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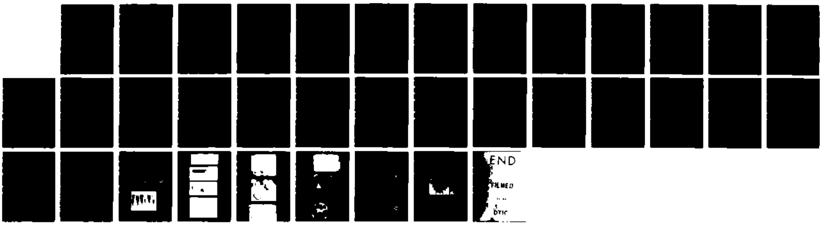

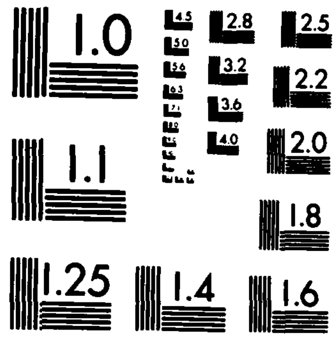

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Sixty anterior teeth were filled using four gutta percha sealer-techniques: lateral, vertical, mechanical, and chloroform-dip. The teeth were mounted in groups and sectioned. Four levels were evaluated for area of canal obturated by gutta percha versus area empty or obturated with sealer. Lateral condensation had significantly less gutta percha in the apical two levels than the other three techniques. By the third and fourth levels, the vertical technique had significantly more sealer present than the chloroform-dip and mechanical techniques. The mechanical and chloroform-dip techniques were not significantly different at any level.

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A COMPARISON OF THE AREA OF THE CANAL SPACE OCCUPIED BY GUTTA PERCHA FOLLOWING FOUR GUTTA-PERCHA AND SEALER OBTURATION TECHNIQUES

Dennis S. Eguchi, D.D.S., M.S.

Donald D. Peters, D.D.S., M.S.

Jeffrey O. Hollinger, D.D.S., M.S., Ph.D.

Lewis Lorton, D.M.D., M.S.

Corresponding Author:

Col. Donald D. Peters
123rd Med Det (DS)
APO NY 09801

Telephone: Wuerzburg, Germany 0931-893-772

ABSTRACT

Sixty anterior teeth were filled using four gutta percha sealer-techniques: lateral, vertical, mechanical, and chloroform-dip. The teeth were mounted in groups and sectioned. Four levels were evaluated for area of canal obturated by gutta percha versus area empty or obturated with sealer. Lateral condensation had significantly less gutta percha in the apical two levels than the other three techniques. By the third and fourth levels, the vertical technique had significantly more sealer present than the chloroform-dip and mechanical techniques. The mechanical and chloroform-dip techniques were not significantly different at any level.

INTRODUCTION

Nguyen (1) in *Pathways to the Pulp* states that the goals for successful endodontics are the total obliteration of the canal space and perfect sealing of the apical foramen, at the dentinocemental junction, with an inert filling material. The integrity of the root canal filling in the apical few millimeters is probably the most critical factor in achieving the goals of successful endodontic treatment (2). If the canal is properly cleansed and shaped, most obturation techniques should accomplish this (1-5). However, the question arises of how long will the obturation technique maintain this apical seal? If a technique utilizes a large volume of sealer during obturation, the canal system may be initially well sealed. Over time, if the sealer resorbs, the canal may not only lose its seal, but also become inadequately filled. Therefore, the amount of sealant should be minimized. The axion of relying, for longer term success, as little as possible on a resorbable paste and as much as possible on a solid core material, which resists resorption, is well accepted by the specialty of endodontics (1,4-6).

Isotope and dye studies have generally demonstrated that complete obliteration of the root canal space is achieved more effectively when a central cone of gutta percha is inserted together with a root canal cement which fills the interstices between the core filling and the dentin (3). The primary objection to paste as an obturation material is that none have been shown to resist resorption well (3,4). Studies have also exhibited the irritational properties of sealers and demonstrated that they do shrink slightly (5-8). The relative amount of sealant to gutta-percha after obturation, using the various solid core gutta-percha techniques, has not been comprehensively studied (9).

Silver cones used with a sealer have long been advocated for filling canals (1). Their non-compressibility prohibiting close adaptation to canals with unusual contours made this technique highly dependent on the resorbable paste. In an attempt to minimize the amount of resorbable paste in the final filling, gutta-percha has generally become the solid core material of choice. This is due to the fact that it can be condensed and shaped against irregularities of the canal while being well tolerated by human tissues (1,10,11).

The most common gutta-percha technique presently used in the United States is the lateral condensation technique (1). The major disadvantages appear to be that at no time is a homogenous mass developed and it appears to rely for seal on a large volume of sealer (4).

Chloropercha techniques, as introduced by Bowman (12), have been popular since they allow homogenization of the gutta-percha filling. However, evaporation of the chloroform leads to excessive and unacceptable shrinkage of the chloropercha (13,14). Also, chloroform has potential carcinogenic properties (1). Therefore, if chloroform is to be used, it should be limited to the chloroform-softened/chloroform-dipped technique, where it has been shown to have the advantages of the chloropercha technique while greatly reducing shrinkage (15).

The third popular gutta-percha technique involves the use of warmed gutta percha to get a homogenous well adapted fill (4). This has been known by many terms including vertical condensation with warm gutta percha, just vertical condensation, or warm "hot" gutta percha (1,4). Procedures have even been developed for heating the gutta-percha before placing it in the canals (17).

Recently, a method has been developed to mechanically condense and heat the gutta percha simultaneously (18). This thermomechanical procedure uses a file-like instrument to create heat by friction and then condenses the gutta percha apico-laterally into the canal (15,18-19).

The actual gutta-percha shrinkage associated with each technique is known (15,16). However, how this shrinkage related to the amounts of sealer present, or even how this shrinkage and amounts of sealer present related to the actual amount of gutta percha present was not known. Therefore, the objective of this study was to compare the amount of sealer and voids present in respect to gutta percha present following each of four obturation techniques: lateral; vertical (warm gutta-percha technique); thermomechanical ("McSpadden Technique"); and chloroform-dip (chloroform-softened lateral condensation).

METHODS AND MATERIALS

Sixty single canal maxillary anteriors and mandibular cuspids were extracted and stored in 5% buffered formalin. A lingual access was prepared in each tooth and a #10 k-file inserted to determine the exact location of the apical foramen. In cases where the file exited short of the anatomical apex, the apical cementum and dentin were removed so the anatomical foramen was at the true terminus of the root (Fig 1). The crowns were reduced so each tooth was 17.0 mm in length. The canals were enlarged sequentially to a size 40 K-file at a working length .5 to 1.0 mm short of actual tooth length. How short was usually determined by the area of apical constriction. A stepback technique was utilized for flaring of the canals to a size 60 file (20-24). Two milliliters of 5.25% sodium hypochlorite were used after every file and the canal was left flooded during instrumentation. After completion of instrumentation, the canal was irrigated with 6 cc of 5.25% sodium hypochlorite, dried by 5 paper points, and stored in sealed vials on moistened gauze to maintain an environment of 100% humidity. The entire sample of prepared teeth was stratified based upon canal configuration at the coronal access (12 oval shaped, 16 large/round, and 32 small/round), and randomized into 4 separate groups of 15 teeth each (25). Each group was then obturated using gutta percha and Proco-sol root canal sealer. The sealer was mixed according to manufacturer's recommendation.

Immediately prior to obturation, each canal was irrigated with 1.5 cc. of isopropyl alcohol and dried with five paper points. A master cone was fitted with tugback 1 mm. short of the working length. A thin coat of sealer was placed using the #35 file by dipping the tip once in the sealer, placing it to length, and then vigorously working it in and out along the walls. The apical 2 mm. of the master cone was dipped in the sealer prior to placement.

The 15 prepared canals of Group 1 were obturated with a lateral condensation technique using size no. 25 accessory points and finger pluggers (1). Group 2 was obturated using a chloroform softened technique (chloroform-dip) (15). The master cone and accessory points were dipped 5 mm into chloroform for 3 sec. and finger pluggers were again used. Group 3 was obturated with a warm gutta-percha technique (vertical condensation) (4). Group 4 was obturated with the thermomechanical compaction technique ("McSpadden Technique") (19). Following obturation, each tooth was replaced in the sealed vial on moistened gauze. They were stored at 37° C for 1 week to allow complete setting of the sealer. Each group of 15 teeth were then attached at right angles to a plastic plate 3 x 35 x 105 mm using cyanoacrylate cement (Fig 2B). The four plastic plates with attached teeth were then boxed using baseplate wax (Fig 2C), the teeth embedded in clear orthodontic resin and cured under water at 20 lbs. of pressure (Fig 2D). When completely set, the wax was removed and a rotary saw (Bronwill TSM 77, San Francisco, CA) with a diamond blade was used to make cross-sectional slices through the blocks and embedded teeth (Fig 2E). The cuts were made using a heavy flow of cold water to minimize gutta-percha smearing. The saw actually made a cut .82 mm thick. The first cut was made so the apical surface was 1.5 mm occlusal to the true anatomical apex or .5 to 1.0 mm into gutta-percha fill (Fig 1). The next 3 cuts were made so the occlusal surface was 4.0, 6.0, and 8.0 mm occlusal to the anatomical apex. This yielded the four levels used for evaluation. Level 1 was the surface of section 1, 1.5 occlusal of the anatomical foramen. The apical surfaces of sections 2-4 became levels 2, 3, and 4 (2 = 2.3 mm., 3 = 4.0 mm., 4 = 6.0 mm.) occlusal to the anatomical apex.

Using a microscope (Wild Stereomicroscope with Photoautomat MPS 55 System, Bunton Inst. Co., Inc., Rockville, MD 20850), color photographs were made at an original magnification (X50) of the filling in each canal (Fig 3-6). There were several instances at the third and fourth levels where two photographs had to be made to ensure that the entire canal area was present. The photographs were then projected from the rear onto a screen at slightly greater than 4 times enlargement, using a Lester Dine twin viewer (Lester Dine, New Hyde Park, New York). The total area of the canal and area of gutta-percha were then traced on clear acetate (Fig 7).

The acetate transfer was fixed with tape to a digitizer tablet that was interfaced with a Zeiss Image Analysis System, an LED cursor, and a 64K CP/M computer. The periphery of the prepared root canal were accurately traced on the digitizer table using the LED cursor (Fig 8). The periphery of all areas of gutta percha, eliminating areas of sealer or voids, were then tracted. A ratio of obturation material to root canal periphery was derived (Fig 7A). When there were areas of gutta percha separated by sealer, each area was measured and the ratio of the sum of the structures to the root canal periphery was derived (Fig 7B).

Because all tracing and coding was done by one investigator (DP), the investigator doing the measuring (JH) did not know which obturation system was being evaluated. All measurements were done in a random, duplicate fashion; the two measurements with the same code were then averaged, and that value was used for the statistical comparison of obturation techniques.

RESULTS

Table 1 shows the actual mean percentage of the canal area obturated by gutta percha at each level for each technique. Figure 9 shows the interaction occurring between techniques between levels two and three. Due to this, statistical inference relative to both level and technique cannot be made. Therefore, one-way analysis of variance between techniques was done for each level (Table 1). The difference was always at a level considered significant ($p<.05$). Level three had the least difference with a significance of $p<.03$. Table 2 shows exactly wheere the differences with a statistically significance of $p<.05$ occurred. At each level, all techniques not connected by lines were different at a $p<.05$. Therefore, at levels 1 and 2, lateral condensation could be considered significantly different from each of the other techniques for amount of sealer and/or voids present. At levels 3 and 4, vertical was considered significantly different from chloroform-dip and mechanical, but not from lateral, while lateral was considered significantly different from mechanical, but not from chloroform-dip.

Table 3 shows the actual number of canals with more than and less than 90% of their area being gutta percha. Figure 10 presents the data graphically. They also show that only with the chloroform-dip technique were any fillings lost during sectioning. One was lost from each of levels one and three, and two from level four. Chi-square analysis was done between the number of canals with less than or more than 90% being filled with gutta percha. Overall, there was again a significant difference ($p<.005$) between techniques. Lateral was again significantly different from the other three techniques ($df = 3$, $x^2 = 11.77$, $p\ .05$). The chloroform-dip fills were not significantly different from the mechanical fills, and both were significantly better than vertical and lateral fills.

DISCUSSION

Prior to discussion of the actual findings, some explanation of tooth selection and technique is needed. Relative to tooth selection, to ensure some consistency in respect to canal size, specimens were accepted for study only after satisfying the following criteria. First, the root canal system had to be a one-canal system. Second, the root canal system had to allow direct-line access to the apical 5.0 mm. Third, the greatest constriction of the canal and apical foramen had to allow unimpeded penetration by a no. 10 K-type file, but not to a no. 20 K-type file. Fourth, only the apical lip of the access opening could be present after reduction of the apical and coronal aspects. This resulted in the complete circumference of the canal being within dentin for its entire 17 mm of length.

Kuttler's (27) finding, in 1955, that the anatomical foramen is often not directly at the anatomical apex dictated a variation in technique. Since the canals were obturated .5-1.0 mm short of the anatomical foramen, it was desired to make measurements from this point. Therefore, any case where the anatomical foramen was short of the anatomical apex was adjusted to place both in the same position (Fig 1). This allowed each group of 15 teeth to be mounted together prior to sectioning. Then all sectioning could be done at specific distances short of the anatomical foramen (Fig 1).

In respect to the actual levels of evaluation, level one and two were slightly closer together than originally planned. It was planned to have the first cut .5-1.0 mm into gutta percha. Then level two was to be 1.0 mm occlusal to level one. This would place the first two cuts in the apical area, which is suppose to be the most critical. Then level three would have been 1.5 mm occlusal to level two, and level four 2.0 mm occlusal to level three. The reason for the slight variation from this plan (Fig 1), was due to the saw cut being only .82 mm in width rather than 1.0 mm.

Since the mechanical, vertical, and chloroform-dip techniques all have shrinkage after obturation (15,16), it was hoped to be able to compare just how voids due to this related to the amounts of sealer present in each case. While some areas of voids were present with all techniques, they appeared truly insignificant compared to the amounts of sealer present (Fig 3-6).

One of the most important findings had to be the high percentages of sealer in the first two levels using lateral condensation. It appears that if techniques are available, which obturate this area using larger amounts of nonresorbable material, that their use should be considered.

Since all canals in this study were large, basically straight canals, other variables which may be more technique-dependent, such as small size or curvature, weren't evaluated. Mechanical condensation does appear to be limited by apical curves (18,19), while vertical condensation needs somewhat greater canal size to allow manipulation of condensation instruments close to the apex (4,9,10). Therefore, more work is being done using these techniques in finer posterior canals.

Since chloroform-dip is basically just a variation on the lateral condensation technique, the variables mentioned should have minimal effect on its results. Therefore, it would appear a better technique for getting larger amounts of gutta percha versus sealer into the canals than lateral condensation alone. This ability of the chloroform-dip technique to get more gutta percha into the canal system than lateral condensation was also shown by Wong *et. al.* (15), where no sealer was used. The mean weight of chloroform-dip obturations of a standard canal at two-week post-obturation weighings was 79.71 mg, while the mean weight of two-week post-obturation weighings for lateral condensation was 77.95 mg. In this study, the increased amounts of sealer seen with the lateral obturations does relate well to this indication of unfilled areas by Wong *et. al.* (15) for lateral condensation.

However, the concern relative to the chloroform-dip technique was shrinkage associated with chloroform techniques. This concern appears reasonable since the only fillings lost were in this chloroform-dip group. There was also a possibility that these empty sections were never filled. This was unlikely for several reasons. First, in each case the sections adjacent to the empty sections were filled. In fact, only one adjacent section was filled less than 90% by gutta percha. Second, all four missing fillings were from different teeth. Third, all fillings were present at level two. This truly appeared to indicate that the only unfilled areas possible was the unfilled section in level one. Interestingly, the second level, which had all fillings present, was the thinnest section (Fig 1-D). For the reasons stated, the data was treated as lost fillings and not unfilled canals.

The two facts, first, that no fills were lost from the second level, and second, that two fills were lost from the fourth level, might indicate that more shrinkage occurred higher up the canal. This would relate well with the concept that the softened-outer surface of gutta percha moves up the canal during condensation. This might lead to both the homogenous mass seen throughout the fillings, and a possible slight increase in shrinkage at higher levels occlusally.

Previously, the overall shrinkage with the chloroform-dip technique was shown to be about 1.4%. This was far less than other chloropercha techniques (15). Still, the loss of fillings, which occurred, could relate to the slightly greater shrinkage that does occur with this technique. However, in this study, the chloroform-dip technique when compared to lateral condensation reduced by more than 10% the amount of sealer present in the first and second levels. It appears the question needing an answer is, which is more important an initial shrinkage of 1.4% or a long-term sealer resorption of +10%? In fact, how this amount of shrinkage relates to leakage is not really known. Zakariasen and Stader (28) did show greater leakage with the other chloropercha techniques, but the other chloropercha techniques have also been shown to have significantly more shrinkage than chloroform-dip (15).

In this study while areas of sealer and gutta percha were easily seen, areas of voids, due to shrinkage, were not easily determined (Fig 3-6). This likely resulted because of the reason discussed, that is, voids of 1-2% of the area are much harder to decern than sealer occupying 5-25% of the area.

One major area of surprise was the increasing percentages of sealer in the vertical fills as sectioning progressed occlusally. After complete evaluation, the reason appeared evident. With the vertical technique you appeared to incorporate large pockets of sealer within the fill mass (Fig 4C,5C,6C). This led to the finding of almost no sealer in some sections and then large pools of it in others. The sealer did appear to have moved somewhat from the apical coronally, but then was trapped periodically during condensation. This also produced the high standard deviations seen within this group (Table 1). The sealer was placed in the same manner for all techniques. Therefore, the pooling should not have resulted due to more sealer being used for this technique than for the other techniques.

The pooling was much on the order shown by Lugassy and Yee (29), although, in this case, the pooling was greater in the vertical group rather than the mechanical. In the first and second levels the pooling was much the same; however, with mechanical, by the third and fourth levels (Fig 5D and 6D), the sealer and gutta percha became so mixed together it became difficult to distinguish between them. This correlated well with the homogenous mass noted by Harris *et. al.* (31). In this study the sealer and gutta percha not only mixed together, but the mass changed color to a violet from pink and white. This was especially true for the third and fourth levels (Fig 6D). Therefore, some question exists of how exact the measurements were of the area of gutta percha to sealer and/or voids in these levels of the mechanical fills. In all other cases, the white sealer and slight area of voids were clearly separate from the pink gutta percha and were easily measured. In the case of the violet mixture, it was recognized that a large part of it could be sealer, but only the definite area of sealer and void were listed as such. Therefore, the low levels of sealer reported in the third and fourth levels of mechanical compaction are probably due to the mixing of sealer and gutta percha rather than an actual decrease in amount of sealer.

Benner *et. al.* (30) showed equal leakage when McSpadden was used with or without sealer. Harris *et. al.* (31) actually showed a better sealing when mechanical compaction did not use sealer. Therefore, there doesn't appear to be any advantage to using sealer with mechanical compaction in these large canals. In fact, Benner *et. al.* (30) showed that if excellent condensation is done close to the apex, the same thing was true for lateral and vertical compaction. Further work is in process to show just what percentage of the area these techniques will leave unfilled if no sealer is used versus when sealer is used in much smaller mesial canals of mandibular molars.

SUMMARY AND CONCLUSION

Sixty single canal anterior teeth were filled using four gutta percha obturation techniques with sealer. The techniques evaluated were lateral condensation, vertical (heated gutta percha) condensation, mechanical condensation (McSpadden instruments) and chloroform-dip condensation. Each group of teeth were then mounted in acrylic and sectioned. Four levels were evaluated to determine the area obturated by gutta percha versus the area left unobturated or filled by sealer.

Several significant facts were observed.

- Lateral condensation had significantly more sealer and less gutta percha than the other three techniques at the apical two levels.

- Chloroform-dip condensation and mechanical condensation, which had the most gutta percha present at all levels, were not significantly different at any level.

- Vertical condensation was not significantly different than lateral condensation at the coronal two levels.

- In the coronal levels of mechanical condensation, the gutta percha and sealer became a homogenous mass. This was basically read as gutta percha for analysis. Therefore, while both lateral condensation and vertical condensation were determined to have significantly more sealer than mechanical condensation at these levels, this result could be questioned.

- Chloroform-dip condensation did have significantly less sealer and/or voids in the coronal two levels than vertical condensation.

- Chloroform-dip condensation was the only technique in which any fills were lost during sectioning.

"The opinions expressed herein are those of the authors and are not to be construed as those of the Department of the Army or the Department of Defense."

Dr. Eguchi is chief of endodontics, Dental Clinic #3, Ft. Campbell, KY. Dr. Peters, former director, endodontic residency, U.S. Army Institute of Dental Research, Walter Reed Army Medical Center, Washington, DC, is current Commander, 123d Medical Detachment (Dental Service), Wuerzburg, Germany. Dr. Hollinger is chief of physiology branch, U.S. Army Institute of Dental Research, Walter Reed Army Medical Center, Washington, DC. Dr. Lorton is chief bioengineering branch, U. S. Army Institute of Dental Research, Presidio of San Francisco, CA. Requests for reprints should be directed to Col. Donald D. Peters; Commander, 123d Medical Detachment (Dental Service); APO NY 09801.

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Table 1. Average percentages (%) and standard deviations (s.d.) of area filled by gutta percha. The significance of the analysis of variance for difference between all techniques is shown for each level.

		T E C H N I Q U E					
		Lateral	Chloroform Dip	Vertical	Mechanical		1-Way ANOVA
Level 1	%	78.39	94.47	91.68	93.63	df=3	F=13.96
	s.d.	10.94	4.05	7.14	5.76		p<.0001
Level 2	%	80.82	92.44	88.23	93.02	df=3	F = 6.42
	s.d.	8.82	4.93	13.47	3.22		p<.0008
Level 3	%	89.93	94.00	88.75	94.82	df=3	F = 3.19
	s.d.	5.70	4.57	10.23	2.49		p<.0306
Level 4	%	89.87	93.05	86.55	95.41	df=3	F = 5.94
	s.d.	6.13	3.92	9.78	1.69		p<.0014

Table 2. One-way analysis of variance using a t-matrix to show actual significance between individual techniques at each level. The variation of all means not connected by lines are significant at a level of p<.05.

Level	TECHNIQUE			
1	Lateral	Vertical	Mechanical	Chloroform-dip
	78.4	91.7	93.6	94.5
2	Lateral	Vertical	Chloroform-dip	Mechanical
	80.8	88.2	92.4	93.2
3	Vertical	Lateral	Chloroform-dip	Mechanical
	88.8	89.9	94.0	94.8
4	Vertical	Lateral	Chloroform-dip	Mechanical
	86.5	89.9	93.0	95.4

Table 3. Number of cases at each level for each technique which had more than and less than 90% of the area being gutta percha.

		TECHNIQUES				
		Lateral	Chloroform dip	Vertical	Mechanical	Level totals*
Level 1	>90%	2	12	10	13	37
	<90%	13	2	5	2	22
Level 2	>90%	3	13	11	12	39
	<90%	12	2	4	3	21
Level 3	>90%	7	13	9	14	43
	<90%	8	1	6	1	16
Level 4	>90%	10	11	7	15	43
	<90%	5	2	8	0	15
Technique** Totals	>90%	22	49	37	54	162
	<90%	38	7	23	6	74
Totals		60	56	60	60	236

*For the significance of the difference between levels in total incidence of <90% being gutta-percha filling: df = 3, $x^2 = 2.83$, $p < NS$.

**For the significance of the difference between techniques in total incidence of <90% being gutta-percha filling: df = 3, $x^2 = 51.32$ $p<.005$.

Table 3. Number of cases at each level for each technique which had more than and less than 90% of the area being gutta percha.

		TECHNIQUES				
		Lateral	Chloroform dip	Vertical	Mechanical	Level totals*
Level 1	>90%	2	12	10	13	37
	<90%	13	2	5	2	22
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	<90%	12	2	4	3	21
Level 3	>90%	7	13	9	14	43
	<90%	8	1	6	1	16
Level 4	>90%	10	11	7	15	43
	<90%	5	2	8	0	15
Technique**	>90%	22	49	37	54	162
Totals	<90%	38	7	23	6	74
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*For the significance of the difference between levels in total incidence of <90% being gutta-percha filling: df = 3, x^2 = 2.83, p < NS.

**For the significance of the difference between techniques in total incidence of <90% being gutta-percha filling: df = 3, x^2 = 51.32 p<.005.

LEGEND

Fig. 1. Diagram showing areas where roots were sectioned.

Fig. 2. A. Representative obturations of vertical (warm) condensation.

B. Teeth attached to apical acrylic plate.

C. Teeth boxed ready for acrylic pour.

D. Teeth stabilized in block of acrylic.

E. Teeth sectioned prior to microscope evaluation.

Fig. 3. Representative photographs of one of best gutta percha obturations at first level for each technique. Each technique had some with little sealer or voids. Original magnifications x50.

A. Lateral condensation

B. Chloroform - dip condensation

C. Vertical condensation

D. McSpadden condensation

Fig. 4. Representative photographs of poor gutta percha obturations at second level for each technique. Original magnifications x50.

A. Lateral condensation - average for this technique at first and second level.

B. Chloroform - dip - only two in this group filled this poorly.

C. Vertical condensation - shows how by second level a few cases did retain excessive amount of sealer.

D. McSpadden condensation - note how sealer and gutta percha are starting to be mixed together.

Fig. 5. Representative photographs at third level for each technique. Original magnification x50.

A. Lateral condensation - average specimen for the level. Note how slight smears of gutta percha did occur occasionally.

Fig. 5. (CONTINUED)

B. Chloroform - dip condensation - average fill for this level. Photograph shows some sealer and some apparent area of shrinkage.

C. Vertical condensation - shows poor fill with large mass of incorporated sealer.

D. McSpadden condensation - shows how sealer and gutta percha incorporated into one mass. Basically interpreted as gutta percha.

Fig. 6. Representative photograph for each technique at fourth level. Original magnification x50. Little change from third level.

A. Lateral condensation

B. Chloroform-dip condensation

C. Vertical condensation

D. McSpadden condensation

Fig. 7. Copies of acetate tracings used to determine area ratios.

A. Lateral condensation at second level

B. Lateral condensation at fourth level

Fig. 8. Diagrammatic representation of procedure used to determine areas. Acetate tracings taped to digitizing board and then light cursor used to trace area outlines for computer input.

Fig. 9. Graph comparing average areas of canal filled by gutta percha at each level for each technique.

Fig. 10. Chart of number of canals with more than and less than 90 percent of their area obturated by gutta percha at each level for each technique.

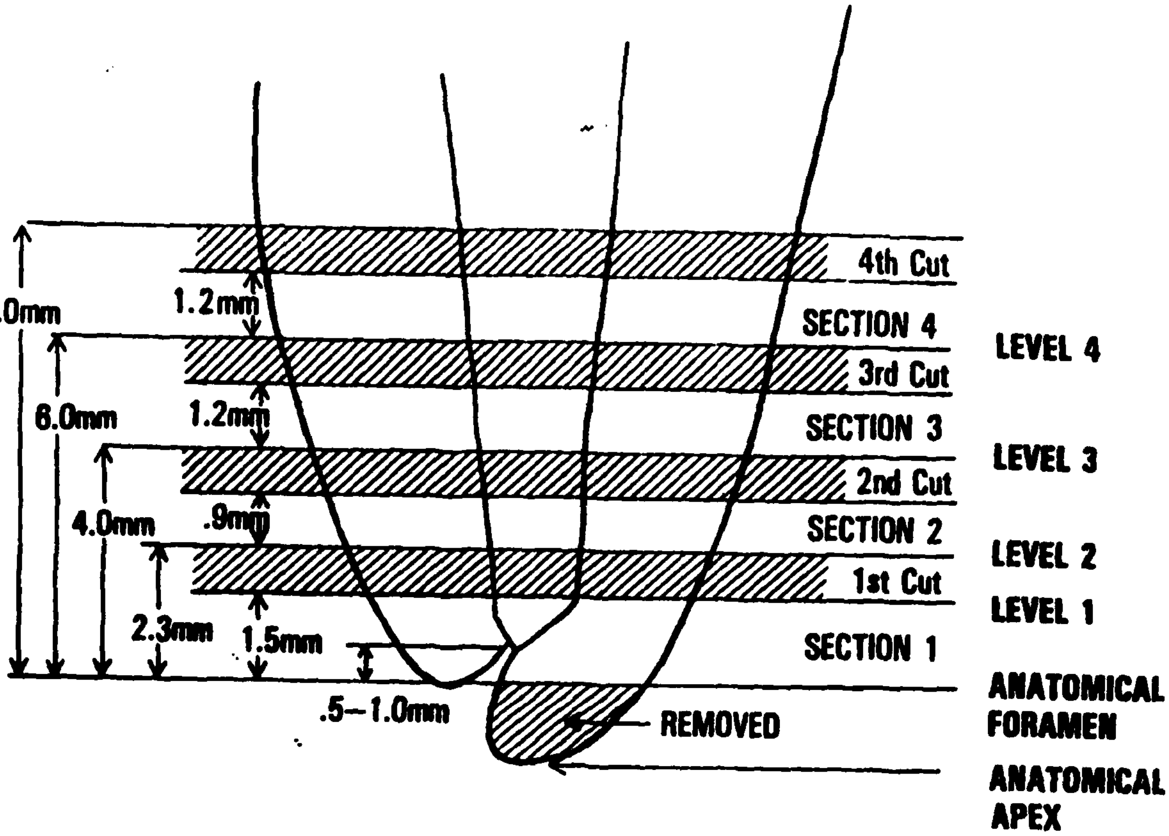


FIGURE 1

FIGURE 2A


FIGURE 2B


FIGURE 2C


FIGURE 2D


FIGURE 2E

FIGURE 3

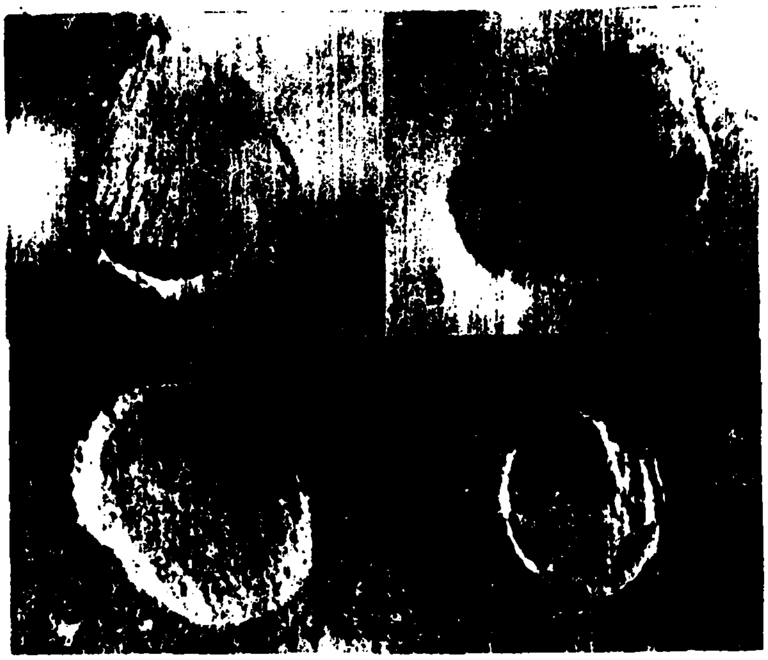


FIGURE 4

FIGURE 5

FIGURE 6

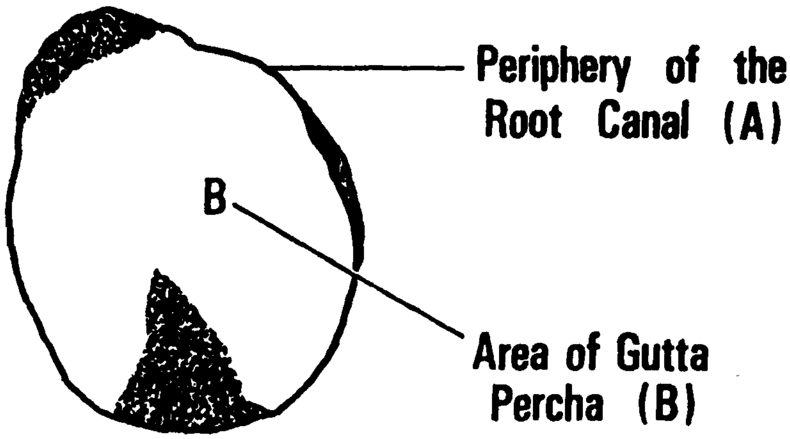
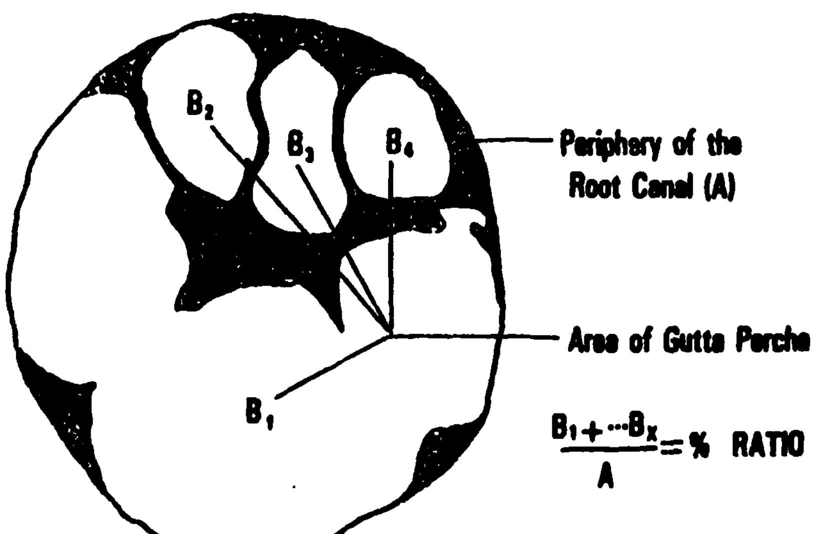


FIGURE 7A

$$\frac{B}{A} = \%\ \text{RATIO}$$



$$\frac{B_1 + \cdots B_X}{A} = \%\ \text{RATIO}$$

FIGURE 7B

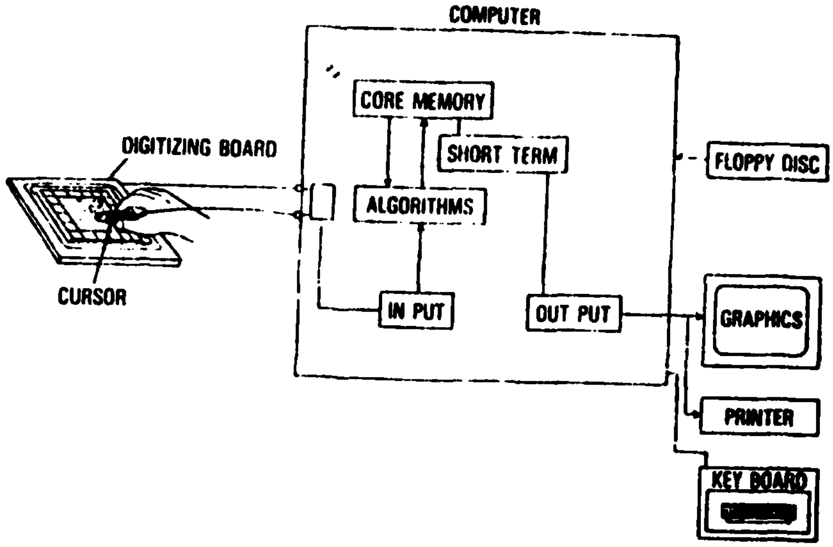


FIGURE 8

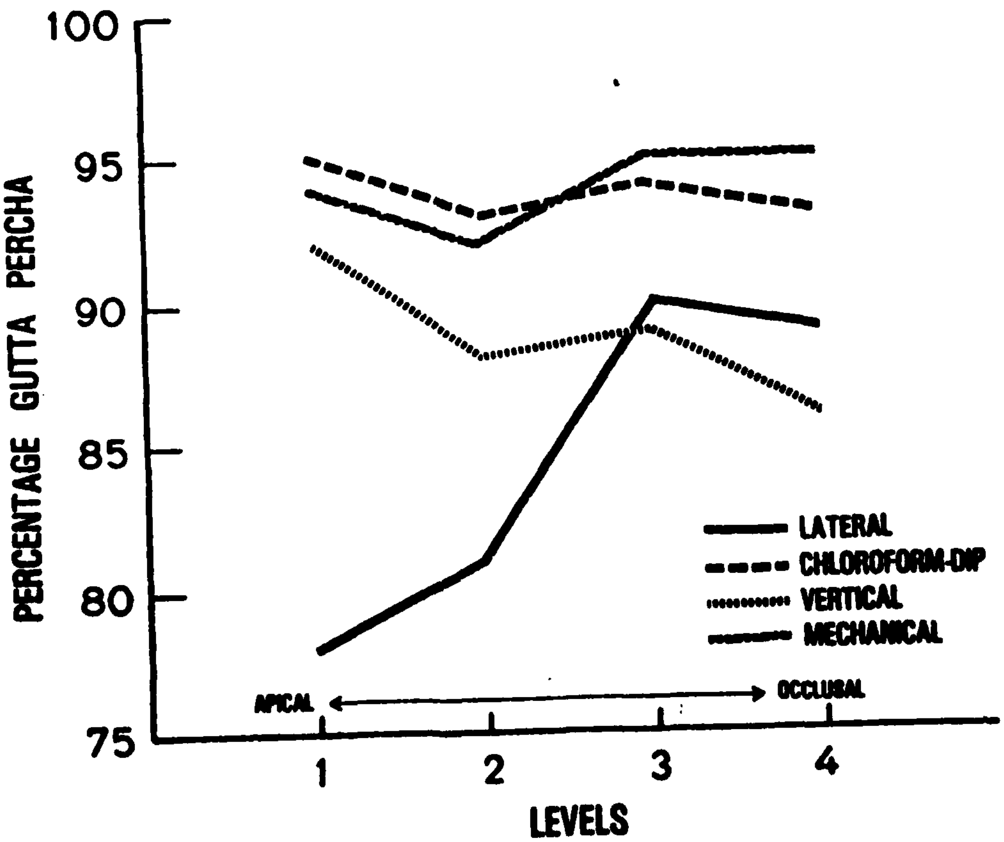


FIGURE 9

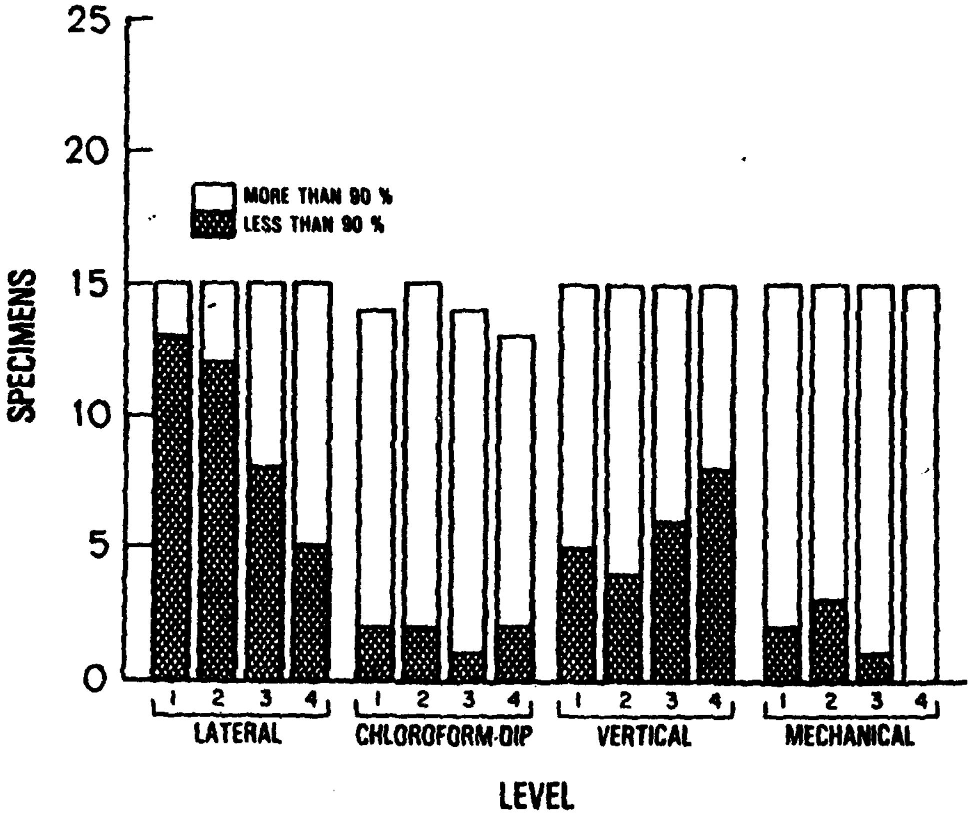

25
20
15
10
5
0
SPECIMENS
MORE THAN 90 %
LESS THAN 90 %
1 2 3 4
LATERAL
1 2 3 4
CHLOROFORM-DIP
1 2 3 4
VERTICAL
1 2 3 4
MECHANICAL
LEVEL

FIGURE 10

END

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