1982

A Histologic Evaluation of One Versus Two Intracanal Preparation Appointments with Residual Sodium Hypochlorite

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A HISTOLOGIC EVALUATION OF ONE VERSUS TWO INTRACANAL PREPARATION APPOINTMENTS WITH RESIDUAL SODIUM HYPOCHLORITE

by

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A Thesis Submitted to the Faculty of the Graduate School
of Loyola University of Chicago in Partial Fulfillment
of the Requirements for the Degree of
Master of Science

May

1982

ACKNOWLEDGEMENTS

I wish to express special appreciation to Dr. Franklin S. Weine for his guidance, suggestions and understanding in the development of this thesis. Thank you to Dr. Hal D. McReynolds and Dr. Scott B. Shellhammer for their omnipresent assistance and encouragement in the completion of this work.

I particularly wish to thank Dr. David B. Foley for his friendship and comradery during our tenure as graduate students. The lessons I learned from him concerning patience, loyalty and service are not written in any textbooks.

DEDICATION

To my wife, Janette, whose motivating influence rekindled my energies continually, whose understanding carried me through moments of despair, whose love supported me in my family responsibilities, and through whose graciousness our home was blessed with four children who are more precious than any earthly treasures.

To my children, Renee, Jennille, Douglas Brent and Nicole, whose early years of life have endured the fact that their father was a professional student.

To my parents, who taught me correct principals and whose support and love have led me to achieve this goal.

VITA

The author, Brent Cloyd Sonnenberg, is the son of John Sonnenberg and Joyce Clair (Dalton) Sonnenberg. He was born August 9, 1951, in Chicago, Illinois.

His elementary education was obtained in public schools of Western Springs and Elmhurst, Illinois, and secondary education at York Community High School, Elmhurst, Illinois, where he was graduated in June, 1969.

In September, 1969, he entered the Brigham Young University, Provo, Utah, to commence his college career.

In September, 1970, he accepted an invitation to serve a two-year committment as a missionary for the Church of Jesus Christ of Latter-Day Saints (Mormons) in Bavaria, West Germany.

After returning to the United States in August, 1972, he reentered the Brigham Young University where he was graduated with a degree of Bachelor of Arts and a major in German.

In September, 1974, he entered Loyola University School of Dentistry, where he received the degree of Doctor of Dental Surgery in May, 1978.

The author's wife is Janette Patterson Sonnenberg, and their children are Renee, Jennille, Douglas Brent and Nicole.

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INTRODUCTION

Cleansing and shaping of the root canal provides for the removal of necrotic tissue, debris and affected dentin. Although there are various methods of canal debridement, the literature shows that no method of preparation has been successful in cleansing thoroughly the critically important apical portion of the canal. It is apparent that further investigation into canal debridement is warranted.

As an adjunct to this debridement process irrigation with sodium hypochlorite has been used with significantly successful results. Since necrotic tissue dissolves readily in sodium hypochlorite, it follows logically that prolonged exposure of the canal contents to the irrigant should maximize the debridement process.

It is the purpose of this study to evaluate histologically roots treated with only one intracanal preparation appointment versus roots treated during two sessions aided by retaining sodium hypochlorite within the canal between appointments.

REVIEW OF THE LITERATURE

Single versus multiple appointment therapy

The question is often asked, "Should a root canal be filled immediately following extirpation of the pulp?" Grossman (1) states that immediate canal filling is not considered good endodontic practice. His claim is directed particularly toward cases in which a local anesthetic solution has been used. Due to the epinephrine in the anesthetic, the pulpal blood vessels experience an initial constriction followed by a secondary dilation which often results in hemorrhage into the canal. With the root apex closed off by a root filling, the hemorrhage can diffuse only into the periapical region resulting in local inflammation. This inflammation would subject the patient to the risk of postoperative pain and sensitivity to percussion of the tooth.

Many authors have recorded the incidence of postoperative pain following immediate canal obturation. Fox, et al. (2), reported a series of 247 cases of immediate canal filling comprising teeth with both vital and non-vital pulps. On postoperative review, 23% of the patients had pain. In 2% the pain was severe, in 8% it was moderate, and in 13% it was slight. O'Keefe (3) evaluated 147 endodontic patients who were treated in either one or two visits. More severe postoperative pain and a higher incidence of mild pain were encountered in the single treatment than in the two-visit treatment. Wolch (4) has advocated immediate root filling in vital but not in non-vital cases. He observed an exacerbation rate of less than 5%. Peters (5) found a 16% incidence of pain in 225 teeth completely instrumented and obturated in one visit, and only 9% when therapy was spread over two appointments. In an evaluation of 228 teeth in which endodontic treatment was completed in either single or multiple visits, Soltanoff (6) concluded that pain occurred in 38% of cases following multi-appointment filling versus 60% of cases following single-visit filling.

Bacteriologic considerations of endodontic therapy

The underlying success of root canal therapy is found on a more histopathologic evaluation rather than on a report of pain. The literature stresses complete debridement of the canal system as one of the primary steps for successful treatment.

As early as 1928, Hatton (7), in a histological study, reported a very high percentage of superficially cleansed root canals with much pulp tissue still remaining after standard instrumentation. Wilkinson wrote in 1929 that the fundamental problem in root canal treatment was the incomplete removal of protein debris and that failures were due to our inability to effect that removal (8). Reig, et al. (9), indicated that after standard endodontic procedures, 80% of instrumented non-vital teeth compared to 55% of instrumented vital teeth had remaining pulp remnants.

Ingle and Zeldow (10) referred to an endodontic triad of canal enlargement, canal "sterilization" and canal obturation as a necessity for satisfactory results. They evaluated the role of mechanical instrumentation in the reduction of the bacterial flora of the canal. Of teeth with pretreatment positive cultures, 95.4% remained infected following instrumentation with sterile water an an irrigating agent.

Rothschild (11) refused to subscribe to the use of intracanal medications in order to enhance endodontic success. He emphasized the primary importance of removing debris which nurtures bacteria rather than attempting to sterilize it _in situ_.

Ingle (14), at the 1961 annual meeting of the AAE, reported on the cause of endodontic failures in over a thousand cases reviewed at the University of Washington Dental School. The greatest single cause of failure was incompletely filled root canals combined with debris-laden root apices.

Seltzer, _et al_. (15), found that endodontic failures may be caused by local or systemic factors. Among the local factors, poor or inadequate debridement of the canal was found to have a definite relationship to the failure rate of therapy.

In a study on monkey teeth, Malooley and associates found that when the filling material did not obturate the apical one third of the canal preparations and infected tissue remained lateral to the sealing material, healing of the periapical lesions did not ensue. According to Crump (16) a poorly filled canal casts doubt on the adequacy of canal preparation. Failures attributed to poor canal obturation may in fact have resulted from initial failure to clean and prepare the canal.

These results emphasized the importance of properly eliminating tissue remnants from the apical portion of the canal in order that an apical seal may be obtained for predictable success (17). Microbes and their by-products, protein degeneration products, or both, remaining in the canal or dentinal recesses may become irritants which could lead to subsequent failures (12,13,68). Winkler and Van Amerongen quite adequately summarized the present attitude towards canal debridement by stating that, "What you take out of the canal is at least as important as what you put into it." (66)

Endodontic instruments

Hand instruments used for preparing canals are basically the file and the reamer (18) with the major difference being the number of cutting flutes per millimeter of shaft length. The instruments are produced by the manufacturer twisting either square or triangular blanks of machined stainless steel. Because the file has more cutting flutes than the reamer, its application during instrumentation is optimized by a filing or rasping motion to scrape the debris-laden canal walls on the withdrawal stroke.

Reaming motion involves the placement of the instrument apically until a small amount of binding is felt. The instrument is then rotated clockwise a certain amount and withdrawn. The clockwise rotation causes the instrument to cut into the canal walls and eliminate the engaged dentin as the instrument is withdrawn from the canal (19).

The file is considered more efficient than the reamer in its type of motion because its cutting edges are more perpendicular to the long axis of the instrument (19). However, a study by Vessey showed that the operator's individual technique of using an instrument is actually more of a determinant in the final canal preparation than the type of instrument used (20).

Prior to 1958 endodontic instruments were not standardized in size or shape (14). The instruments were numbered from 1 to 12. Each manufacturer had his own specifications, and therefore, a size number 3 file made by one company may not have the same taper, length or diameter of a number 3 file manufactured by another company (19). A great step forward in the field of endodontics occurred in 1958 when the Second International Conference on Endodontics at the suggestion of Ingle and Levine (21), adopted specifications for a system of standardized instruments. These specifications established the following:

1. A formula for the diameter and taper in each instrument size.
2. A formula for a graduated increment in size from one instrument to the next.
3. A new instrument numbering system based on instrument diameter.

Standardized instruments have been welcomed as an aid both clinically and academically. Reliance on standard instruments enables the operator to advance confidently from one instrument to the next and conclude with predictably sized preparations. Academically, standardization allows research investigations and experiments to be compared or reproduced accurrately.

Canal configuration and its apical termination

Canal configuration and its endodontic significance has been reported extensively in the literature (22,23,24,25,26,27,67). Many roots that were long suspected of containing a single canal have been shown to exhibit multiple canals with clinically significant frequency.

Rankine-Wilson and Henry (28) reported that of 111 mandibular incisors studied, 59.5% demonstrated a single canal, 35.3% were observed to have bifurcated canals which joined within the root before exiting at the apex, and 5.2% had separate and distinct exit sites. Generally, long and slender roots contained a single canal while divided canals were found in short and blunted roots.

Weine, et al. (29), categorized canal configuration of the mesiobuccal root in 208 maxillary first molars. Single canals were found in 48.5% of the roots, 37.5% showed two canals which merged toward the apex, and 14% displayed two distinct canals with separate apical foramina.

Green (30), Skidmore (31), and Vertucci (13) similarily reported multiple canal configurations in various teeth. Failure to find these often-present multiple canals would jeopardize clinical success.

Kuttler (32) examined 402 root apices on a microscopic level to describe the apical extent of canal configuration. He observed the center of the principal apical foramen to be localized in the apical vertex of the root in only 32% of the cases where a minor diameter of the root canal is found in the dentin just before the canal penetrates the terminal funnel-like cementum portion of the root. Kuttler recommends preparing and filling the canal system to the minor diameter, which always is located short of the radiographic apex.

Intracanal preparation

The conclusions derived from the studies on canal configuration played a major role in developing current concepts of canal preparation. Weine (19) emphasized that even though canal preparation is often tedious, canal debridement is of paramount importance. The objective of making the final root canal preparation conform to the general shape and direction of the original canal may be the most neglected phase of endodontic instrumentation at the present time. This neglect subsequently leads to inadequate canal debridement (69).

Haga (33) measured 161 root canals in 131 teeth following instrumentation with K-type standardized files. Enlargement of the canals was halted two sizes larger than the first instrument that began to "bite" 5 to 6 millimeters from the apex for canals less than a size 35 instrument. Canals larger than this were prepared three sizes larger than the first "biting" instrument. All types of extracted human teeth were used except third molars. The method of enlargement was to insert the file into the root canal until there was a definite stop and then the instrument was given a quarter turn and withdrawn. This reaming action was continued until the file reached the desired working length. Water was used an an irrigant during all preparation procedures.

The roots were sectioned perpendicular to the long axis of the canal so that the preparation could be examined 2 millimeters and 6 millimeters from the tip of the root. These two particular levels were chosen since preparation of the root canal for filling is aimed at the apical third of the root.

The results showed that the instruments in many of the canals made a cut only on three walls, leaving a void in the fourth wall. He considered a preparation inadequate when voids and irregularities were not removed. The percentage of inadequate preparations was surprisingly high in all teeth except maxillary central incisors. Inadequate preparations were found in 82% of mesiobuccal canals of maxillary molars, 81% of mesial canals of mandibular molars, 79% of mandibular incisors and 75% of mandibular bicuspids.

Among his conclusions, Haga stated that one cannot assume that an adequate preparation has been cut even though clinically the preparation may "feel" adequate and "white dentin chips" are being removed by the instrument. He found it extremely difficult to prepare round preparations at the 2 millimeter level unless the canal was instrumented large enough or was straight initially (as in maxillary central incisors). He concluded that more attention should be paid to the preparation of root canals.

Gutierrez and Garcia (34) conducted a study in 1968 designed to determine the shape of canals after enlargement and detect any differences between work done with files and reamers versus reamers alone. Thirty lower incisors and 30 canines were enlarged with files and reamers, whereas another 30 lower incisors and 30 canines were instrumented with reamers only. At the completion of preparation the teeth were filled with mercaptan rubber impression paste and split longitudinally in a bucco-lingual direction. One striking observation was that several of the prepared canals had a constriction near the junction of the middle and apical thirds of the roots which then widened again near the apical foramen. These root canals had an hourglass shape and not a truly round prepared apical area.

Their statistics showed that 78.3% of the incisors and 85% of the canines (upper and lower) had canal walls which were not possible to negotiate because of buccal, lingual or mixed fin-like prolongations. In many cases, even those without prolongations, the instruments left a pathway through the geometric center of the canal, cutting off only a minute part of the dentin walls.

The authors stated that although it was not a main objective of their article they felt it was important to call attention to these prolongations and their role in the accumulation of pulpal debris and in the interference with a tight root canal obturation. They also concluded that even though all the teeth were enlarged to relatively large sizes, a high percentage of the canals were not adequately debrided.

Vessey (20) examined the possibility that the type of instrument used would determine the final shape of the canal. He compared files to reamers and filing action to reaming action on 33 lower incisors. After preparation was completed, the teeth were examined at 1 millimeter intervals starting 1 millimeter short of the working length and continuing up to 4 millimeters short of the working length. He concluded that a more round preparation could be attained by using reaming action and it made no difference whether a file or reamer was used. Therefore, the method of using an instrument is more significant than the type of instrument used in determining the final shape of the canals.

Schneider in 1971 reported on a study designed to determine the frequency with which round preparations could be produced by hand instrumentation in the apical third of straight and curved canals. He found that straight canals were prepared round much more readily than were curved canals. At the 1 millimeter level, only 37% of the prepared curved canals were round (35).

Davis, et al., studied the post-debridement canal anatomy of 217 teeth. They found that the prepared canal was very dissimilar to the instruments used to prepare them, especially in the apical third of the root (36).

Numerous studies (37,38,39,40,41,42) were initiated to investigate the ability of mechanically driven endodontic instruments to debride the canal system. Along with others, O'Connell and Brayton (42) found hand instrumentation to be better than preparations by the use of the Giromatic handpiece in the shape of the preparation, elimination of morphologic aberrations, surface smoothness and apical preparation.

Jungman, et al., studied the use of four common techniques of root canal instrumentation and evaluated the final shape of the canal by measuring the widest and narrowest cross-sectional diameters at the 1½, 3, 4½ and 6 millimeter levels from the apex. One hundred and fifty mandibular molars were divided into three groups as follows:

Group 1 - Control, received no instrumentation.

Group 2 - One of the mesial canals was prepared with K-type files and filing action and the other canal was prepared with a reamer and reaming action.

Group 3 - One of the mesial canals was prepared with K-type files and reaming action and the other mesial canal was prepared with the Giromatic handpiece using Giromatic reamers.

Instrumentation was considered complete when each canal was enlarged 2 instrument sizes beyond the first size that was necessary to cut dentin in the apical part of the canal.

They concluded that no technique of instrumentation will predictably produce a round preparation in the apical portion. Reaming action with a K-type file produced the roundest preparation. The least round preparation was produced by using filing action with a K-type file (43).

Weine, Kelly and Lio (44) used a system of clear casting resin blocks which contained simulated curved canals in order to demonstrate the effects of preparation procedures on canal shape. The canals were prepared by a variety of techniques and operators. In spite of this fact, all of the final preparations showed the following three characteristics:

1. The same "hourglass" appearance described by Gutierrez and Garcia was present. Weine called the constriction area the "elbow."
2. Whether the files were precurved or straight, they tended to straighten within the canal.
3. Each succeeding file went further away from the inner portion of the curve between the "elbow" and the tip of the preparation.

If a canal was prepared past the apical foramen, this migration of successive instruments away from the inside of the curve gave the foramen a teardrop shape. Weine called this the apical "zip." In order to avoid this "zipping" phenomena, Weine recommended removing flutes of the file on the outside of the curve near the tip (44).

Also in 1976, Walton (45) published a study in which he evaluated debridement of root canals by estimating the percentage of walls that had actually been planed by files. The 91 canals evaluated were prepared _in situ_ on teeth that were to be extracted for prosthetic or periodontal reasons. The degree of curvature of each canal was determined by Schneider's method (35). Canals were divided into two groups depending on whether their degree of curvature was greater or less than ten degrees. In all cases irrigation was carried out with 5% sodium hypochlorite. Working lengths of 1 to 2 millimeters from the radiographic apex were obtained and canals were prepared in one of the three following ways:

1. Filed. Instruments were teased to working length, twisted until bound, and withdrawn while forcing them against the walls. This type of instrumentation was continued to at least two sizes beyond that which resulted in the length of the file being covered with clean dentin shavings and the walls felt smooth.
2. Reamed. Files were used in a reaming motion at working length until they could be rotated freely. Instruments were not intentionally forced against the walls in a filing action when withdrawn. The criteria for completion of instrumentation were the same as for the filed teeth.
3. Step-back filed. The canal was prepared at working length to a size 25 or 30 instrument by reaming action. From that point successively larger files were inserted to about 0.5 to 1 millimeter shorter lengths. This was continued until at least a number 60 file was reached. When the step-back filing was begun, the files were rotated and withdrawn repeatedly while forcing the instruments against walls in a filing motion.

Sections of the prepared canals were obtained either at 1000 micron intervals through the long axis of the root or at 311 micron intervals in cross section. In order to evaluate whether the walls had been planed by the instruments, the percentage of walls in each section that had the predentin layer removed was estimated.

According to a statistical analysis of the results, step-back filing consistently, in all comparisons, planed more walls than did reaming or filing. The authors felt that this was true because larger instruments were used in most of the length of each canal. These larger instruments were believed to cut more efficiently and were stiffer so they could be forced against the walls.

The poorest percentage of walls planed with all methods occurred in curved canals. Reaming and filing were the least effective. Both methods tended to remove tooth structure on the inside of the mid-portion of the curve and on the outside of the curve as it approached the apex. The walls opposite these areas were apparently untouched and contained layers of predentin and adherent cells and debris.

Step-back filing also tended to plane the outside of the apical portion of the curve, but did remove structure on the outside of the mid-portion of the canal. This resulted in a tapered and more completely debrided canal. Even though step-back filing scored the best of the three methods, it planed only 79% of the walls in curved canals.

The authors felt that preparing canals until the walls felt smooth and white dentin shavings were recovered were inaccurate determinants of total debridement.

Littman (46) reported on a unique method of evaluating canal debridement. Ninety extracted human premolars were cleared of pulp tissue by soaking in sodium hypochlorite and then a radio-opaque medium was suctioned into each tooth. The teeth were instrumented and the resulting preparations x-rayed to see how much of the radio-opaque medium was still remaining on the canal walls. The teeth were prepared by one of the three following methods:

Method 1 - hand preparation to a size 50 apical preparation

Method 2 - Giromatic handpiece and Giromatic reamers to a size 50 apical preparation

Method 3 - hand preparation to an apical size 35 followed by a 1 millimeter reduction in working length for each succeeding instrument up to a size 60

Three different operators were used and each operator prepared canals by each of the three methods described. Irrigating solutions were intentionally omitted to evaluate only the effect of mechanical cleansing.

The study showed that no technique removed all the debris from the root canal system and that the three methods of instrumentation used are inadequate in total canal debridement. The author also noted that the performance of the operator appeared to have greater significance than the preparation technique employed.

Effect of irrigating solutions

The conclusions from these canal preparation studies support the emphasis for the use of an irrigating agent to aid in the debridement of the root canal. There has been much discussion about the type, strength, and method of use of such agents to optimize their benefits. Coolidge recommended the use of "chlorine solutions" in irrigating canals (47). Walker suggested the use of double-strength chlorinated soda as a canal irrigating chemical because of its germicidal property and its ability to dissolve organic material (48). Grossman also recommended the use of double-strength chlorinated soda (49).

Grossman and Meiman in 1941 added further credence to the use of chlorinated solutions when they showed that it is an effective solvent of pulp tissue. They found it dissolved pulps of freshly extracted teeth in less than 24 hours and at times in less than one hour (50). Realizing that the ultimate success of root canal therapy was predicated upon the elimination of necrotic pulp tissue from the canal, Grossman and Meiman found that sodium hypochlorite was a more effective pulp tissue solvent than potassium hydroxide, sulfuric acid, sodium hydroxide, hydrochloric acid, and papain.

Studies were done to evaluate the effectiveness of sodium hypochlorite as a bacteriocidal irrigant. Auerbach, in a study involving 60 teeth with nonvital pulps, found that 78% of the teeth which had positive initial cultures yielded negative cultures after debridment of the canals with chlorinated soda as an irrigant (51).

Steward reported two successive negative cultures in approximately 76% of infected canals after chemomechanical preparation in which 3%

hydrogen peroxide and sodium hypochlorite were used (52).

Ingle and Zeldow (10) instrumented 89 teeth with nonvital pulps using sterile distilled water as an irrigant. They showed that only 4.6% of infected canals yielded two successive growth-free cultures. These findings show the importance of the antibacterial action of irrigating agents used by Auerbach and Stewart. Nicholls (53) and Shih, _et al_. (54), showed the participatory effect of irrigation as a means of debriding the canal. The bacterial population in the root canal may be highly reduced, but the canal is not rendered sterile.

Masterton concluded that chemical debridement can play an important part in the treatment of chronic periapical abscesses. Irrigating with chlorinated soda will reduce the root canal microorganism population (15).

In 1971 Senia, _et al_. (55), reported on a study that was designed to evaluate the solvent action of 5.2% sodium hypochlorite in canals of extracted mandibular molars. They found that large volumes of sodium hypochlorite were required to contact pulp tissue remnants completely following instrumentation, otherwise the use of sodium hypochlorite is no better than normal saline at the 1 and 3 millimeter levels from the apex.

Spangberg (56) said that 5.2% sodium hypochlorite was too toxic for use as an endodontic irrigant and recommended the use of a 0.5% concentration. This recommendation was based on the results of a cytotoxicity study using HeLa and L cells. Trowbridge (57) criticized the extrapolation of this _in vitro_ assessment of cytotoxicity to connective tissue cells in vivo. There is no evidence that the clinical use of irrigants with a greater concentration than 0.5% sodium hypochlorite has any effect on lessening postoperative discomfort.

Baker, et al. (58), studied the efficacy of various irrigating solutions including saline, hydrogen peroxide, hydrogen peroxide plus sodium hypochlorite, sodium hypochlorite, glyoxide, glyoxide plus sodium hypochlorite, RC Prep, and EDTA. Their scanning electron micrographic evaluation showed significant amounts of tissue and debris remaining on the prepared root canal walls.

McComb and Smith (59), in a similar study, described a "smear layer" consisting of superficial debris and embedded erythrocytes scattered over the surface of instrumented canal walls. Chemomechanically instrumented canals with 6% sodium hypochlorite and 3% hydrogen peroxide. A commercially available chelating agent, REDTA, completely eliminated the "smear layer" when used during instrumentation or when sealed within the prepared canal for 24 hours.

The research continued to investigate the most effective irrigating agent to assist in debriding instrumented canals. Svec and Harrison (60), compared the cleanliness of canals prepared with sodium hypochlorite and hydrogen peroxide to those prepared with normal saline. The prepared teeth were sectioned at the 1, 3, and 5 millimeter levels from the anatomic apex. The results still showed pulp and dentinal debris, but the sodium hypochlorite and hydrogen peroxide combination was found to be significantly more effective as an irrigating agent than the normal saline.

Harrison and Hand (61) in 1981 studied the effect of dilution on the antibacterial property of 5.2% sodium hypochlorite. By exposing a bacterial infested test solution to increasingly diluted concentrations of sodium hypochlorite, 3% hydrogen peroxide, a combination of 3% hydrogen peroxide and 5.2% sodium hypochlorite, and normal saline they concluded that 5.2% sodium hypochlorite was the most effective antibacterial agent. Any decreased dilution of 5.25% sodium hypochlorite significantly decreased its antibacterial properties. They also reported that the combination of 3% hydrogen peroxide and 5.25% sodium hypochlorite showed no antibacterial effectiveness against the test solution.

To study the effect of effervescence in debridement of the apical regions of root canals, Svec and Harrison (62) chemomechanically prepared single rooted teeth with either the combination of hydrogen peroxide and sodium hypochlorite solution or sodium hypochlorite alone as irrigants. They found that irrigation with the combination solution did not produce significantly cleaner root canals than did irrigation with 5.25% sodium hypochlorite alone. Also, the importance attributed to the role of effervescence in debriding canals (1,19,63,64,65) was not substantiated by their statistical analysis.

MATERIALS AND METHODS

This study was performed on three adult Beagle dogs. The dogs were procured through the Animal Research Facility at the Loyola University Medical Center. Upon their arrival at the Research Facility the dogs were observed for a minimum of 7 days to ensure that they were healthy. The dogs weighed between 10 and 12 kilograms. Each dog was identified by a numbered collar tag.

On the scheduled laboratory day the dog was not fed in order to avoid complications while it was under general anesthesia. Prior to induction of the anesthetic solution the dog's front legs were partially shaved to expose the location of the large superficial veins.

General anesthesia was administered by intravenous injection of sodium pentobarbital.* The dosage was calculated on the basis of one cubic centimeter (cc.) for each 2 kg. body weight. According to the manufacturer, 1.0 cc. contained 65 milligrams of the barbiturate. Sodium pentobarbital is a long-acting barbiturate whose principal action is depression of the central nervous system. Induction of anesthetic was immediate and uncomplicated in all cases. The dog was then secured to the operating table with tape.

A subcutaneous injection of 2 cc. of atropine was administered

*W.A. Butler Co., Columbus, Ohio

to inhibit salivary flow. In the small dose used, it also acted to stimulate the respiratory system and nullify any bradycardia.

For each dog, the mandibular 3rd and 4th bicuspid teeth and 1st molar tooth were instrumented. The mandibular left side on each dog was treated with the two-appointment technique and the mandibular right side was treated with the one-appointment technique.

The jaws were retracted by means of a spring loaded device that attached to the maxillary and mandibular cuspids on the opposite side of the mouth that was being instrumented. Due to the lack of salivary flow while the dogs were under anesthesia it was felt that a rubber dam was not required. The teeth were isolated by buccal and lingual placement of 4x4 inch gauze pads.

Initial opening into the pulp chamber was made by reducing the entire crown until the mesial and distal pulp horns were exposed. This was done with a large heatless stone. At this point a #4 round bur was used to remove the remainder of the chamber roof. Access openings were made wide in order to eliminate any tooth structure that might interfere with direct access to the canal.

It was next determined for each canal what the largest file was that would reach the full working length without any forcing or rotating, but which would slightly bind at the apex. This was designated the initial instrument.

For the one-appointment technique, all canals were instrumented apically with standard 25 millimeter K-type files three sizes larger than the initial instrument in a circumferential filing manner. This final instrument used at the apex was considered the master apical file (MAF). The canals were irrigated repeatedly with copious amounts of 5.25% sodium hypochlorite. A flared preparation, as described by Weine (11), was accomplished by using successively larger instruments each at 1 millimeter shorter lengths until three sizes larger than the MAF were reached. Care was taken to intermittently regain full working length with the MAF after each flaring instrument was used. This prevented any debris from packing into the apical area of the canal. The canals were then irrigated with 5.25% sodium hypochlorite, flushed with alcohol, dried with paper points and sealed with IRM* covering a sterile cotten pellet.

For the two-appointment technique, all canals were instrumented exactly as described in the one-appointment technique. However, after flaring the preparations the canals were irrigated with 5.25% sodium hypochlorite and the chambers aspirated without making an effort to dry the canals. This method retained any residual irrigant that remained in contact with the canal walls. The orifices were then sealed with IRM covering a cotton pellet moistened with sodium hypochlorite.

After one week these canals were reopened, the instrument working lengths reconfirmed and the walls freshened by a minimal circumferential filing motion. Again these two-appointment canals were irrigated, flushed with alcohol, dried with paper points and sealed closed with

*L.D. Caulk Co., Milford, Delaware

IRM covering a sterile cotton pellet.

The dogs were immediately sacrificed by IV injection of Beuthanasia-D.* The active ingredients of this preparation are pentobarbital sodium (195 mg/ml) and phenytoin sodium (25 mg/ml). The recommended dosage is 1 ml/kg body weight. The segments of mandible containing the experimental teeth were immediately removed and placed in formalin.

The mandible segments were kept in formalin for 10 days and then the individual teeth were removed. This was accomplished by grinding away the bone with a high speed handpiece and round acrylic bur. When all the bone and soft tissue were removed from the teeth, the teeth were cut into their respective mesial and distal root segments. In this manner each root could be placed in a separate specimen bottle of formalin and its identity maintained throughout the study. Each root was labeled with a code designating dog number, instrumentation technique, tooth and root position (mesial and distal).

Each root was decalcified in D'calcifier** solution for 19 hours. The apical delta common to dog teeth was then trimmed from each root with a razor blade under a lighted magnifying lens. This trimming was done by the author and was stopped at the first sight of a central canal. The temporary IRM filling and cotton pellet were also removed.

The specimens were imbedded in paraffin and a 10 micron thick

* Burns-Biotec Laboratory, Oakland, California
** Lerner Laboratories, New Haven, Connecticut

section was then cut perpendicular to the long axis of the canal at distances 1, 2 and 3 millimeters from the trimmed root end. The sections from each root were placed on a single slide and stained with hematoxylin and eosin.

RESULTS

Ranges of instrument sizes and root lengths

The range of initial instrument sizes, final instrument sizes and the average working lengths for the various roots are given in Table I. In all cases the initial instrument ranges for the premolar and molar roots were sizes 15-25 and sizes 45-50, respectfully. The average working length of the roots increased from anterior to posterior except for the distal root of the molar. All working lengths were measured from a coronal area of tooth structure close to the gingiva after the cusps had been ground flat.

Evaluation of a control root

A portion of the odontoblastic layer of cells was observed to have shrunken away from the predentin during fixation of an uninstrumented control root (Figure 1). At a higher magnification the dentin, predentin and odontoblastic layer with some stretching of the processes are identified clearly (Figure 2). The central core of pulp tissue with blood vessels can also be observed.

Results of roots instrumented during two appointments

The results for roots instrumented with the two-appointment technique are given in Table II. Cross sections examined at the level of the root 1mm from the apex showed predentin remaining in the 3rd and 4th premolar roots. Figures 3, 4, and 5 show increasingly higher magnifications of residual debris as it appeared during the histologic evaluation. No predentin was visible at the 2mm or 3mm levels in any of the roots treated with the two-appointment technique.

A cloud of amorphous basophilic material appeared in many of the prepared sections (Figure 4). This is not characteristic of evaluated residual pulpal debris. Also fragmented chips of apparent dentin were splashed across many of the sections. These should not be confused with what was evaluated as debris adjacent to the walls of the prepared canals.

When predentin was observed at the 1mm level there always was accompanying residual debris. Four premolar roots of dog #2 showed debris without evidence of predentin (Figure 6 & 7). Debris was not apparent at the 2mm and 3mm levels of any of the treated roots.

Of the preparations at the 1mm level, 44% remained centered within the root. The slightly irregular walls characteristic of preparations made with rasping or filing motion can be observed in a well-centered preparation in Figure 8. The majority of centered preparations were observed in the larger diameter roots, namely the distal root of the 4th premolar and the mesial and distal roots of the molar.

In contrast, an eccentric preparation with a marked deviation from the original canal space can be seen in Figure 9. At the 2mm level only 2 of the 18 sections showed any eccentricity of the preparation. All of the instrumented roots at the 3mm level demonstrated well-centered preparations.

A statistical summary for the roots instrumented with the two-appointment technique is found in Table IV.

Results of roots instrumented during one-appointment

The results for roots instrumented with the one-appointment technique are given in Table III. No debris or predentin were observed in molar roots following the preparation procedure. When predentin was evident in the premolar roots there always was evidence of debris. No debris was observed without accompanying predentin. Predentin and debris were observed only at the 1mm level.

All of the molar root preparation at the 1mm level were centered within the root. Only two of the premolar root preparations at the 1mm level were considered centered within the root. All of the preparations at the 3mm level were centered.

A summary of the statistics for roots instrumented with the one-appointment technique is found in Table V.

DISCUSSION

Canal preparation is considered the most important phase of endodontic therapy (1,10,11). It is a process of adequately debriding the canal of soft tissue and affected dentin as well as properly shaping it to accept a root canal filling. Clinically great care is taken to assure the complete removal of canal contents. Copious amounts of sodium hypochlorite used as an irrigant with careful manipulation of standardized files has greatly improved debridement techniques. Since previous research showed sodium hypochlorite to be a solvent of necrotic tissue (1,15,50,51), this study investigated the possibility of realizing a greater degree of debridement by leaving residual sodium hypochlorite within instrumented canals utilizing a two-appointment compared to a one-appointment technique.

Limitations of using dogs as experimental animals

Barker and Lockett (70) suggested the utilization of dogs as suitable endodontic research animals. They recommended the use of the mandibular 2nd, 3rd and 4th premolars when performing root canal procedures. In the present research, the author found the 2nd premolar unacceptable for instrumentation procedures. The root stock was very short and no tactile sense could be experienced with the instruments. The first molar was used as a substitute in order to maintain the sample size in each category.

Considering the roots used in this study, it should be remembered that the canals are essentially straight and round. The only human teeth that consistently fit into this category are the maxillary central incisors. The final instrument sizes ranging from 30 to 70 also clinically correlate to human maxillary central incisors. Further research should be considered and designed to examine teeth that have a broader spectrum of applicability.

Single versus multiple appointments

The data in this research indicate that the goal of completely debriding the canal system remains elusive except when preparing large straight canals. Complete debridement is more a function of instrumentation as opposed to irrigation. Unless the instruments are able to contact every surface of the canal, complete debridement will not be realized. Large, direct and unobstructed access cavities are required to debride root canals successfully and confidently, irrespective of the number of instrumentation appointments.

Effect of access cavity preparations on canal debridement

Access cavity preparations in the experimental teeth were intentionally opened extremely wide. Such effort is also encouraged in human clinical situations in order to minimize any deflective forces on the inserted instruments. Direct access helps the operator to maintain original canal shape throughout the length of the canal, particularly at the apical extent of the preparation (19).

In the straight experimental teeth studied, only 47% of the sections examined demonstrated well-centered preparations at the 1mm level, 92% at the 2mm level and 100% at the 3mm level. All but one of the large molar roots were observed to have centered preparations at the 1mm level. This indicates that almost no deviations of the larger sized instruments occurred in these straight canals. Such comparisons strongly suggest that great care should be exercised in preventing instrument deflections when using small sized instruments in a root exhibiting any degree of curvature.

Comparison of remaining predentin and debris

No predentin or debris was observed at the 2mm or 3mm levels in any root. These findings can be attributed to the effectiveness of the flaring or step-back filing procedure. Numerous studies have advocated flaring the canal preparation (1,14,18,19,44,46,65,69). A flared preparation not only realizes maximal debridement but also eventually allows for more complete obturation of the canal.

Debris was always evident adjacent to the canal walls when predentin remained intact. The two-appointment technique of retaining sodium hypochlorite within the canal between appointments seemed to have no effect on debris. Perhaps if the canals were oblong or figure-eight shaped, as in many human teeth, there would be a more demonstrable effect of the residual irrigant. Further research needs to be investigated with such a hypothesis in mind.

One confusing observation of the cross sections at the 1mm level was that four canals of dog #2 treated with the two-appointment technique demonstrated debris without evidence of accompanying predentin (Figure 6 & 7). A possible explanation of this is that the initial instruments were not large enough, therefore resulting in a small master apical file (MAF). Subsequently, the MAF was large enough only to remove the predentin and not any additional canal debris created during the flaring procedure. Careful selection of the largest initial instrument will aid in assurring more complete canal debridement.

Artifacts not constituting canal debris

The amorphous material commonly observed in the lumen of the canal must not be confused with what was considered intracanal debris. This basophilic cloud (Figure 2) is an artifact that often remains during the staining procedures. The raised edges of the sectioned specimen cause a pooling of stain within the lumen area. If not carefully rinsed, stain will only be diluted and not completely eliminated during the washing procedure.

The fragmented chips of dentin (Figure 7) that were apparent in many sections can only be the result of careless laboratory processing. Dull cutting blades or old staining solutions contaminated by previous washings could easily account for the splash of the dentin across the sections.

SUMMARY

Thirty-six root canals in three Beagle dogs were prepared utilizing filing action and sodium hypochlorite irrigation by the following techniques:

1. Eighteen canals were prepared and completely dried at one instrumentation session. This was considered the one-appointment technique.
2. Eighteen canals were prepared at one instrumentation session leaving the canals intentionally moistened with sodium hypochlorite. After one week the canals were reentered, lightly instrumented with the master apical file, irrigated and dried completely. This was considered the two-appointment technique.

Canals by both methods were enlarged at full working length to three sizes larger than the initial instrument. They were also flared by using each of the next three progressively larger instruments 1.0mm short of the proceeding instrument.

Histologic cross-sections of the roots were cut at levels 1mm, 2mm and 3mm from the apical extent of the canal. These sections were blindly evaluated and compared according to evidence of remaining debris and predentin.

It was concluded that no demonstrable effect on canal debridement

could be attributed to the residual sodium hypochlorite with the two-appointment technique. Direct access cavities allowing instruments to reach the apical extent of intracanal preparation without any obstructions seems to be the major determining factor in completely removing predentin and debris at the 1mm level. A flared preparation is extremely effective in creating smooth and clean canal walls within 2mm of the apex.

CONCLUSIONS

The following conclusions were drawn after completing this investigation:

1. In straight and round canals residual sodium hypochlorite is not found to be an additional debridement aid. Its effect may be greater in oval or figure-eight shaped canals most commonly found in human teeth. Further studies might well be initiated to investigate such an assumption.
2. Direct access to the apical extent of the intracanal preparation is important to obtain complete debridement. The slightest lateral deflection or flexing of the instrument within a canal will likely result in incompletely prepared areas to within the apical 1mm of the canal.
3. A flared preparation is effective in predictably removing predentin and debris to within 2mm of the apices of straight round canals.

Table I: Initial and Final Instrument Sizes and Average Working Lengths

Root	Initial Instrument (Range)	Final Instrument (Range)	Average Lengths (mm)
3mm	15-25	30-40	9
3d	15-25	30-40	9
4m	15-25	30-40	11.5
4d	15-25	30-40	11.5
Mm	45-50	60-70	14.5
Md	45-50	60-70	13

Table II: Two-Appointment Technique Roots - Distribution of Results

	Root Specification	1mm Level D1	1mm Level D2	1mm Level D3	2mm Level D1	2mm Level D2	2mm Level D3	3mm Level D1	3mm Level D2	3mm Level D3
Evidence of	3m	X								
	3d	X								
Predentin	4m	X		X						
	4d			X						
	Mm									
	Md									
Evidence of	3m	X	X							
	3d	X	X							
Debris	4m	X	X	X						
	4d		X	X						
	Mm									
	Md									
Centered	3m					X	X	X	X	X
	3d				X	X	X	X	X	X
Preparation	4m		X			X	X	X	X	X
	4d	X	X		X	X	X	X	X	X
	Mm		X	X	X	X	X	X	X	X
	Md	X	X	X	X	X	X	X	X	X
Eccentric	3m	X	X	X	X					
	3d	X	X	X						
Preparation	4m	X		X	X					
	4d			X						
	Mm	X								
	Md									

Legend: 3 = 3rd premolar
4 = 4th premolar
M = 1st molar
m = mesial root
d = distal root
D1 = dog #1
D2 = dog #2
D3 = dog #3

Table III: One-Appointment Technique Roots - Distribution of Results

	Root Specification	1mm Level D1	D2	D3	2mm Level D1	D2	D3	3mm Level D1	D2	D3
Evidence of	3m	X	X							
	3d	X	X	X						
Predentin	4m	X	X							
	4d	X	X							
	Mm									
	Md									
Evidence of	3m	X	X							
	3d	X	X	X						
Debris	4m	X	X							
	4d	X	X							
	Mm									
	Md									
Centered	3m	X		X	X	X	X	X	X	X
	3d				X	X	X	X	X	X
Preparation	4m				X	X	X	X	X	X
	4d				X		X	X	X	X
	Mm	X	X	X	X	X	X	X	X	X
	Md	X	X	X	X	X	X	X	X	X
Eccentric	3m		X							
	3d	X	X	X						
Preparation	4m	X	X	X						
	4d	X	X	X		X				
	Mm									
	Md									

Table IV: Summary of Two-Appointment Technique Results

	1mm Level	2mm Level	3mm Level
Evidence of Predentin			
Number of Roots	5		
Percentage	28		
Evidence of Debris			
Number of Roots	9		
Percentage	50		
Centered Preparation			
Number of Roots	8	16	18
Percentage	44	89	100
Eccentric Preparation			
Number of Roots	10	2	
Percentage	56	11	

Table V: Summary of One-Appointment Technique Results

	1mm Level	2mm Level	3mm Level
Evidence of Predentin			
Number of Roots	9		
Percentage	50		
Evidence of Debris			
Number of Roots	9		
Percentage	50		
Centered Preparation			
Number of Roots	8	17	18
Percentage	44	94	100
Eccentric Preparation			
Number of Roots	10	1	
Percentage	56	6	

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FIGURES

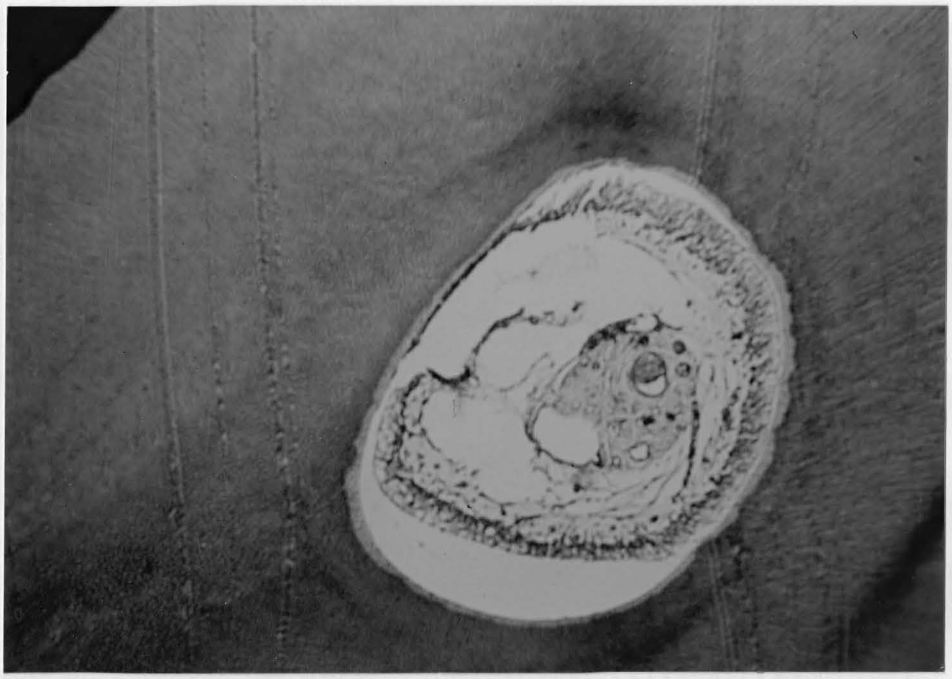

Figure 1. Low magnification of an uninstrumented control root cross-section cut 1mm from apical extent of canal. (Mag. 25X, H&E stain.)

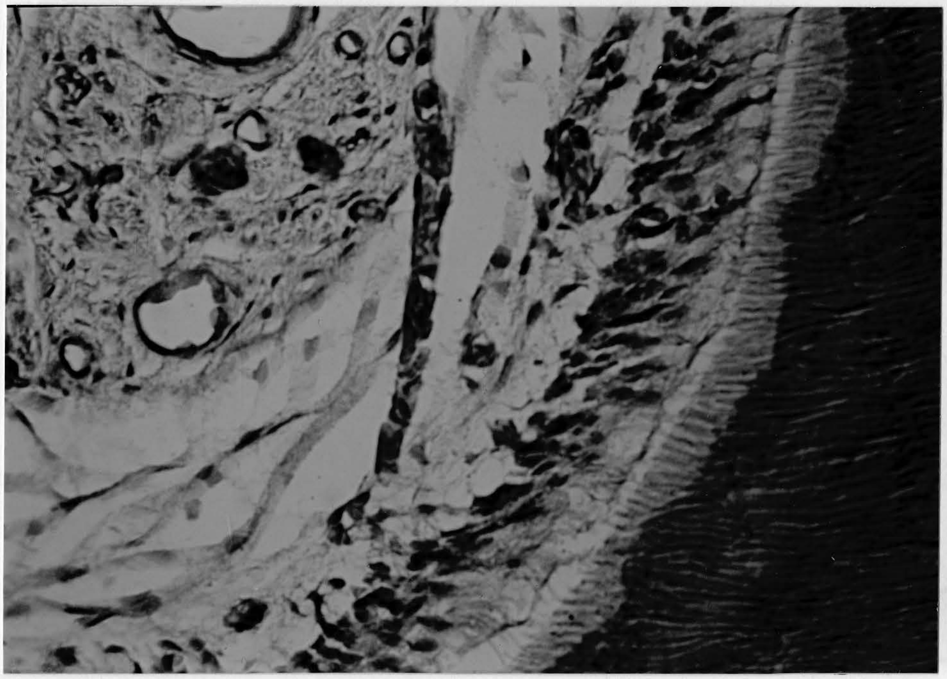

Figure 2. Higher magnification of Figure 1 demonstrating normal appearance of dentinoblastic layer, central core and included blood vessels. (Mag. 100X, H&E stain.)

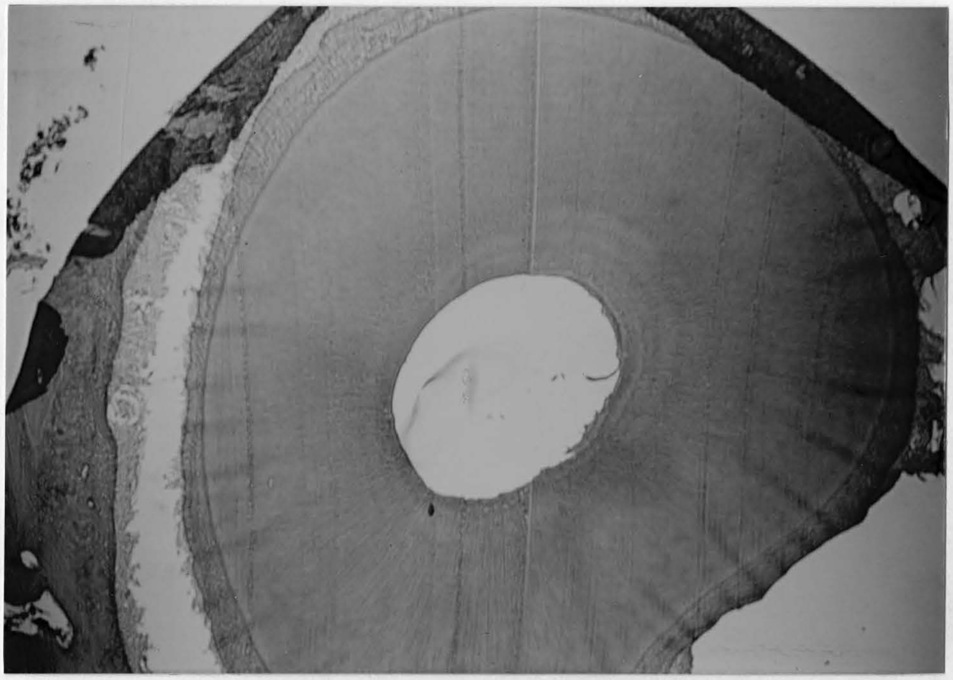

Figure 3. Low magnification of two-appointment technique root cross-section cut 1 mm from apical extent of canal preparation. (Mag. 10X, H&E stain.)

Figure 4. Higher magnification of same two-appointment technique root viewed in Figure 3. Note amorphous material collected in canal lumen. (Mag. 25X, H&E stain.)

Figure 5. Higher magnification of same two-appointment technique root viewed in Figure 4 demonstrating debris and predentin peeling from canal wall. (Mag. 100X, H&E stain.)

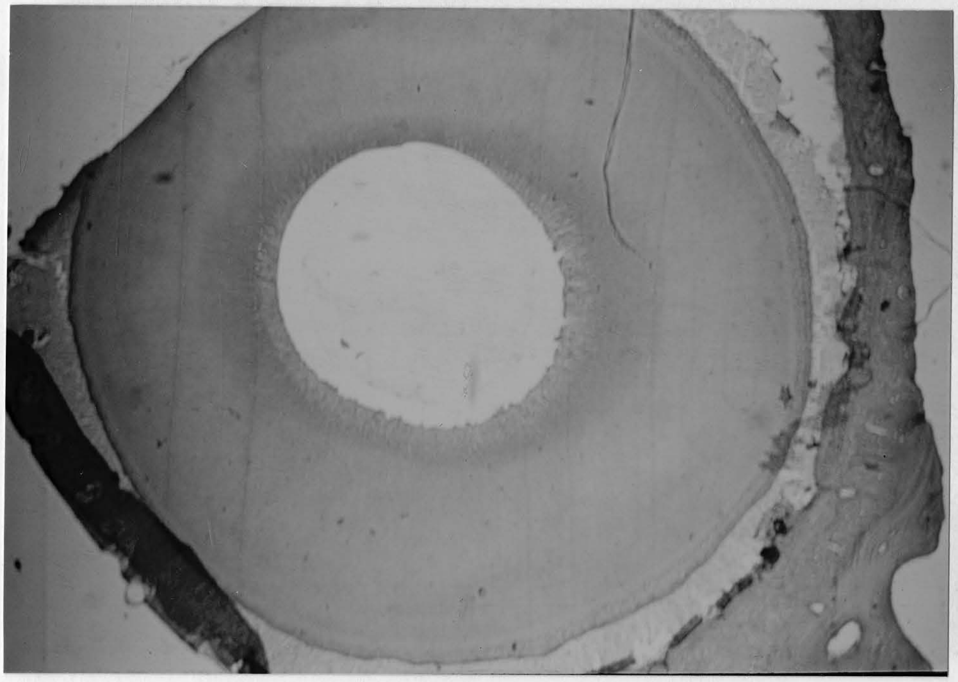

Figure 6. Cross-section of premolar root instrumented with two-appointment technique showing well-centered preparation within root. (Mag. 10X, H&E stain.)

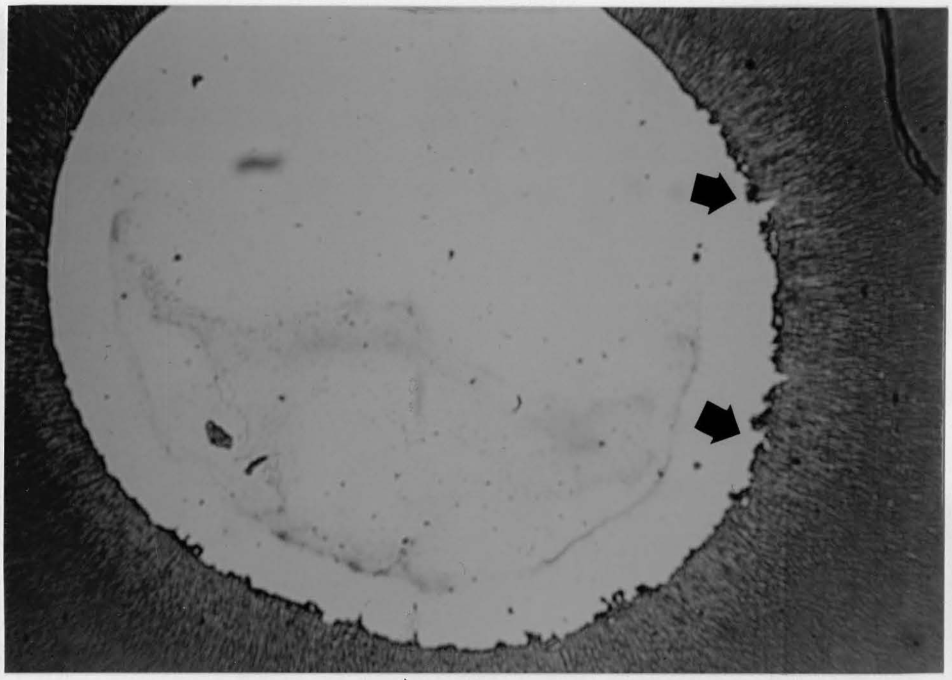

Figure 7. Higher magnification of Figure 6 demonstrating ditched and lightly prepared areas with remaining debris (arrows). Dentin chips appear splashed across the section. (Mag. 25X, H&E stain.)

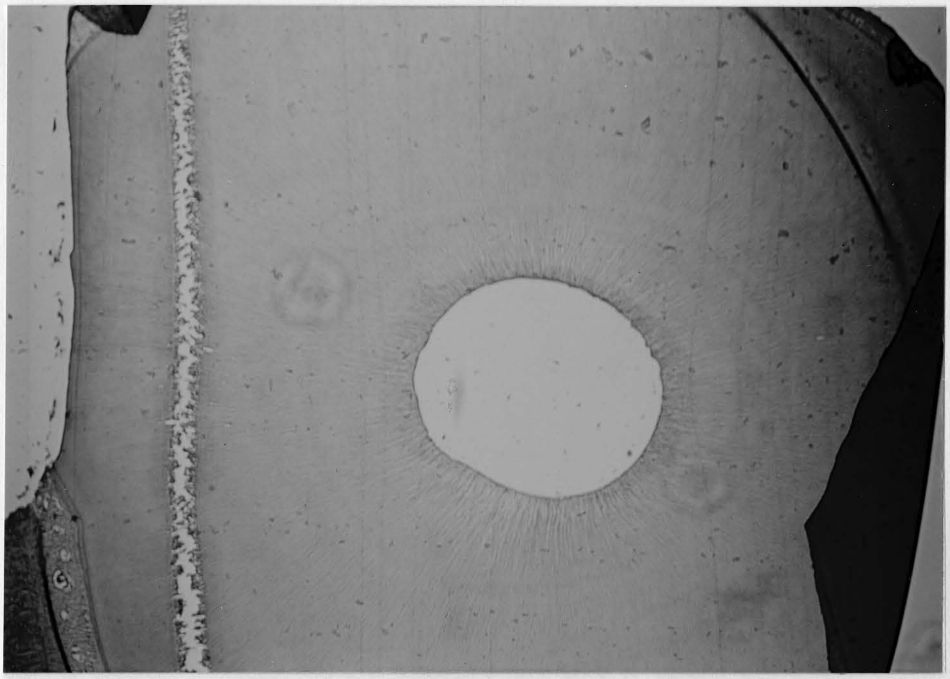

Figure 8. Well-centered, debris-free preparation at 1mm level. (Mag. 10X, H&E stain.)

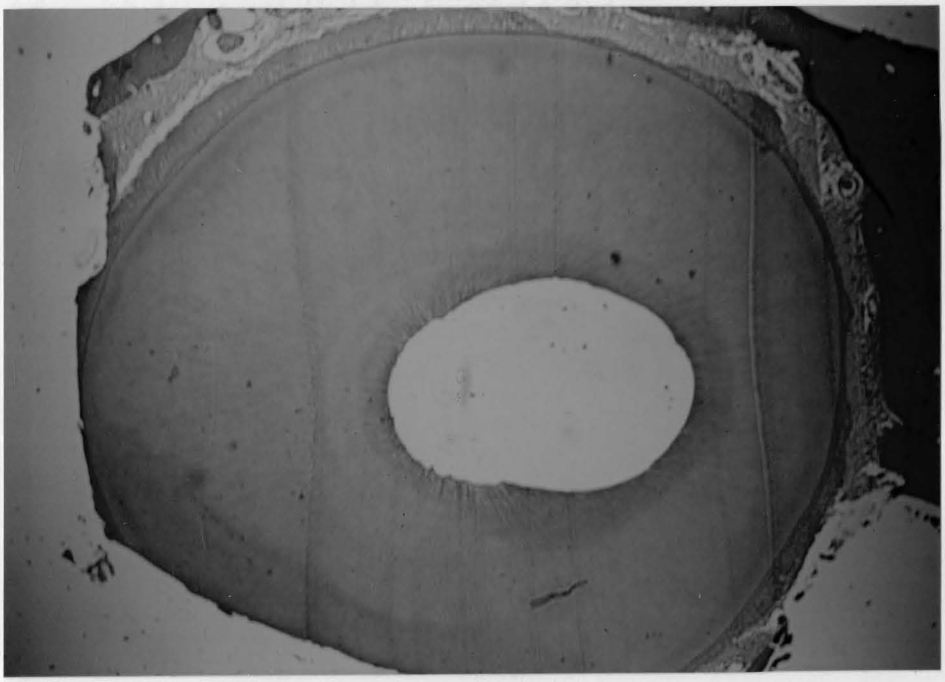

Figure 9. Eccentric preparation deviating from central canal. (Mag. 10X, H&E stain.)

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 in Oral Biology.

6-22-82
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