High levels of gutta-percha were shown to produce stronger, more rigid filling materials, while high levels of zinc oxide tended to increase brittleness and thereby decrease flow (11). Gutta-percha points also become brittle by oxidation and storage under artificial light (12). This process can be reversed and the gutta-percha rejuvenated by alternate heating and cooling (13).
THE USE OF PLASTIC BLOCKS

Ideally, endodontic procedures should be studied and compared using human teeth. However, it is impossible to obtain a sufficiently large number of teeth with root canals that have the same length, size, configurations, curvature, and dentin hardness (14). Weine, Kelly and Lio, were the first to introduce the use of simulated root canals formed in clear polyester casting resin (15). These plastic blocks have cutting properties similar to dentin (16, 17). According to Weine et al (18), the microhardness of the clear casting resin used in that original study is 22 kg/mm3, whereas that of root dentin near the pulp is 35 kg/mm3.

The validity of these simulated root canals for the investigation of root canal preparation and obturation was evaluated by Lim (17), and Ahmad (19). They both found simulated canals to be a valid model for evaluating endodontic procedures. Several studies investigating different endodontic techniques, procedures, and instruments have used these plastic blocks (20,21,22,23).

Since 1975 plastic blocks have been used in the Endodontic Department of the Loyola University School of Dentistry for experimental and teaching purposes, and in many other dental schools in the world (16,24,25).
Many methods of obturating a root canal with gutta-percha and sealer have been described. Some are old, tried and true; other are new, innovative, and awaiting final judgment.

The most popular filling techniques are the following:

1- Lateral condensation.

2- Vertical condensation of warmed gutta-percha.

3- Injectables (thermoplasticized gutta-percha technique).

4- Compaction (McSpadden technique).

5- Solvent techniques (Chemically plasticized gutta-percha-chloro-percha, eucapercha technique).

6- Combination of gutta-percha and a solid core (Thermafil technique).

1- Lateral condensation: (2) In the lateral condensation technique of obturation, a gutta-percha cone, called the primary or master cone, is selected to fit as closely as possible to the apical portion of the prepared canal and this is confirmed with a radiograph. The sealer is then mixed to the proper consistency and placed in the canal (27). Then the tip of the master cone is coated with the sealer and replaced in its correct position within the
canal. A previously fit spreader is placed in the canal alongside the master cone, and pushed apically to within 1 mm from the apical end of the canal. It should be left long enough to prevent the springback of gutta-percha. The spreader is removed and then an accessory cone is inserted into the space created by the spreader, after being dipped into a thin mix of the sealer. This procedure is repeated until a dense filling is obtained (2).

In a survey of the Diplomates of the American Board of Endodontics conducted by Taintor and Ross (6), lateral condensation of gutta-percha was the most preferred filling technique by a wide margin among these endodontists.

Lateral condensation requires a conservative preparation, is relative easy to use, and offers a controlled placement of the filling material (28). It is less likely to carry the filling material beyond the root apex, thus less likely to cause patient discomfort (29). The filling obtained during lateral condensation provides positive dimensional stability (29).

Still, some clinicians believe that the root canal filling laterally condensed lacks homogenisity and is less well adapted to the dentinal walls. This is probably true if a major step of root canal preparation is missing, i.e., "flaring". Allison et al (30) found that deep spreader penetration to within 1 to 2 mm from the apex, was the most important factor in providing a good apical seal. This was possible only if the root canal had sufficient flaring. The
importance of deep spreader placement was emphasized by Rice and Weine (22). They recommended spreaders to be fit before the filling to within 1-2 mm from the apex, because the greatest condensation is at the tip of the spreader (wedge point).

Schilder (7) believed that only chemically or heat softened gutta-percha can be deformed to provide a good adaptation to the dentinal walls.

Friedman and Sandrik (11) demonstrated that it is possible to deform and condense plastically the gutta-percha in a cold environment (as in the lateral condensation) if enough amount of force is sustained over an adequate period of time. The opponents of lateral condensation use the argument of force to attack again. They say that the amount of force used during lateral condensation is never controlled. Therefore, more root fractures and residual stress are associated with lateral condensation. Dang and Walton (31) studied the incidence of vertical root fracture and the amount of root distortion created during lateral condensation of gutta-percha with either D11 spreader or B-finger pluggers. They found that only the more tapered hand D11 spreader produced vertical root fractures, although very few in number. Also, the D11 spreader caused greater root distortion than did the B-finger plugger. Only finger pluggers are recommended by the technique described by Weine (2). Harvey and his group (32), found that the forces
applied during lateral condensation by eight clinicians ranged from 1 to 3 kg. and very little residual stress remained. A Temple University study reported that vertical condensation caused more cracks in the teeth than those filled by lateral condensation (35).

It seems reasonable to conclude that in order to obtain an adequate apical seal only a minimal amount of force is required. Any excess of pressure might create ledges in the canal (22). Hatton et al (34) studied the effect of condensation force on the quality of the apical seal. They instrumented and laterally condensed a large number of extracted teeth, using predetermined different amounts of force: 1.0, 1.5, 2.0, and 2.5 kg. The statistical analysis of the apical leakage by the methylene blue dye showed no significant difference in the leakage among the four different condensation pressures.

Wong et al (35) found that vertical condensation technique replicated the canal system better than the lateral condensation or the mechanical compaction. Some coalescence of master and accessory cones was observed in the 2-3 apical mms. In this study Wong failed to describe the exact technique used during the lateral condensation. No sealer was used in association with this study, and therefore the conclusion of this study cannot be used clinically. Larder and colleagues (36) compared, in a different study, the replication abilities of lateral condensation and warm gutta-percha (vertical condensation) with sealer,
and found no significant difference between these two filling methods. Marshall and Massler (37) found, in their radioisotope microleakage study, that the use of a sealer greatly improved the efficiency of all the filling techniques they examined. Lateral condensation with sealer gave the best apical seal.

All these studies proved that lateral condensation adequately used can provide an excellent apical seal and a homogeneous and dense fill.

2- Vertical Condensation of Warmed Gutta-Percha: This technique was introduced by Schilder (29), as a variation of the Coolidge sectional technique (38). This method of vertical condensation is used with an aggressive use of the step-back technique of root canal preparation (5). The master cone is cemented short of the apical seat, thus differing with the lateral condensation technique. The gutta-percha is softened by heat applied with a carrier and packed with sufficient vertical pressure to force it apically to produce flow throughout the root canal system. This condensation is done with a series of root canal hand pluggers, which are rigid and have a greater diameter than the spreaders used for lateral condensation. This procedure of heating and condensing is repeated until the apical portion of gutta-percha is heated and completely condensed in the apical portion of the canal. Because of the relatively large root canal preparation required,
reports suggesting that the tooth is considerably weakened have been made. Also, if much heat is generated by the constant use of hot instruments to soften the gutta-percha, this might jeopardize the integrity of the periodontal ligament. Goodman and Schilder (39) found that the maximum temperature in the body of the canal during vertical warm gutta-percha technique reached 80 °C (176 °F), and 45 °C (113 °F) in the apical region. However Hand and his group (40) examined the histologic changes of the lateral periodontal tissues in six miniature pigs after root canal obturation by a warm gutta-percha technique and found a slight inflammatory response that lasted for a short time period. They concluded that the heat used in this technique did not endanger the integrity of lateral periodontium. They warned that excess heat could result in an uncertain damage to these structures (40).

In many instances, the vertical condensation with the preparation suggested by Schilder produces a small puff of excess sealer that may cause discomfort and effect the rate of success (26). This technique is relatively time consuming but produces a very compact filling, flowing in unusual places (3). In a scanning electron microscope study, Lifshitz et al (41) evaluated the effectiveness of the vertical condensation method in providing an adequate seal in association with a sealer. They found that gutta-percha vertically condensed provided an excellent seal.
Brothman (42), in a comparative study of the vertical and lateral condensation of gutta-percha, found no statistical difference in filling efficacy. The histological sections, however, showed the lateral condensation filling the apical third slightly better than the vertical condensation. He noticed that lateral condensation filled the ribbon-shaped canals better.

3- Injectables: Thermoplasticized Gutta-Percha Techniques: It was first developed by Marlin whose system delivers the gutta-percha out of a pressure system that consists of an electrically heated syringe barrel warmed to 160 F. This barrel is well insulated to prevent accidental burn injuries. A selection of silver needles ranging in size from 18 to 25 gauge are used. These needles are not only flexible, but carry heat to assure the gutta-percha remains plastic to the tip (43, 3). The needle is selected to extend 3 to 5 mm short of the apex, in a canal prepared using a step-back technique. Sealer is placed and the gutta-percha slowly extruded as the needle is withdrawn. This system is available commercially under the name of Obtura System.

Another thermoplasticized gutta-percha filling technique was developed by Michanowicz and co-workers (44). This method involves the use of a carpule containing a relatively lower temperature (70 C) gutta-percha formulation. A special heater warms the gutta-percha sufficiently to
flow under pressure and it is discharged through a needle of suitable gauge into the root canal. The system is commercially marketed under the name of Ultrafill from the Hygenic Corporation. Much elaborate research was conducted to examine and evaluate these interesting and futuristic methods.

Yee and Marlin (43) evaluated the seal obtained by using the Obtura technique. They used a dye penetration method, and found that the injected molded obturation provided a seal with a comparable quality to the conventional techniques. Torabinejad et al (45), observed in their scanning electron micrographs, that the adaptation of the injected thermoplasticized gutta-percha root canal fillings was equal or superior to that of fillings produced by the other generally accepted procedures tested and known to be clinically efficient.

Marlin and associates (46), followed up 125 teeth filled with the Obtura system from 6 months to a year, about half of which had periapical lesions and partial or complete healing was obtained in 94% of the cases. Molyvdas (47) evaluated the possible effect of heat transmitted to the periodontal tissues with the Obtura root canal filling device in dog teeth without sealer. He found inflammatory reaction at all observation periods (1, 3, 7, 28, and 56 days). The inflammatory reaction and destruction of collagen fibers were localized in the area around the apical delta, while the alveolar surrounding bone, the
roots of the teeth, and the periodontal ligament at the side of the root surfaces remained normal. Michanowicz (44) investigated the sealing properties of Ultrafill, with and without sealer, using methylene blue dye. It was shown in his study that low-temperature gutta-percha created a good seal especially if used in conjunction with sealer.

Czonsthowsky et al (48) tested the apical seal of a low-temperature thermoplasticized gutta-percha system by quantitatively determining the leakage of radioactive isotopes. They found no statistically significant difference when the lateral condensation group was compared with the low-temperature injection gutta-percha group, with and without sealer. In a similar study done by ElDeeb (49), no statistically significant difference in methylene blue dye leakage was observed between the lateral condensation and the injection-molded thermoplasticized gutta-percha technique when sealer was used. Leakage increased significantly when the injection technique was used without sealer. Overfilling occurred in 75% of the time with vertical condensation of thermoplasticized gutta-percha.

Schilder and colleagues (50) warned that thermoplasticized method of obturation, if it brings the apical gutta-percha to temperatures above 45 C, can produce some shrinkage as the gutta-percha cools, and therefore, unless vertical pressure is combined with the injection method of obturation, the interface seal between the canal
dentinal walls and the gutta-percha is jeopardized, and voids can occur in the final set filling. Skinner et al (50), tested the need for sealer when using an injection-molded thermoplasticized gutta-percha technique in straight canals. A significant difference of dye penetration was found between the group with sealer and those without sealer, the sealer group having the least amount of leakage. Therefore, sealer is an essential part of the Obtura System. However, in large straight canals no significant difference in leakage was seen whether or not vertical compaction was used in conjunction with the Obtura system.

Michanowicz (52) monitored radiographically 50 teeth filled with the Ultrafil system over a period of 24 months. An equal number of teeth were filled with the lateral condensation technique and used as control. There was a significant amount of repair irrespective of the obturation technique used.

It seems logical to conclude that the injectable thermoplasticized gutta-percha techniques offer many advantages: time saving, capacity to fill large canals and internal resorptions. But, contrary to what the manufacturer claims, they are very much technique-sensitive and the operator must be certain to have prepared a sure apical stop. Otherwise huge, unwanted overfills could occur.

4- Compaction (McSpadden Technique): This
thermoplasticized gutta-percha filling technique was first introduced by McSpadden in 1979 (53). The heat is created by the rotating of a special compacting instrument similar to a Hedstrom file, only with reverse flutes called a "compactor". This instrument is rotated in a slow-speed contra-angle hand piece at 8000 r.p.m. alongside gutta-percha cones inside the root canal and forces the filling material apically and laterally (4). This technique was best used to fill straight canals enlarged to at least the size of 45, and flared using the step-back method. This technique offers many advantages: the ease of selection and insertion of gutta-percha cones, the rapid filling of canals three-dimensionally including irregular spaces, and that this technique requires only a few seconds to fill the root canal (27). At the same time, it can be criticized in its failure to fill narrow and curved canals, the frequent breakage of the compactor file, and the possible shrinkage of the cooled, set filling (3). The fact that this technique was very difficult to master has led to a rapid decline of the considerable enthusiasm it created in its early days. This technique was subjected to a number of different studies. Bernier and his group (54) evaluated the apical seal produced by this technique using Ca 45 and compared it with the lateral and vertical condensation techniques, finding no significant difference.

Doulan (3) examined the mean temperature rise in
the midroot surface of 50 incisors and premolars. He found a 2.72°C increase in temperature. Only 16% of these teeth had temperature increase of more than 4°C. Wong and his colleagues (35) compared the filling obtained by compaction, vertical, and lateral condensation techniques. The filling produced by the McSpadden compactor showed incomplete heat compaction resulting in a spiral-like apical portion. The laterally condensed filling showed coalescence of primary and accessory points at the apex, but separating in the midcanal. The vertical condensation filling was homogeneous and the replication of prepared walls was excellent.

The average time required to fill the canal by the compactor was 1.2 minutes, the lateral condensation was 5.62 minutes, and the vertical method 7.99 minutes.

5- Solvent techniques (chemically plasticized gutta-percha, chloropercha, eucapercha techniques):
Gutta-percha can be dissolved by various solvents such as chloroform, oil of eucalyptol, or xylo1. The resulting slightly viscous and highly plastic gutta-percha can be forced into fine, tortuous canals where other solid-core fillings may not be inserted satisfactorily (7). Eucapercha has been suggested to replace chloropercha since chloroform has been designated a potential carcinogen (55), as recommended by Morse and Wilcko (56,57). They warned that the US Food and Drug Administration lists chloroform as carcinogen, and that the ADA has removed chloroform from
the list of Accepted Dental Materials. Many variations of solvent techniques have been used successfully by experienced endodontists i.e; the Callahan-Johnston diffusion technique, and the Nygaard-Ostby technique (26).

These techniques could be useful in filling some inaccessible portions of the root canal system as in the case of ledge formation(2). Since all solvents are highly volatile, a measurable amount of shrinkage takes place gradually as they evaporate. Sometimes, gross excess of filling material may be forced into the periodontal tissue. Since these solvents are irritants, considerable discomfort may occur until they have been phagocitized from the apical periodontium.

Torabinejad and his colleagues (48) compared the adaptation of root canal fillings produced by four obturation techniques to the surrounding dentinal walls under the scanning electron microscope. They found the Kloropercha N-0 produced filamentous-like extensions, and a finely wrinkled appearance of the apical third. Lateral condensation produced good adaptation apically, but a poorer one in the mid-third region of the canal. The vertical condensation provided a close adaptation in the apical and mid-third. On the other hand, the injected thermoplasticized gutta-percha resulted in an impression-like filling with few minor voids.

Wong et al (58), examined the efficacy of three chloropercha filling techniques in replicating an
artificial standard root canal system: chloropercha, kloropercha N-0, and chloroform dip. All three chloroform techniques replicated the canal system significantly better than the lateral condensation without sealer (which is not generally recommended). The volumetric evaluation showed the chloropercha filling decreased in volume 12.42% in two weeks; whereas, Kloropercha N-0 decreased only 4.86%, and chloroform dip only 1.40%. Since the quality of the final seal is related to the amount of shrinkage, then it appears that the chloroform dip is the most desirable of the chloroform techniques. Because the lateral condensation showed no shrinkage, this might compensate for the poorer replication quality of the lateral condensation as a final result.

6- Thermafill: This technique was introduced by W.B. Johnson as a unique root canal filling technique in 1979 (59). This claim of originality can be challenged if we go back far enough in the dental literature to an early reference in a paper read before the New York Odontological Society by Dr. Safford G. Perry in 1883. Perry claimed that he had been using pointed gold wires rapped with soft gutta-percha as endodontic filing material (9). Recently this endodontic filling technique as described by Johnson was patented under the name of Thermafil (60). This device uses a flexible stainless steel carrier which has the same diameter of the last instrument used at the apex. Each
carrier is supposedly coated with a layer of alpha-phase gutta-percha. This gutta-percha is warmed in a flame until the surface glistens, and the file is forced into the canal which has previously been coated with cement, until it reaches its working length. With apical pressure applied, the file is twisted until it breaks at a notch previously made at the desired level to provide room for a post.

It was very important to include Thermafil in this review of root canal filling techniques because since its introduction, this device was supported by a nation-wide, intensive, and potentially misleading marketing campaign. Until very recently, they emphasized the speed of filling the root canals, and over-looked all the other aspects of a successful endodontic treatment. Unfortunately, this technique received a widespread acceptance from the general dentists. What could be more appealing than the promise of filling a root canal in less than 60 seconds, and looking good radiographically? From the beginning it was very clear to the endodontic experts that this technique could encourage underpreparation of the root canals, promote sloppy techniques, and would be very hard to retreat in case of failure. In fact, failures have shown up in the endodontists's offices all over the country.

Beatty and his group (61), compared the average apical dye penetration observed after obturation with four root canal gutta-percha obturation techniques: single gutta-percha cone, laterally condensed gutta-percha,
ultrafil technique, and Thermafil. The thermoplastic
gutta-percha techniques of Ultrafil and Thermafil were
judged more effective than the single cone or lateral
condensation in restricting apical dye penetration. The
Thermafil obturation technique had the least dye
penetration of the methods used in this study. The pictures
showed in this study failed to show a standard apical
preparation, and demonstrated teeth with an apical stop and
others without and all these non-standardized preparations
were included in the same study. Llares and ElDeeb (62)
compared the effectiveness of the Thermafil obturation
technique with the laterally condensed gutta-percha in
both straight and curved canals. The linear dye leakage
measurements they calculated demonstrated that canines
obturated with the lateral condensation technique leaked
significantly less than those obturated using the Thermafil
technique (p=0.02). Although molars obturated with Thermafil
leaked more than those obturated with the lateral
condensation, the difference was not statistically significant.

Degrood and Vertucci (63) found Thermafil to
produce an inferior apical seal compared to lateral
condensation and Ultrafil.
MATERIALS AND METHODS

Plastic blocks were made using the technique described by Schulz-Bongert and Weine (14). Extra-fine smooth broaches were prepared to obtain standardized curves and they were lubricated with vaseline. A mix of clear polyester casting resin (Richard W. Pecina and Associates, Inc., Waukegan, IL) was prepared according to the manufacturer's directions. A similar mixture of resin-base and catalyst (4:1) was used each time, in order to obtain the same cutting properties in all the blocks used in this study. The mixture was prepared on a vibrator to eliminate bubbles and poured into a mold obtained from empty gutta-percha plastic vials (Sybron/Kerr, Romulus, MI). The curved and lubricated broaches were suspended and held in the resin by the plastic cover of the vial. Only 15 mm of the smooth broaches were allowed to be submerged into the resin, in order to obtain standardized canals.

To simulate the figure eight canals, we removed the handles of two size "C"-finger pluggers (Maillefer, The L.D. Caulk Co. Div. of Dentsply International Inc, Milford, DE,) and soldered them together with a hydroflame (Hydroflame precision soldering unit, Unitek, Monrovia, CA.). They were lubricated and inserted into the clear resin in the same
manner as for the single curved canals.

The blocks were not used earlier than 2 weeks after mixing the resin, since only then are the chemical reactions completed and the desirable degree of hardness achieved.

**Preparation of the simulated root canals:** In order to obtain a complete apical stop, the canals were instrumented at a working length 0.5 to 1.0 mm short of the actual 15 mm canal length. All the plastic blocks were covered with masking tape to prevent visualization of the files within the canals during preparation and obturation to simulate the clinical conditions as closely as permittable.

The canals were prepared with K-flex files (Sybron/Kerr, Romulus MI) sizes 10 through 30. A stepback technique was utilized for flaring of the coronal portion of the canals to a size 60 file. Two ml of tap water were used after every file and the canal was left flooded during instrumentation. After completion of instrumentation, the canal was irrigated with 5 ml of tap water and dried with five paper points. As a final test for completion of canal preparation, a size "B"-finger plugger had to fit easily to the complete working length. The same sequence of instrumentation was used to prepare the figure eight canals, but instead of the circumferential filing, the anticurvature method was used (64).

**Intracanal filling:** The Hygenic corporation provided us with Spectrapoint (The Hygenic Corporation,
Akron, OH) accessory gutta-percha cones which were designed and fabricated specifically for this study. These points were coded with six colors that match the international color code system (white, yellow, red, blue, green, black). Three sizes of accessory cones were available (15, 20, 25).

The canals were filled using the following technique: A gutta-percha cone, called the primary or master cone, was selected to fit as closely as possible to the instrumented canal. The majority of the canals in this study required a size 30 or 35 master cone. Only Kerr gutta-percha was used as a master cone because it had a color different than the Hygenic gutta-percha, and therefore, an additional color in the study was obtained. The curved single canals were divided into three groups, each group contained 10 prepared canals which were filled with different type of sealer. Three types of sealers were used: 1- Roth root canal cement type 801 elite grade (Roth International Ltd, Chicago, IL)

2- Dr Wach's formula root canal sealer (Sargent's Drugs, Chicago, IL)

3- Pulp canal sealer (Sybron/Kerr, Romulus MI).

Only three figure eight canals were included in each group of sealer. The sealer was mixed to the proper consistency according to the manufacturer instructions. Attention was paid to have
equal amount of sealer in every mixture. A reamer one size smaller than the last file (MAF) was dipped in the sealer, placed to the length, worked in and out, and rotated counterclockwise along the walls. The tip of the master cone was coated with the sealer and replaced to its correct position within the canal. The tip of the previously fit B finger plugger was modified with a diamond-edged fingernail file as described by Gerstein (7) and placed in the canal alongside the master cone and pushed apically to within 1 mm from the apical end of the canal, and left for one minute to allow the gutta-percha to deform. The spreader was removed and a size 20 white accessory cone was dipped into a thin mix of the sealer and then inserted into the space created by the plugger. This procedure was repeated until the total sequence of color coded accessory cones had been used and a dense filling had been obtained. The excess of gutta-percha was removed by a heated instrument.

The figure eight canals were filled differently: they required two master cones and two sets of accessory cones condensed separately in each side of the canal.

Following obturation, each group of canals was placed in a sealed vial on moistened gauze, and were stored at room temperature for one week to allow complete setting of the sealer before starting the sectioning process.

**Preparation of the sections:** The bulk of the
plastic block surrounding the filled canals was trimmed down with carbide acrylic bur, leaving a small cone of plastic around the gutta-percha. A rotary diamond disc (911 HF-220, 0.15 mm Brasseler USA, Inc. Dental Rotary Instruments, Savannah, GA) was used to make cross-sectional slices through the plastic and embedded gutta-percha. The whole cutting process was done in a heatless manner using a heavy flow of cold water. Despite the careful cooling, the superficial microns of the cut gutta-percha showed some degree of smearing and melting that prevented the clear visualization of the interfaces between the gutta-percha cones. A second cut with a No: 15 surgical blade (Bard-Parker Division of Becton, Dickinson and company, Rutherford, NJ) was necessary to remove this melted layer and expose a clear image of interfaces. The diamond disc actually made a cut 0.15 mm thick. The first cut was made so the first apical level was 1.5 mm occlusal to the true anatomical apex or 0.5 to 1.0 mm into the gutta-percha fill. Then five other cuts were made 1 mm apart. This yielded the six levels used for evaluation in this study. Level one was the surface of section one, level two the surface of section two and so on.

Following each cut, the specimen was mounted to the base of the stereomicroscope (Olympus, Tokyo, Japan) with boxing wax so that the apex was facing the lense. A photograph was then taken at x40 using a camera body
(Olympus) with an attached cable release mounted to the stereomicroscope utilizing an adapter and using Ektachrome 160 Tungsten color slide film (Eastman Kodak Co., Rochester NY).

There were several instances at the fifth and sixth levels of the figure eight specimens where two photographs had to be made to ensure the entire canal area was included in the study.

The photographs were then projected on a screen, evaluated, and graded. Three different grades were used to evaluate the effectiveness of the lateral condensation technique in association with three different sealers used in this study.

**Grade A:** The sections show complete gutta-percha deformation and close adaptation to the dentinal walls and each other. No or minimal junctions between the accessory cones are present with no sealer or very little amounts of sealer. Impression for clinical prognosis would be excellent.

**Grade B:** The sections show complete gutta-percha deformation and close adaptation to the dentinal walls. Small junctions between the accessory cones are noticeable but appear completely filled with sealer. Less than two islands of sealer are present. Impression for clinical prognosis is less than group A, but still should be acceptable.
**Grade C:** The sections show a questionable seal with minimal degree of cone deformation. Noticeable junctions between the cones are present but most are filled with sealer. Some voids and sealer islands (more than two) are present. From a prognosis standpoint, clinical failure could follow.

To evaluate any significant statistical difference among the three groups, the Post-Hoc analysis of variance was used.
RESULTS

Lateral condensation of gutta-percha produced a well condensed and closely adapted fillings to the canal walls in almost all the specimens included in this study. Only minimal amounts of sealer were observed in the form of few small islands of sealer floating in a colorful sea of gutta-percha.

All the sections were examined and evaluated in the same manner as described in figs (2-33).

The collected data of all the sections were organized in the following tables and was statistically analyzed.

In tables (1-3) we evaluated the performance of each sealer by calculating the grades obtained by the ten canals in each category of sealer at the different levels.

In table (4) we can see the number of accessory cones at each level of the three different sealers used in this study.

In tables (5-7) we evaluated the grades obtained by each canal at the different levels in each category of sealer.
**TABLE 1**

WACH'S SEALER: GRADES OBTAINED AT THE DIFFERENT LEVELS

<table>
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<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
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<tr>
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<td>8</td>
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<td>0</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

**TABLE 2**

ROTH'S SEALER: GRADES OBTAINED AT THE DIFFERENT LEVELS

<table>
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<th>C</th>
</tr>
</thead>
<tbody>
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<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
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<td>2</td>
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</tr>
<tr>
<td>6</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>GRADE LEVEL</td>
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<td>B</td>
<td>C</td>
</tr>
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<td>WACH'S</td>
<td>PCS</td>
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<td>7 3</td>
</tr>
<tr>
<td></td>
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<td>6 4</td>
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<td>2 6 2</td>
<td>1 5 3 1</td>
</tr>
<tr>
<td></td>
<td>6 2 2</td>
<td>2 5 3</td>
<td>1 5 3 1</td>
</tr>
<tr>
<td></td>
<td>4 3 2 1</td>
<td>2 5 3</td>
<td>1 6 3</td>
</tr>
</tbody>
</table>

**Table 4:** The number of accessory cones at each level of the three different sealers used in this study.
**Table 5**

**Wach's Sealer: The Grades Obtained by Each Canal at the Different Levels**

<table>
<thead>
<tr>
<th>Level</th>
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<th>4</th>
<th>5</th>
<th>6</th>
</tr>
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<tbody>
<tr>
<td>Canal</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>W1</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>W2</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>W3</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>W4</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>W5</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>W6</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
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<td>A</td>
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<td>A</td>
<td>A</td>
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<td>A</td>
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</tbody>
</table>
**TABLE 6**

ROTH'S SEALER: THE GRADES OBTAINED BY EACH CANAL AT THE DIFFERENT LEVELS

<table>
<thead>
<tr>
<th>CANAL</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
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<td>B</td>
<td>A</td>
</tr>
<tr>
<td>R2</td>
<td>C</td>
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<td>B</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>R2</td>
<td>A</td>
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<td>A</td>
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</tr>
<tr>
<td>R10</td>
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<td>A</td>
<td>B</td>
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</tr>
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</table>
### TABLE 7

**Pulp Canal Sealer: The Grades Obtained by Each Canal at the Different Levels**

<table>
<thead>
<tr>
<th>CANAL</th>
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</tr>
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<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>PCS3</td>
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</tr>
<tr>
<td>PCS4</td>
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</tr>
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<td>PCS5</td>
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</tr>
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<td>PCS6</td>
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<td>A</td>
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</tr>
<tr>
<td>PCS7</td>
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</tbody>
</table>
The analysis of variance of the general model of the three tables 5-7 showed significance, $F$ value 7.84, and $p \leq 0.0021$.

The Post-Hoc test demonstrated no significant difference between Roth's sealer and Wach's Paste, but they were both significantly better than Pulp Canal Sealer.
Fig 2: Pulp Canal Sealer, first level. Complete seal of the canal space without any evidence of sealer present. This section is rated A.
Fig 3: Pulp Canal Sealer, level 2. This slide shows complete seal with excellent deformation and adaptation to the walls. No junction between the accessory and master cone is evident. An island of sealer is present at 6 o'clock. Some degree of smearing at 3 o'clock. This section is rated B.
Fig 4: Pulp Canal Sealer, level 3. This slide shows a completely sealed canal where the two separate accessory cones demonstrate perfect deformation and close adaptation to the canal walls with no or very little junctions present. Some degree of smearing due to the cutting procedure at 1 o'clock. This section is rated A.
Fig 5: Pulp Canal Sealer, level 4. This section shows the two accessories in direct contact with each other. Two islands of sealer at 6 and 10 o'clock, an area of smearing at 7 o'clock. This section is rated B.
Fig 6: Pulp Canal Sealer, fifth level. Complete seal. Minimal amount of sealer at 11 o'clock that does not seem to jeopardize the clinical outcome. The third accessory (red) came in direct contact with the second (yellow) and is completely deformed. At 9 o'clock few silver particles, smearing is noticeable at 3 o'clock. This section is rated A.
Fig 7: Pulp Canal sealer, sixth level. Complete deformation of the gutta-percha and close adaptation to the canal walls. Minimal junctions and sealer islands. The fourth accessory (blue) is starting to appear. Silver particles can be seen in different regions. This section is rated A.
Fig 8: Wach's paste, first level. Complete seal of the canal space without any evidence of sealer present. This section is rated A.
Fig 9: Wach's paste, second level. This section shows complete seal with excellent deformation and adaptation to the canal walls. No junction between the accessory and master cone is evident. Some degree of smearing at 11 o'clock. This section is rated A.
Fig 10: Wach's paste, third level. This section shows the two accessory cones completely deformed and adapted to the canal walls, and are in direct contact with each other. An island of sealer and very minimal junction at 11 o'clock. This section is rated A.
Fig 11: Wach's paste fourth level. This section shows excellent deformation of the cones and a complete seal of the canal space. The fifth accessory cone (green) came between the third (red) and the fourth (blue) cones. An area of smearing, minimal junctions at 6 o'clock. This section is rated A.
Fig 12: Wach's paste, fifth level. Complete deformation and close adaptation to the canal walls. Very small area of sealer at 2 o'clock, no junctions. This section is rated A.
Fig 13: Wach's paste, sixth level. Complete deformation of the gutta-percha and close adaptation to the minute details of the canal walls with no junctions present at all. An artifact at 12 o'clock. This section is rated A.
Fig 14: Roth's sealer, first level. Complete seal of the canal space without any evidence of sealer present. The first accessory cone (white) is starting to appear at 12 o'clock. This section is rated A.
Fig 15: Roth's sealer, second level. Complete seal of the canal with no sealer present, the first accessory is completely round with almost no evidence of junctional space with the master cone. Smearing at 11 o'clock. This section is rated A.
Fig 16: Roth's sealer, third level. Complete obliteration of the canal. The first accessory is deformed considerably. Small amount of sealer in a tearing zone 5 o'clock. This section is rated A.
Fig 17: Roth's sealer, fourth level. Completely filled canal with excellent deformation and almost no junctional zone present. This section is rated A.
Fig 18: Roth's sealer, fifth level. Very good seal with minimal amount of sealer. The three accessory cones show a great amount of deformation. Smearing at 2 o'clock. Center, sealer. This section is rated A.
Fig 19: Roth's sealer, sixth level. The root canal space seems to be sealed and all the accessory cones show considerable deformation. The master cone in this section, as in many other sections, demonstrates voids that appear to be related to the material itself (Kerr). This section is rated A.
Fig 20: Roth's sealer, level 1. This section shows a complete seal where the gutta-percha adapts and deforms completely to the walls with no or minimal junctions between the accessory and master cones. The first accessory cone is located in the periphery with some of the master cone caught between the canal walls and the accessory cone. Smearing at 3 o'clock. This section is rated A.
Fig 21: Wach's paste specimen sectioned at level two that shows complete deformation and perfect seal.
Fig 22: Wach's paste, third level. Notice that the third accessory (red) penetrated the master cone completely providing an excellent seal.
Fig 23: At this fourth level of the same specimen, the master cone (orange) disappeared leaving only the three first accessory cones in a homogeneous mass of gutta-percha.
Fig 24: The fourth accessory cone (blue) penetrates the second one (yellow) and the master cone still absent at this level and the seal still excellent.
Fig 25: At this level the fifth accessory cone (green) penetrates the first cone (white) with the master cone still absent. Although two islands of sealer are present, they do not seem to affect the apical seal.
Fig 26: The sixth level shows a completely sealed canal where the master cone reappeared. The mass of gutta-percha is so homogeneous that no distinguished junctions could be seen between the different cones.
Fig 27: This section was included to demonstrate that even at higher levels (10 mm) the canals still show the same excellent seal shown at lower levels.
Figure 28: In this section we notice that the fourth accessory cone (blue) has a larger diameter than the second (yellow) and the third (red) accessories indicating deeper spreader penetration while spreading for the fourth cone. The blue cone is located on the other side of the canal. The second cone has also a larger diameter than the third.
Fig 29: This section was obtained in one of the specimens that was filled five days earlier. The sealer extruded slowly only few minutes after the cutting was done.
Fig 30: This figure eight canal shows an acceptable filling with nice deformation and adaptation. The two master cones used in this canal fused together completely.
Fig 31: In this section the master cone is located centrally having the first two accessories on the left and the last three accessories on the right side.
Fig 32: This first level section shows a completely filled tear-shaped canal. This area represents a zipped canal.
Fig 33: The master cone in this section is floating in the air and surrounded by a completely empty canal. This section is graded C.
DISCUSSION

This study was the first study that has brought us a clear picture of the inside of the canal during the lateral condensation technique. Inspired by the study done by Weine in the seventies, it provided a multiple level three dimensional pattern of the laterally condensed obturations.

To analyze the findings of this study, some discussion is needed with respect to the following topics:

- The pattern of distribution of the master and accessory gutta-percha cones.
- The entrance or penetration point and its effect on the spreader depth of penetration, on the pattern of distribution of gutta-percha cones, and the cones distortion and adaptation to the canal walls.
- The amount of force applied during the spreader penetration and the importance of flaring and pre-fitting of the spreader in reducing the force applied on the canal walls and avoiding ledge formation.
- The pathway of the spreader within the root canal.
- The importance of size variation between the finger spreaders and accessory gutta-percha cones.
- The importance of the type of spreader movements during the insertion and condensation.
- The internal residual pressure.
- The role of sealer in the cold lateral condensation technique.
- The problems associated with filling of the figure eight canals with the lateral condensation technique and resultant recommendations.

Although each one of these topics probably could be the subject of an independent study, we will try to discuss all of them knowing that in some cases we will rather raise more questions than providing answers. This is normal since this was the first time the colorcoded gutta-percha has been used in a canal filling study.

**DISTRIBUTION PATTERNS OF ACCESSORIES:** Although no special attention was made during condensation to place the finger spreader in a specific location at the orifice, we noticed five patterns of distribution of the gutta-percha accessory cones:

1- Sequential lateral distribution: as seen in figs 18,6,10,11, all the accessory cones are located in the the same order they were placed initially and on one side only from the deformed and well condensed master cone. These accessories show perfect deformation. It is very logical to associate this pattern with a single location of spreader penetration.
2- Arbitrary lateral distribution: as seen in figs 25 and 27 the accessory cones are located in an arbitrary distribution on one side of the condensed master cone. This distribution pattern can be associated with a multiple penetration points or by the deflection of the spreader after entering the canal through the entry point by the gutta-percha cones in a way that it takes the path of the least resistance.

The greatest concentration of condensation force is located at the tip of the spreader and, therefore, less condensation forces are applied on the gutta-percha area farther away from the spreader tip. This makes the following penetration of the spreader a little difficult because it has to go in an area of already highly condensed gutta-percha with the biggest concentration of residual force. If we change the entry point after few accessories, we will notice the spreader penetrates with less resistance and reaches areas deeper within the canal. In fig 27, the fourth accessory (blue) was larger (deeper spreader penetration) than the second and third accessories (yellow and red). This can be explained by the fact that the second location had less concentration of residual forces because it was farther away from the highly condensed zone. Therefore, in order to obtain the maximum of condensation during lateral condensation, it is important after the insertion of the first one or two accessories that the entry point and spread be altered to a site as far as
possible from the first points. This becomes less important
in the condensation of the coronal zone because the
spreader shaft in this region plays a significant role in
addition to the tip, especially if circular swing movements
are used. Once the excess of gutta-percha is removed and
slightly condensed vertically, the gutta-percha mass in the
coronal portion of the root canal will be well condensed.

3- Central displacement of the master cone: as seen
in fig 30.

4- Central condensation pattern: figs 21, 27, 19.
In this pattern of distribution, the spreader is surrounded
completely by gutta-percha and provides condensation forces
from the center to the periphery. This pattern (called by
Weine central as opposed to, lateral condensation) improves
the possibility of obliterating the root canal spaces and
helps filling the lateral and accessory canals in the
region, if present.

5- Vertical condensation pattern: figs 22, 23, 24. In
many instances the master cone or one of the accessory
cones were severed and pushed apically. This confirms the
fact that the so-called lateral condensation has both major
condensation components: lateral and vertical.

These different distribution patterns confirm the
inappropriateness of the term lateral condensation because
it excludes all the other dimensions offered by this
technique. The more accurate term would be finger spreader
or plugger condensation technique.

The amount of force applied during the spreader penetration plays an important role in achieving dense fills, but more important is the closeness of the spreader tip to the minor diameter. The closer it is, the better the condensation obtained. This system works as a compression chamber where the spreader, the apical stop, and the lateral canal walls constitute the solid components of the chamber that cannot deform. Gutta-percha is the only component that is compactible. Before any compaction can take place, the spreader must displace the gutta-percha into the areas of the least resistance. This is helped by the lubricating characteristics of the sealer. Once the major voids in the canal are filled, then the force applied is used in compacting the gutta-percha and obliterating the entire canal system three dimensionally.

The deep spreader penetration can never be achieved without an appropriate flaring of the canal. One can never overemphasize the major importance of flaring. Prefitting of the finger spreader is a very efficient way to determine the completeness of the root canal preparation. Trying to overcome the lack of flaring by applying additional amount of force will never help and might create ledges in the canal walls where no further condensation can be obtained past this point, and every additional amount of force applied will enhance the ledge. This was called the "wedge point by Rice and Weine (22).
Double-spreading: Sometimes, even in fairly well prepared canals, gutta-percha resistance to deformation can occur. Gutta-percha is a material that can be deformed plastically if enough amount of constant force is applied and sustained over an adequate period of time (1 minute). We found that spreading twice (double spreading) helped make the entry easier; even better is to use one size smaller spreader than the desired size then followed by the required size (65). This helps providing a more gradual spreading without the need to use excessive force. Since smaller spreaders have little vertical condensation action this technique can be of great assistance in avoiding overfills in those cases where the apical stop could not be established.

It was noticed in some of the specimens that were prepared without masking tape that the spreader never takes a straight path in the canal, but rather it advances in a spiral type of movement that is probably guided by the areas of least resistance and helped by the lubricating effect of the sealer. This might not have any clinical implications but could sometimes alter the measurements of the accessory cones.

The peripheral location of the first accessory cone in all the specimens confirms the information described by Weine, Kelly, and Lio (15) and Rice and Weine (22). The spreader always tended to straighten within the canal toward the external wall of the curved portion of the
canal, then the spreader crosses over to the other side near the elbow.

Size variation between the finger spreaders and accessory gutta-percha cones is a relatively important element in the lateral condensation technique (66). A large variety of finger spreaders and accessory gutta-percha cones are presently available for use in endodontics. Personal preference, availability of materials, and shape of the canal preparation usually determine which instruments and cones are selected. The compatibility in size and shape of the spreader and the accessory cones used may be a significant factor in the successful obturation of the root canal system. Due to manufacturer variations and lack of standardization for finger spreaders, there appears to be a great deal of inconsistency between finger spreaders and the accessory cones.

It is very important that an accessory cone corresponds to like-sized finger spreader at D1 diameter but not as important at the D16 diameter. Using a finger spreader compatible at both levels with the accessory cone is even better. In addition to the diameter and taper of the finger spreader and accessory cones, many factors must be remembered such as the size, shape, and curvature of the root canal and the type of movement used during the condensation. A rotational, circular, or swing movement creates greater taper coronally and makes the insertion
of the following accessory cones easier. A spreader which closely matches but is slightly larger than the gutta-percha cones would be most ideal to obtain a well dense root canal filling.

It was noticed in the unmasked specimens that none of the accessory cones went to the full length of the space created by the spreader that matches or was slightly larger than the accessory cones. All the accessories were at least 1 mm short and then the next spreading squeezed these cones apically and filled the void more completely. This is probably due to the spring back effect of the gutta-percha after spreader removal. Using a much larger spreader could eliminate this insignificant problem but probably necessitates a larger canal preparation and unnecessary removal of tooth structure.

The sealer in almost all the specimens seemed to move coronally, but was trapped periodically during the condensation leaving behind few small islands of sealer.

The extrusion of sealer in fig 28 is not at all an indication of an enormous amount of sealer present in the canal; on the contrary it was, in most cases, limited to the first two levels. As a result of the internal residual pressure released by the cutting, the gutta-percha managed to squeeze out the small amount of sealer trapped inside the canal system. A very important conclusion can be drawn from this phenomenon: it is very likely that the amount of pressure resulting from the lateral condensation to be
sufficient to extrude into and obliterate any accessory or lateral canal present in this region.

Although gutta-percha is an effective endodontic sealing material, it cannot adapt closely enough to the canal walls to provide the necessary seal (67). Therefore, a sealer must be used to provide an interface between the gutta-percha and the canal walls. The sealer is needed to fill in irregularities and minor discrepancies between the filling and the dentin (37). Another important function of a sealer is to lubricate the path of the accessory cones.

Wach's paste and Roth's sealer were significantly better sealers to be used in association with the lateral condensation technique as compared with Pulp Canal Sealer. They provided better deformation and adaptation of gutta-percha to the canal walls, less junctional zones, and fewer islands of residual sealer. Therefore, on the basis of this study the use of Pulp Canal Sealer could not be recommended in the lateral condensation technique.

Although no significant difference was found between Roth and Wach's paste, Wach's paste gave a more homogeneous appearance of the gutta-percha mass and was the only sealer that showed the vertical pattern of condensation where the gutta-percha cones were severed by the spreader tip. A slightly thinner mix of Wach's was easier to manipulate than the consistency recommended by the manufacturer. In addition, Wach's paste seemed to facilitate better the spreader penetration than the other
two sealers used in this study, as shown in table 4.

The only reason silver particles are added to the Pulp Canal Sealer is to improve its radiopacity. This encourages the reliance on sealers instead of gutta-percha in obtaining a dense fill. Furthermore, these particles are responsible for the staining problems associated with this sealer.

**Voids:** Kerr's gutta-percha was used as a master cone in all the specimens and showed the presence of voids in almost all the sections. The Hygenic Corporation gutta-percha showed no such voids. The same results were obtained when gutta-percha points of the two companies were cut and examined under the dissecting microscope. Although the clinical importance of this observation is not significant, it is certainly worth the investigation effort in the future where all types of commercially available gutta-percha are examined in a well-designed experiment.

**Figure eight canals:** Lateral condensation showed similar performance in the figure eight canals. The gutta-percha points were deformed in a very satisfactory way but less than those used in the normal round or ovoid canals. It is important to mention that two size C spreaders used to simulate the figure eight canals. After the preparation of these two canals we obtained canals that required two master cones size 55. Larger master cones are more difficult to deform. Many attempts failed to solder smaller size spreaders.
The best way of condensing the figure eight canals is to alternate the spreading between the two poles of the canal, thus allowing the two master cones to merge together in the isthmus zone, to create one homogeneous mass of gutta-percha.

Plastic blocks once again have proven to be a reliable technique for the investigation of root canal preparation and obturation. Figure eight canals are now a new model of plastic block canals that can be added to the different types of canals suggested by Schultz-Bongert and Weine(14).

The Spectrapoint accessory cones provided us with a tremendous amount of information about the lateral condensation. It allowed us to obtain a clear inside picture of the root canal filling, understand and demonstrate many mechanical aspects of the lateral condensation. The use of Spectrapoint accessory cones will be a very valid and indispensable method in many intracanal preparation and obturation studies to come.

In addition to the beautiful pictures obtained by the use of the colorcoded cones, a wide range of further studies can now be done using this technique such as: the effect of different types of spreaders, the effect of the spreader tip, the influence of the different ingredients of the various brands of gutta-percha on their ability to deform..etc.
CONCLUSIONS

Curved canals in plastic blocks were prepared and filled with gutta-percha using standard lateral condensation method. By using specially prepared colorcoded cones it was possible to identify each individual cone inserted into the canal. After filling, cross sections were made using a heatless technique at various levels and the surfaces were examined under magnification with a dissecting microscope and photographed. Variation was made as to the type of sealer used. Also, both single and two-merging canals were studied.

Based on the photographs taken, the following conclusions were made:

1- It had been suggested that lateral condensation produced canal fillings in which individual cones retained their original shape and were not distorted against the canal walls and against each other, but that these cones are suspended in a sea of cement. In this study we found that lateral condensation produced a well adapted fillings to the canal walls and the cones were distorted by the spreader and rarely were round or ovoid. Minimal amounts of sealer were observed.

2- Wach's paste and Roth's sealer were
significantly better sealers to be used in the lateral condensation technique as compared with the Pulp Canal Sealer.

3- Lateral condensation can provide excellent fillings if an important aspect of canal preparation is respected—"flaring"

4- The use of Spectrapoint accessory cones has been proven a very reliable method in intracanal preparation and filling studies.

5- Plastic blocks are a valid and useful tool in endodontic research.
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APPROVAL SHEET

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

01-16-91
Date

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