IATROGENIC ROOT FRACTURE ASSOCIATED WITH SCREW POSTS

by

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ABSTRACT

Three hundred and thirty upper lateral incisors were sectioned and examined for craze lines or cracks resulting from the insertion of a screw post. Two post systems were compared: the Dentatus screw post and the Kurer crown saver.

A precision torque wrench was used in the experiment to measure the torques applied to the roots while inserting each of the posts.

Every tooth was sectioned at three different levels. The sections were microscopically examined under ultraviolet light using a fluorescent penetrating dye (Rhodamine 6G) to record the occurence of craze lines.

Based on the findings of this study, the following conclusions are made:

1) Dentinal crazing or microscopic fracture can be observed as a function of the torque applied with the Dentatus screw post and the Kurer crown saver system in roots that do not demonstrate fracture when examined with the naked eye.

2) There is a considerably higher probability of dentinal crazing with the Dentatus screw post system than with the Kurer crown saver system.

3) The probability of dentinal crazing at torques of 6 ozf in or less is extremely small if not negligible with the Dentatus system. The torque required to seat Dentatus posts ranges from 4 to 6 ozf in.

4) The probability of dentinal crazing at torques of 8 ozf in or less is extremely small if not negligible with the Kurer crown saver system. The torque required to cut the threads with Kurer tap is 8 ozf in if the tap is not cleaned periodically during tapping, and of 6 ozf in if it is.

5) Both systems are relatively safe when care is exercised. The dentist must determine for each case whether the additional retention provided by a screw post system justifies the risk of possible root fracture.

RESUME

Trois cent trente incisives latérales supérieures ont été sectionnées et examinées pour la détection des lignes de fractures résultant de l'insertion des "screw posts". Deux systèmes de pivots sont comparés dans cette étude: Les "pivots Dentatus" et les "Kurer crown saver".

Une façon précise a été utilisée dans l'expérience pour mesurer les torsions appliquées aux racines durant l'insertion de chacun des pivots.

Chaque dent a été sectionnée à trois niveaux différents. Les sections obtenues ont été examinées microscopiquement en moyen des rayons ultraviolets tout en utilisant la teinture fluorescente pénétrante (Rhodamine 6G) pour enregistrer les lignes de fractures.

En se basant sur les résultats de cette étude, les conclusions suivantes ont été faites:

1) Les fractures dentinales ou fractures microscopiques pouvaient être observées comme fonction de la torsion appliquée avec le "Dentatus screw post" et le système "Kurer crown saver" dans les cas où les racines n'ont pas démontré une fracture quand elles ont été examinées à l'oeil nu.

2) La probabilité de fracture dentinale avec le système "Dentatus screw post" a été considérablement plus élevée qu'avec le système "Kurer crown saver".

3) La probabilité de fracture dentinale à une torsion de 6 onces/force/pouce ou moins est beaucoup moins grande ou négligible avec le système "Dentatus". La torsion requise pour adapter le pivot "Dentatus" est quelque part entre 4 et 6 onces/force/pouce.

4) La probabilité de fracture dentinale sous une torsion de 8 onces/force/pouce ou moins est excessivement petite ou négligible avec le système "Kurer crown saver". La torsion requise pour tailler le filetage avec les forets "Kurer" est 8 onces/force/pouce si la foret n'est pas périodiquement nettoyée durant le taillage, et de 6 onces/force/pouce si elle l'est.

5) Les deux systèmes sont relativement sans danger si le taillage est fait avec précaution. Le dentiste doit déterminer pour chaque cas si la retention additionnelle atteinte par le "screw post" justifie le risque de la fracture de la racine.

To my wife, all my gratitude for
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INTRODUCTION

The restoration of pulpless teeth requires the clinician to carry out careful preoperative planning and to follow exacting clinical procedures in order to achieve adequate retention of the restoration and to provide the maximum protection for the remaining tooth structure.

Healey wrote: "The remaining coronal portion of the treated pulpless tooth quite apparently is more brittle or fragile than when it contained a vital pulp."[1] This observation is often attributed to decreased moisture content.

The alleged brittleness of pulpless teeth has never been substantiated. A study conducted by Stanford, Weigel, Paffenbarger and Sweeney,[2] showed that the modulus of elasticity, proportional limit and strength were similar for vital and pulpless teeth. Helfer, Melnik and Schilder[3] demonstrated however that there was 9% less moisture in the calcified tissues of pulpless teeth than in those of vital teeth.

The endodontically treated tooth has been reinforced traditionally with an intracoronal post for these reasons. Numerous materials and techniques have been described in the literature. Until recently, the cast gold post and core was considered the universal restoration of choice.

The post and core provides support and retention for the coronal restoration, and its shape and length are so designed to prevent root fracture.[4]

The cemented cast gold post possesses the following disadvantages:

1) Its construction is time consuming. Two appointments are necessary before the final foundation coping is cemented into the root canal.

2) It provides less than maximum retention. The post is tapered and smooth. It is not as retentive[5] as a serrated parallel sided post or a threaded post.

3) It is expensive. The technique is both demanding for the dentist and the patient. Materials and laboratory costs are high.

Dentistry has seen an ever-increasing utilization of other techniques of constructing foundations for endodontically treated teeth. Prefabricated pins, posts and wires cemented and/or threaded into the root canal provide excellent retention and support for core foundations.

The prefabricated posts are available in a variety of shapes and designs. These are tapered and smooth, parallel and serrated, barbed and threaded. The threaded posts are divided into two systems:

1) Self-threading. These posts gain retention within the canal by cutting grooves. The most commonly used types are: Dentatus, F.K.G., Radix-Anchor and Anthogyr.

2) The Kurer crown saver system. These parallel sided posts are screwed into a thread created in the root canal by a machined tap.

The threaded post systems have gained great popularity because of certain obvious advantages:

1) They are more retentive than conventional tapered or parallel cemented posts.

2) They are simple to use.

3) Their lengths and diameters provide clinical versatility.

4) They require reduced chair time for the procedure.

5) They are inexpensive.

Nothwithstanding the advantages of these systems, there is some controversy regarding their use. Standlee, Caputo, Collard and Pollack[6] stated that tapered screw posts tend to exhibit a wedging effect which concentrates the stress in the coronal portion of the dentin. These severe stresses in dentin can predispose to root fracture. They established also that tapping procedures can cause dentinal crazing unless done slowly and carefully, and in function these dowel cores localize stress around threads and the coronal interface.

Most of the studies dealing with screw posts in the literature refer to their retentive properties and stress distribution. Calderón-Durney[7] conducted an investigation to determine the torque required to insert threaded posts into the root canal and compared it with that required to fracture the root.

There exists however, no experimental evidence to substantiate the presence of dentinal crazing produced during placement of screw posts, but there have been several studies reported employing self-threaded pins.[8,9]

It is the purpose of this investigation to evaluate the probability of dentinal crazing as a function of the torque applied with two different types of commonly used screw posts. This is accomplished by microscopic examination of sections of the roots while employing a fluorescent dye technique.

REVIEW OF LITERATURE

ROLE OF ENDODONTICS IN RESTORATIVE DENTISTRY

Methods of utilizing the pulp chamber and pulp canals for retention in the restoration of mutilated pulpless teeth as well as the reinforcement of weakened endodontically treated teeth have existed in dentistry for over 100 years. Richmond introduced a post-crown technique for endodontically treated teeth in 1870. The Davis post-crown system and other post-crown techniques were developed subsequently.[10]

Endodontic therapy today is preserving many hopelessly deteriorated teeth. However, with it the number of operative procedures has increased enormously to permit the utilization of these teeth as useful components of the masticatory system. Before recommending endodontic therapy to the patient, the dentist must make a thorough evaluation of the tooth and the masticatory system to enable him to form an accurate diagnosis. The following considerations must be included:

1) Is the tooth strategically important ?
2) Is the tooth treatable ?
3) Is the tooth restorable ?
4) What is the status of the periodontal tissues ?

Blair[11] suggested the use of elective endodontics to achieve a more desirable crown-root ratio, a narrower occlusal table, adequate embrasure space, improved direction of the vertical force of mastication, parallelism with other abutments and reestablishment of the occlusal plane. Elective endodontics is performed also in teeth with furcation involvement which may require hemisection and root amputation or hemisection and reassembly.

Bender, Seltzer and Saltanoff[12] established five criteria to judge success of endodontic therapy:

1) absence of pain or swelling
2) disappearance of fistula
3) no loss of function
4) no evidence of further tissue destruction
5) radiographic evidence of the eliminated or arrested area of rarefaction after six months to two years.

Nicholls[13] suggested a two year period of observation to determine success of endodontic therapy. Rosen[4] stated that the success of endodontics was the absence of an apical pathologic condition and the presence of an intact lamina dura.

Baraban[14] claimed that adequate apical sealing of the root canal and the absence of periapical pathosis over a period of time and a good assessment of the quality and quantity of its periodontal support were conducive to successful endodontic therapy. Schilder[15] presented the following triad for successful endodontic therapy:

1) Complete cleaning and shaping of the canals
2) Complete sterilization of the canals
3) Complete three-dimensional obturation of the root canal system.

If the tissue around an endodontically treated tooth fails to heal and becomes asymptomatic, it requires reevaluation. Stewart[16] suggested that re-treatment, periapical curettage, root resection and a retrograde restoration, hemisection or extraction should be considered.

THE PULPLESS ENDODONTICALLY TREATED TOOTH

The successful completion of the endodontics phase of treatment, followed by the restorative phase, namely the restoration of form, function, appearance and long term protection of the remaining tooth structure, is a mandatory requisite of any restoration. There is a general impression that pulpless teeth are more brittle or fragile than teeth with vital pulps.[1,4,14,17-19] Rosen[4] stated that pulpless teeth have a number of common characteristics:

1) They are brittle. Being deprived of a central blood supply, the dentin becomes desiccated and inelastic.
2) They possess little or no coronal tooth structure. The access opening for root canal treatment extends usually to the only intact surface, leaving the crown undermined.
3) They possess lowered resistance against decay and no longer have the faculty of detection of a developing lesion through pain.
4) They have lost the ability to form secondary or reparative dentin.

The reduced elasticity of a pulpless tooth may be explained in part, by a loss of moisture content. In 1972, Helfer, Melnik and Schilder,[3] demonstrated that there was 9% less moisture in the calcified tissues of non-vital teeth as compared with the calcified tissues of vital teeth, although no demonstrable qualitative change in the bound water was found.

Endodontically treated teeth, could be more fragile because of the reduced amount of remaining dentin. Consequently, they are highly susceptible to both horizontal and vertical fracture. Biomechanical preparation weakens the tooth. Sound enamel and dentin are removed for convenience to provide visibility for locating the canal access for shaping its apical one third.[1,4,20-22] Calcified or obliterated canals are often found in previously restored teeth. In such cases chelating agents are used as an aid to instrumentation, which may further decrease the strength of the residual preparation (EDTA 10 to 15%),[21,22] leaving the root canal walls smoother but with a "sugared" appearance.[23,24]

Whilst guttapercha is the material of choice for obturation, techniques employing flaring of the coronal one-third of the canal can further weaken the tooth.[21,22,25] Furthermore, to avoid root fracture, care should be taken not to use excessive force in the condensation of guttapercha or in the fitting of an oversized silver cone.[26] The canal filling material adds little or no strength to the tooth in replacing this lost tooth structure.

Some clinicians accept the placement of a Class I restoration in teeth that require nothing more than occlusal access and that possess sufficient structure after completion of endodontic therapy.[27]

Frank[17] in 1959 said that where the marginal ridge is no longer intact, the buccal and the lingual cusps should be capped or tied together to give the coronal portion of the tooth a chain of continuous strength. Most authors[1,14,28-30] agree with the shoeing of the cusps as the minimal consideration to protect the tooth from vertical fracture. The onlay should always be of the reverse bevel type to provide protection and to enhance resistance form. The reverse bevel alone is inadequate in many situations. Extension of the restoration in an apical direction is recommended to provide a retentive brace around the cusps.[30] A three-quarter crown, a full gold crown or a veneer crown may be indicated, based on the amount and the condition of the remaining tooth structure. These restorations require greater removal of tooth structure, leaving the tooth weaker and susceptible to horizontal fracture.

Some vertical support is recommended for teeth in which the remaining dentinal walls are thin, to protect against horizontal fracture.[31,32] Posts and pins provide vertical support for the restoration. It is conceded, however, that posts and pins perform a major role in providing retention rather than protection against horizontal fracture.

PINS

The use of pins to retain filling material in restoring teeth to their original morphology or as a foundation for crowns is a widely used clinical procedure. At present, there is a choice of three types of pins: cemented pins, friction-lock pins and threaded pins (thread-mate-system).

In 1951 Markley[31] reported, "where extreme loss of tooth structure makes dentin locks inadequate 0.025 threaded iridio-platinum wire pins cemented into holes provided excellent supplementary retention".

After the introduction of cemented pins, the friction-lock type and the thread-mate-system (TMS)* were developed.

The friction-lock system** is based on a tight fit of the pin in the hole (a 0.022 inch pin is placed into a channel prepared with a 0.021 inch drill).

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* Whaledent, New York, N.Y.

** Unitek, Monrovia, California.

The self-threading pin system utilizes pins that are threaded into undersized channels:

1) TMS Regular 0.031 inch pin, 0.027 inch drill
2) TMS Minim 0.024 inch pin, 0.021 inch drill
3) TMS Minikin 0.021 inch pin, 0.017 inch drill

Moffa, Razzano, and Doyle[5] reported the results of a study on retention of these three types of pins placed in dentin. They showed that the cemented pins were the least retentive. The friction-locked pins were two to three times as retentive as the cemented pins. The self-threading pins were five to six times as retentive as the cemented pins. They also reported an increase in retention of the cemented and self-threading pins within the dentin with an increase in the diameter of the pin. With increased pin length greater retention was noted for all types of pins.

Courtade[33] said that a 2 mm pin height above the dentin provides the maximum retention for the amalgam restoration. He recommended that the selected area for pin placement should be 1 mm from the dento-enamel junction and at least 1 mm from the pulp. He also recommended the use of one pin for each missing cusp.

Lorey, Embrell and Myers[34] found that the retention of cemented castings increased as the diameter and the length of the pins were increased; also the retention increased when threaded pins were used instead of smooth cylindrical pins. A similar study was done by Moffa and Phillips.[35] They established that:

1) Threaded wrought pins were more retentive than smooth cast pins, providing the pin length exceeded 1 mm.
2) There was a direct relationship between both pin length and retention, and pin number and retention.
3) The 0.75 mm diameter pin (larger diameter) had the greatest retention for all combinations of pin lengths and numbers.

Newburg and Pameijer[36] conducted an investigation in which different post and core systems were subjected to tensile, shear, and torque forces and their abilities to resist such forces were measured. They stated that:

- A post and core made of composite resin alone is the least retentive.
- The retention of composite resin core by four threaded pins compares favorably with other accepted techniques.
- A round post retaining a composite resin core used in conjunction with threaded pins increases the ability to resist displacement.
- A composite resin core used with threaded pins and/or cemented posts in the root canal was a reliable method.

EFFECTS OF PIN PLACEMENT

The fracture of both dentin and enamel takes place along planes determined by the distribution of stresses rather than by the structure of the materials.[37] Kasloff, Swartz and Phillips[38] reported cracking and crazing of hard dental tissues induced by moderate and high speed cutting instruments.

The adverse effect of the use of pins in restorative dentistry has been investigated by several groups. Trabert, Caputo, Collard and Standlee[39] studied the internal stresses and possible damage to the dentin and pulp produced by retentive pins.

Standlee, Collard and Caputo[9] investigated dentinal defects caused by retentive pins, using a fluorescent dye to trace the cracks and craze lines. Their study showed that cracks and craze lines do occur in dentin with the placement of friction-lock and self-threading pins. They also concluded that dentinal failures caused by pin placement may be the source of future enamel or pulpal involvement. They postulated that the application of repeated masticatory forces on the restoration-pin-dentin system could result in the propagation and widening of these cracks.

A photoelastic study later performed by Standlee, Caputo and Collard[40] showed that high stress concentrations (and possible fracture) resulted from the placement of friction-lock or self-threading pins.

More evidence to support the belief that retentive pin procedures induce craze lines was presented by Dilts, Welk, Laswell and George.[8] The use of fluorescent dye showed a definite crazing during pin hole preparation and pin placement.

Pameijer and Stallard[41] studied the retentive pin procedure using a scanning electron microscope with a replica technique designed to avoid specimen preparation artifacts. They found no evidence of crazing using this technique in vacuo. The authors concluded that it would be an oversimplification to state that pins never cause crazing of tooth structure.

Kai Chu Chan and Svare[42] compared the dentinal crazing ability of retention pins and machinist's taps. They found that 54% of the retention pins produced dentinal crazing which corroborates the results of Dilts et al.,[8] whereas only 20% of the taps produced crazing.

Because of this crazing, great care is indicated when pins are placed in non-vital teeth, as they ultimately may cause fracture of the dentin. Rosen [43] recommends the pre-tapping of pin-holes with a Whaledent part E threader* before inserting thread-mate-system® pins into dentin that appears brittle. The tapping procedure does temporarily stress the dentin but the pin ultimately seats passively.

The length of time the tooth has been non-vital should be a factor when the use of pins is being considered. With time, the dentin becomes less elastic. This increases the possibility of initiation of fracture lines as a result of the placement of pins which rely on the compression of the dentin for retention.

The use of cemented pins eliminates the dependence on the dentin for retention and rarely causes a fracture line in the dentin,[8,9] but their retentive properties are lower.[5]

The friction-locked pins rely on the elasticity of the dentin for retention. They are only twice as retentive as the cemented pins and are contraindicated in non-vital teeth.[5]

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* Whaladent Int. New York, N.Y., 10001

The self-threading pins utilize the elasticity of the dentin for retention. Their superior retentive properties in dentin and restorative materials often permits a shallower placement. It is possible to achieve some retention with a depth of 1 mm. However, depths of 1.5 to 2 mm are commonly used and recommended.

Caution must be exercised as most authors agree that there is a tendency for stresses to develop at the interface between the restoration and dentin.[44] Disparities between the skills of different operators can represent a major source of complication.

Pin retained cores or foundations for non-vital teeth are indicated in the following situations:

1) In teeth with fine, short, divergent or tortuous canals.
2) Teeth with calcified canals.
3) Teeth with inadequately obturated canals that demonstrate no pathology in which re-treatment is deemed unfeasible or too risky.
4) Where severe fracture of a tooth prevents isolation for proper root canal therapy without first constructing a foundation.
5) Where an existing post cannot or should not be removed because of the risk of root fracture.

The tooth should have some remaining coronal dentin to provide space for the retentive pins and support for the foundation.[4] If not, gingivoplasty and/or osteoplasty procedures may be indicated.

Markley[45] has described the technique for restoring lost tooth structure of pulpless teeth by the cementation of non-parallel pins into dentin and condensation of amalgam within a matrix about them. He stated that, "a weak, broken down tooth or root, ringed with 4 to 8 pins and restored with amalgam, is strengthened and splinted against possible splitting. Thus, it is far stronger than the familiar dowel and coping casting which actually tends to split the root". Courtade refers to that technique as "restoring lost dentin".[46]

Roberts[47] described a similar technique for non-vital posterior teeth. He recommended the building up of foundations by placing Dentatus screw posts into the root canal or root canals and subsequently finishing the restoration with amalgam.

The major drawback of amalgam is that 24 hours are required to achieve high strength. This can be partially overcome by the use of 1:1 alloy to mercury ratio and the use of spherical alloys.

The use of composite resin in place of amalgam for pin and post foundations has been recommended.[19,22,48-51] Spalten[48] described a technique for foundations using self-threading pins for retention of the composite resin core. The technique requires no condensation, and additions may be made to the primary mix if necessary. After 5 minutes the matrix is removed and the tooth is prepared for the veneer restoration.

The advantages of composite resin are:

- ease of manipulation
- strength comparable to that of tooth structure and amalgam

- fast set of the material
- final preparation in one sitting
- the preparation can be cut easily without a slurry of debris.[52]
- if the final restoration binds during insertion, the composite resin will show a definite mark so interferences are easily reduced.[48]

In an investigation conducted by Newburg and Pameijer[36] where different post and core systems were subjected to tensile, shear and torque forces, they concluded that: " The procedure in which composite resins are used to restore the coronal portion of pulpless teeth, with threaded pins and/or cemented posts in the root canal, is reliable".

Landwerlen and Berry[49] described a technique using T.M.S. pins for retention of the resin. The resin was injected with a disposable-tip syringe into the prepared posthole and finally around the threaded pins. This technique reduced the possibility of entrapping air. A celluloid crown form filled with composite was placed over the injected material and allowed to set. Few clinicians concur with their results.

Baraban[53] described a technique for the fabrication of an immediate composite-resin core retained by Para-post* and/or T.M.S. pin (s).*

There are four basic steps in this technique:

1) Reinforce the root by means of a post in single-rooted teeth.

* Whaledent International, New York, N.Y. 10001

2) Provide retention for the composite-resin core by means of the threaded post and T.M.S. pins where possible.

3) Condense the composite-resin over the root face using an annealed copper band about the circumference of the gingival portion of the root.

4) Shape the set composite-resin to that of the desired crown preparation.

This basic technique is applicable also to multi-rooted teeth. An aluminum shell crown can be used in lieu of the copper band to simplify the procedure.[52]

Steele[19] described a reinforced composite-resin foundation for endodontically treated teeth. He used a tapered serrated stainless steel wire which was spot welded to form a cross which fitted loosely into the root canal. The sequence of this technique is as follows:

1) The bar of the cross rested in notches on the mesial and distal dentinal walls which acted as stops.

2) The dowel space was filled with an opaque composite-resin.

3) The metal cross was inserted into the dowel space while the composite was still fluid.

4) A crown form previously adapted was inserted and wedged on the proximal surfaces of the remaining tooth. One or more holes were placed in the crown form to accomodate a syringe tip. A second mix of composite-resin was injected filling the crown form.

5) After the resin polymerised, the tooth was prepared.

Stahl and O'Neil[50] described a technique where the composite-resin was used as dowel and core. They used a Clev-Dent C-R syringe* to insert the composite-resin as far apically as possible into the prepared canal. The back pressure forced the syringe out of the canal. While the canal was filled by the dentist, the assistant loaded the core material from the same mix into the previously prepared polycarbonate crown. The loaded crown was joined to the dowel material. After allowing 8 minutes for the material to set, the crown was removed and the core was ready for preparation. They claimed that this technique eliminated considerable time and expense for both the dentist and the patient. It required only one visit for the patient. However, the value of composite-resin functioning alone as a post and core is questioned by most investigators, because of its poor tensile strength and brittleness.

Federick and Serene[21] described a technique for the secondary intention dowel core. They described a clinical situation in which a dowel and core was required for an endodontically treated tooth having an existing, permanently cemented, porcelain-fused-to-metal crown. They used a 0.050 inch stainless steel Para-post cemented in the dowel space. The dowel was reduced to a level adequate to provide retention for the composite-resin. The pulp chamber was filled with composite-resin to the external surface of the access opening in the crown. The composite-resin was reduced and polished to be contiguous with the anatomy of the porcelain-fused-to-metal crown.

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* Clev-Dent. Div. Cavitron Corp., Cleveland, Ohio.

Kahn, Fishman and Malone[51] described a simplified method for constructing a core following endodontic treatment. The "core form" was made of thin, transparent polyethylene and was available in different sizes. The "core form" was trimmed with scissors to fit closely around the gingival third of an endodontically treated tooth.

After the cementation of the metal dowel, a mix of composite-resin was applied to the inside of the "core form", around the dowel and into the undercuts in the pulp chamber. The core was placed in position over the prepared crown allowing the composite to polymerize. The thin "core form" was split and removed. Tapered diamond stones were used to remove any flash and to refine the preparation for full coverage.

Henry and Bower[22] described different methods to restore existing crown and bridge restorations to normal function following pulp death. They recommended that for secondary intention post-core construction in multi-rooted teeth either tapered (Endowel)* and/or cylindrical cemented posts can be utilized (Para-post). Amalgam condensed ~~to the bottom~~ of the access opening was used to hold the posts together as a core matrix material and was continuous with the final restoration.

They suggested that in cases of uncertain endodontic prognosis the Para-post system was temporarily placed by using a silicone rubber luting agent such as Trial.** The opening was sealed with a cement until the prognosis was clear. They added that secondary intention root filled abutment teeth, left unsupported by a post system, had a high risk of fracture and had to be restored as soon as possible.

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* Unitek, Monrovia, U.S.A.

** Opotow Dental Mfg. Co. Inc., New York, U.S.A.

Kantor and Pines[54] conducted a comparative study of restorative techniques for pulpless teeth. They claimed that when a pulpless tooth with intact coronal dentin had undergone conservative endodontic therapy it required reinforcement before restoration. A single post cemented in the root canal was the treatment of choice.

They claimed that this procedure doubled the strength of the tooth. They favored the gold core over the composite-resin or amalgam cores. The composite-resin cores were friable and had inadequate density. Nevertheless, they suggested the use of composite-resin cores in single restorations that were not likely to become abutments.

Pin-retained amalgam cores and composite cores are relatively recent innovations and this undoubtedly accounts for the lack of research on them. Though their tensile strength does not compare with that of cast gold they are adequate as foundation materials. The relatively poor tensile strengths of both amalgam and composite-resin can be tolerated when these materials are used as core materials only.

A major objective of the post core system is to derive retention from mutilated endodontically treated teeth. The prefabricated posts, commercially available when used in conjunction with strategically placed pins, achieve this objective far better than tapered castings. The weaknesses in the composite-resin and amalgam core materials can be compensated for by proper tooth preparation. A shoulder prepared on sound tooth structure provides the major resistance form for the subsequent crown restoration. The bevel enhances the restoration and as well exerts a bracing action on the root. The relatively poor tensile strength of the composite-resins and amalgam core materials is therefore rarely challenged during function even when such teeth are used as abutments.[52]

These methods are gaining great popularity because of their economy, ease of application and the subsequent reduction in chair time.

SCREW POSTS AND MACHINED TAPPED POSTS

Screw posts and machined tapped posts are capable of providing more retention than commercially available cemented prefabricated posts.[55,56]

Gerstein and Burnell[57] stated that screw posts may fracture under masticatory stress. They also believed that the length of the post was difficult to control and there was a danger of fracturing the root by overzealous threading. Perel and Muroff[26] and Lau[58] stated that screw posts were of questionable value because of the danger of cracking the root.

Caputo and Standlee[59] recommended that the screw post should be just slightly larger than the prepared canal. They also stated: "Excessive force is to be avoided when inserting the screw post. If binding is encountered while the post is being screwed to place it should be removed and a smaller post inserted or further preparation of the root canal completed".

In 1967, Kurer[55] introduced a new system for the retention of post crowns named the Kurer Anchor System. A threaded post is united to a head made of soft brass by the process of staking, a method by which the female portion in the head is made smaller than the male portion of the shank. In order to prepare the root to receive the post, the system provides:

1) An engine reamer
2) A root facer, that prepares the root face to receive the brass head of the post.

3) A tap, matching the reamer, used to cut the threads in the prepared root canal, permitting the threaded post to be screwed to place.

The Kurer system uses both dentin elasticity and cement luting for retention.[60]

Johnson, Schwartz and Blackwell[61] stated that the screw post systems are only indicated if some coronal tooth structure remains. They are frequently used in conjunction with pins for added retention in an amalgam or composite-resin buildup.

Colley, Hampson and Lehman[56] studied the retention of post crowns taking into consideration:

a) length of dowel

b) degree of taper

c) surface roughness

They found that parallel-sided dowels were more retentive than tapered ones. Roughness of, or serrations on the surface of the post increased axial retention. Also, increased length improved retention for all dowels tested. Studies of cement film thickness along the surface of the dowels showed that preparing a root canal with a reamer matched to a standard-size dowel was preferable to prefabricating a dowel from a wax pattern of the prepared root canal.

Standlee, Caputo, Collard and Pollack[6] compared the stress distribution in three different types of endodontic posts: smooth side tapered posts, smooth side parallel posts and threaded posts. They used the photoelastic method of stress analysis. They established that the tapered posts demonstrated the least installation stresses. Constant digital pressure was required with parallel posts during cementation in order to stop the tendency to "bounce". High apical stresses were detected with this type of post.

The threaded post presented some critical obstacles. The taps generated high stresses adjacent to the threads and at the apical seat. They suggested the withdrawal of the tap for cleaning debris after every two turns, otherwise high stresses, cracking of specimens and fracture of the taps were observed. If the tap was used correctly no significant residual stresses were detected. The tapered posts exhibited a wedging effect and produced the highest shoulder stress concentrations.

Kurer, Combe and Grant[60] conducted a study to assess the axial retention of dowels. Whalebone was chosen as a suitable material to cement different types of dowels (standard stainless steel dowel, sharp-edged grooves, round-edged grooves, sandblasted and threaded).

They established that there was an increase in resistance to axial displacement with increasing length of the dowel. Increasing the diameter of the dowel did not have a significant effect. They also observed that, in general, there was a greater resistance to axial displacement for screw threaded dowels when compared with the other types. They showed that screw threaded dowels were the least dependent on cement for axial retention.

The fact that a post is cemented within the tooth structure does not necessarily eliminate the possibility of corrosion. Both cementum and dentin of extracted teeth are permeable to fluids,[62] therefore it is conceivable that fluid can come into contact with posts cemented within tooth roots. Hence, where possible, gold alloys and heavy platinum metals are the materials of choice as a safeguard against corrosion and the possibility of root fracture due to corrosion.[63]

Derand[63] advocated the following precautions when using a screw post:

1) Never use screw posts which are discolored or show a defective surface.

2) Do not grind or cut a screw post on the part to be placed in the root canal.

3) Do not leave the cement border in contact with saliva from one day to another.

4) For important roots use posts of gold or noble alloys.

MANUFACTURED POSTS

Manufactured posts are widely used in many techniques to reinforce endodontically treated teeth.[22,28,48,53,57-59,64,65] There are tapered manufactured posts that are standardized in size with endodontic files and reamers (Kerr Endoposts*).

A second type is the parallel-sided posts which are usually supplied with drills of matched size for preparation of the canal. These posts are made of four materials: gold, stainless steel, aluminum and plastic[64] (Whaledent's Para-post System**).

The Kerr Endoposts are available in sizes of 70 to 140 in a regular high-fusing gold platinum alloy.[57] An Endopost of the same size as the last file used to prepare the canal is fitted to the prepared depth. This results in close adaptation of the Endopost to the walls of the canal.[28] After the post is seated, the core is then fabricated out of wax or self-

* Kerr Mfg. Co., Romulus, Mich.

** Whaledent Inc., Brooklyn, N.Y.

curing acrylic. The post and core are then sprued, invested and the core is cast to the post.[57]

The possibilities of root perforation are minimized with this technique because hand instruments are used to prepare the canal and to remove the filling material. The shape of the Endopost is similar to that of the prepared root canal.[28,57] These posts, according to Kapsimalis,[28] provide the maximum amount of frictional resistance to displacement without weakening the root.

Canals that are ovoid or square in cross section are best fitted with cast gold post and cores.[4]

Baraban[64] stated the following advantages for the Para-post system:

1) It affords a standardized procedure for the fabrication of posts and cores.

2) The range of the gauges of the Para-post drills from 0.036 to 0.070 permits their use in most roots.

3) The equipment is advantageous for the direct technique.

4) It may be used for temporary crowns.

5) In selected cases the post and core may be fabricated and cemented in one visit.

6) It may be used to reinforce an endodontically treated tooth for which a cast core is not necessary.

Colley et al.[56] stated that parallel-sided posts have more retention than tapered posts. They transmit axial forces in line with the long axis of the tooth. Tapered posts transmit forces to the walls of the root canal[66] and where the core does not fit closely to the root surface the wedging effect will tend to split the root.

Hanson and Caputo[67] conducted a study to demonstrate the retention of a variety of prefabricated dowels with different types of cementing mediums. They concluded that the 0.06 inch diameter Parapost exhibited the highest retention for all the cements tested.

Johnson, Schwartz and Blackwell[61] believed that the chances for root perforation were greater with the use of the parallel-sided post since it does not conform to the natural shape of the canal. Also, with the use of the parallel-sided posts, the root becomes weaker because of the removal of more dentin. They established the following advantages of manufactured dowels over cast posts:

1) The direct method can be used.
2) No direct patterns or impressions of the canals are required.
3) They permit fast, easy and accurate adaptation to the canal.
4) The manufactured dowels can be used with composite-resin core (Adaptic)* and pins in a one visit technique.
5) Closer adaptation to the prepared canal requires a thinner layer of cement.
6) Less time is involved in the technique and manufactured posts are cheaper than cast posts.

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* Johnson & Johnson, New Brunswick, N.J.

CAST POSTS

Traditionally, the most common method used for restoring endodontically treated teeth is by means of a cast post and core which is cemented to place to form a foundation. Rosen[4] referred to the post and core as an intracoronal crutch. He also described the extra coronal brace as a subgingival collar of gold which extends as far as possible beyond the gingival seat of the core and completely surrounds the perimeter of the cervical part of the tooth. It is an extension of the restored crown which by its hugging action prevents vertical shattering of the root.

Perel and Muroff[26] stated that the post and core should always be a separate entity from the crown because:

a) It is difficult to obtain a positive seating of the post portion and a marginal seal of the cast crown simultaneously.

b) The crown retainer might have to be removed at some future time without disturbing the removal of the post.

Cast posts provide protection from horizontal as well as vertical fracture. Because their insertion and retention in the prepared canal is independent of dentin elasticity, they produce no lateral stress that can crack or fracture the root if they have a positive seat.[54] The greatest protection against vertical fracture is provided by the bracing action of the crown rather than the design of the post and core.[4]

Rosen[4] reported a direct method of making the wax pattern for a single rooted tooth. He also described an indirect method of obtaining the wax pattern for multi-rooted teeth when paralleling of the posts was impossible because of the divergence of the roots. He stated: "Posts for multi-rooted teeth need not be as long as for single-rooted teeth. Posts and cores for teeth with divergent roots are constructed in two or three sections. These are cemented in place independently and can be united with mortise joints or semi-precision locks to provide additional strength".

Silverstein[68] described a direct wax up of a post-core for pulpless teeth, where a temporary acrylic resin-crown is employed as a guide for making the wax pattern.

Baraban[14] described three methods for taking an impression for constructing post and cores:

1) Copper band and compound.
2) Copper band and compound in combination with silicone or rubber base for the post impression.
3) Rubber base or silicone.

He also described a cast post and core technique with parallel retentive pins for the reconstruction of multi-rooted teeth.

Christy and Pipko[66] described the fabrication of a dual-post veneer crown. They claimed that the procedure had many advantages over other techniques. They stated that the length, diameter and type of material used in the dowel post all affect its retention and strength. The longer and wider the post is, the greater will be its strength and retention.

Certain authors advocate a post length equal to one half the length of the remaining root.[14] Others advocate a post length equal to the occluso-gingival height of the final restoration.[4,17,18,20,30,69] Still others advocate a length of two thirds of the remaining root.[66,70]

The fourth group advocates a length equal to three quarters or more of the remaining root length but leaving 3 mm of intact filling from the apex.[59] Still another concept is that the dowel length should extend to one half the length of the root contained in bone.[26]

Standlee and associates[6] studied the stress distibution from endodontic posts and concluded that stress concentration decreased with increased post length. According to Weine,[71] short posts can actually increase the possibility of root fracture whereas the long post distributes the stress throughout the root that it contacts which is well surrounded by bone . Short, wide posts can be more conducive to root fracture because of the amount of root structure removed to accomodate the post and the lack of bone surrounding any of the prepared portion of the tooth.

Johnson[72] reported that,although both length and diameter significantly affect the retention of a dowel post, shape is the most important variable in dowel post design. He found that an increase in length or diameter produced an increase in retention in the range of 30% to 43%, but that a change in shape from tapered to parallel-sided serrated dowel post resulted in an increased retention of 4.5 times.

Colley and associates[56] reported that serrations on the surface of the post increase the retention of the post.

Mondelli, Piccino and Berbert[70] described a technique by which an acrylic resin pattern was used to construct a cast dowel and core. First, the dowel portion of the acrylic resin cylinder was adjusted to fit the canal. The base of the core was made by adding acrylic resin by the flow method. Finally, to insure a complete coping, excess acrylic resin was added to the foundation. Wax was used to fill the voids between the acrylic dowel and the walls of the canal. They also described an indirect method to construct the post and cores.

Rosenberg and Antonoff[20] described a similar method for the fabrication of a post and core. They employed Duralay* with the brush technique for the impression of the root canal. A previously prepared plastic sprue was introduced into the canal and after one minute the plastic sprue was removed from the canal with the Duralay adhering to it.

Kahn and co-workers[51] described a procedure to construct a gold post core. A plastic "core form" was adapted to the root after the Endowel was placed in the root canal and cut short of occlusion. The "core form" was filled with inlay wax and placed over the dowel and remainder of the crown. Another alternative was to use Duralay in the "core form" instead of wax. They claimed that no impressions and casts were necessary. The only laboratory work necessary was to sprue, invest, burn out and cast.

Lister[73] described another approach for a tooth with large canals, but divergent roots, fabricating a dowel post for one canal. The post was lubricated and inserted into the tooth or die and a second dowel post core built up around this original post. The original post was removed, leaving a pathway for insertion through the core. The core and remaining post were cast in one piece. The post-core was cemented first and the second post was cemented through the opening in the core.

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* Reliance Dental Mfg. Co., Chicago, Ill.

No one design will suffice in every case in the restoration of endodontically treated teeth. A parallel, serrated, cemented device in a precisely matched channel has the ideal combination of characteristics. When tooth morphology or heavy function requires increased retention,this may be achieved by increasing post length, diameter or by utilizing the resilience of dentin.

However, the dentist must be aware that the price for more retention is the increasing risk of damaged tooth structure.[59]

MATERIALS AND METHODS

Selection of the posts

The most commonly used screw post systems are:

1) Self-threading posts. Such as:

- Dentatus
- F.K.G.
- Radix-Anchor
- Anthogyr

2) Posts requiring a pre-tapped thread:

- Kurer crown saver

Dentatus Screw Post System:*

The Dentatus screw post *(Fig. 1)* is a versatile system. The posts are self-tapping and gold plated. They are made of a flexible brass-like alloy. Twenty different combinations of thicknesses and lengths are provided in a kit enabling the selection of a screw post that will fit most root canals.

To facilitate the final fit, the root canal is reamed to the exact size of the appropriate screw post with a Dentatus reamer that corresponds to the size of the screw post. The available lengths of the matching reamers are 28 and 33 mm.

The posts are supplied in six different diameters. Only sizes 13 and 15 are supplied in extra long lengths.

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* Weil Dental Supplies Ltd. Toronto, Canada.

The following diameters of posts are available:

Post Number	Corresponding reamer number	Diameters of post in mm
18	1	1.05
17	2	1.20
16	3	1.35
15	4	1.50
14	5	1.65
13	6	1.80

The lengths of the posts are:

Short	(S)	- 7.8 mm
Medium	(M)	- 9.3 mm
Long	(L)	- 11.8 mm
Extra Long	(XL)	- 14.2 mm

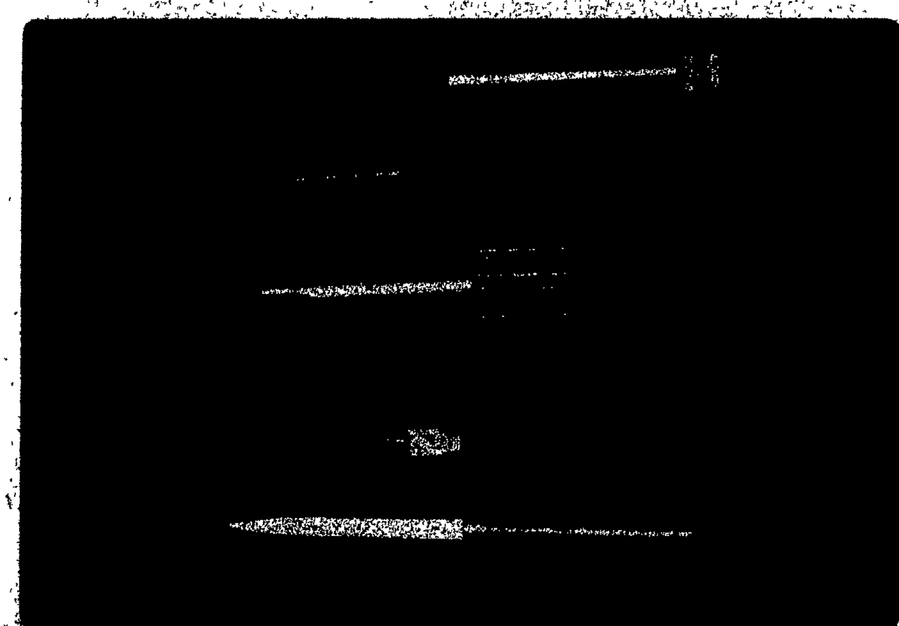

Fig. 1 Dentatus posts No. 16 and 15 with corresponding reamers and wrench.

Two types of keys are available for insertion of the post. One is a socket type key and the other is a Phillips head screwdriver which is used for narrow access cavities.

The versatility and ease of manipulation have made this system popular in spite of the fact that no studies have been reported verifying their safety and effectiveness.

F.K.G. Screw Post System:*

This system is similar to the Dentatus system with two basic differences:

a) The posts are made of stainless steel.

b) The posts are supplied in 10 different lengths, but only one diameter.

For the preparation of the root canal to receive the post, Peeso reamers** are used. The No. 3 Peeso reamer provides the exact matching diameter for all the posts.

The lengths of F.K.G. posts are:

60 - 6.50 mm	062 - 11.25 mm
060 - 7.50 mm	63 - 12 mm
61 - 8.25 mm	063 - 13 mm
061 - 9.75 mm	64 - 14 mm
62 - 10.75 mm	064 - 15 mm

The system comes with Phillips type screwdriver and a wrench for the application of the posts in the root canal.

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* Union Broach Co., Long Island City, N.Y. 11101

** Idem.

Radix-Anchor Screw Post System*

The Radix-Anchor posts (*Fig. 2*) are made of stainless steel. They are cylindrical with thread forming "cutting barbs". These "cutting barbs", according to the manufacturer, reduce the danger of splitting the root. The barbs are confined to the coronal segment of the post where there is greater supportive bulk of tooth structure. There are four vertical grooves in each post that permit the excess of cement and captive air to escape coronally during sealing.

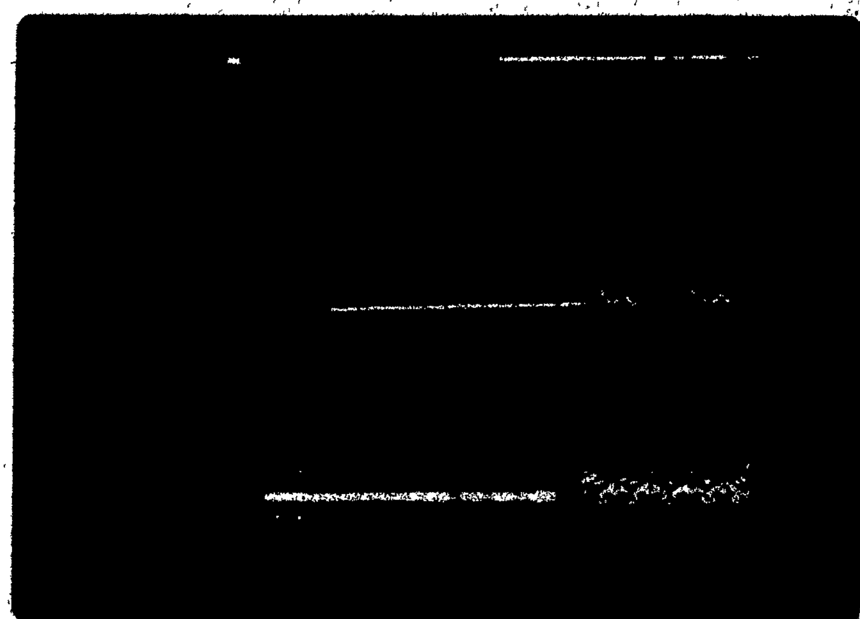

Fig. 2 *Radix-Anchor system including reamer, gauge, wrench and post.*

* Star Dental Mfg. Co., In. Conshohocken, P.A. 19428.

The Radix-Anchor posts are supplied in two sizes (No. 2 - small size and No. 3 - large size). The system is provided with matched reamers, gauges and wrenches.

Size	Diameter of post without barbs	Diameter of post including barbs	Length of post	Diameter of head	Height of head
2	1.35 mm	1.65 mm	8 mm	3 mm	3.8 mm
3	1.60 mm	1.90 mm	10 mm	4 mm	5.0 mm

A greater variety of diameters and lengths would make this system far more versatile.

Anthogyr Screw Post System:*

These posts are also made of stainless steel and are very similar to the F.K.G. system. The system does not provide a matching reamer to prepare the root canal, making this procedure uncertain.

They are supplied in four different diameters:

Extra thin	0.9 mm
Thin	1.1 mm
Medium	1.3 mm
Thick	1.5 mm

The lengths are as follows:

	Extra thin post	Thin post	Medium post	Thick post
short	6 mm	7 mm	8 mm	9 mm
medium	8 mm	9 mm	10 mm	11 mm
long	10 mm	11 mm	12 mm	13 mm

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* Mo-Dent, Montreal, Canada.

Kurer Crown Saver Kit:*

This kit is similar to the Kurer Anchorage system, but differs in that no heads are supplied on the posts *(Fig. 3)*. The crown saver posts are available in two different thicknesses:

	Post diameter
No. 0 Extra Small	1.60 mm
No. 1 Small	1.68 mm

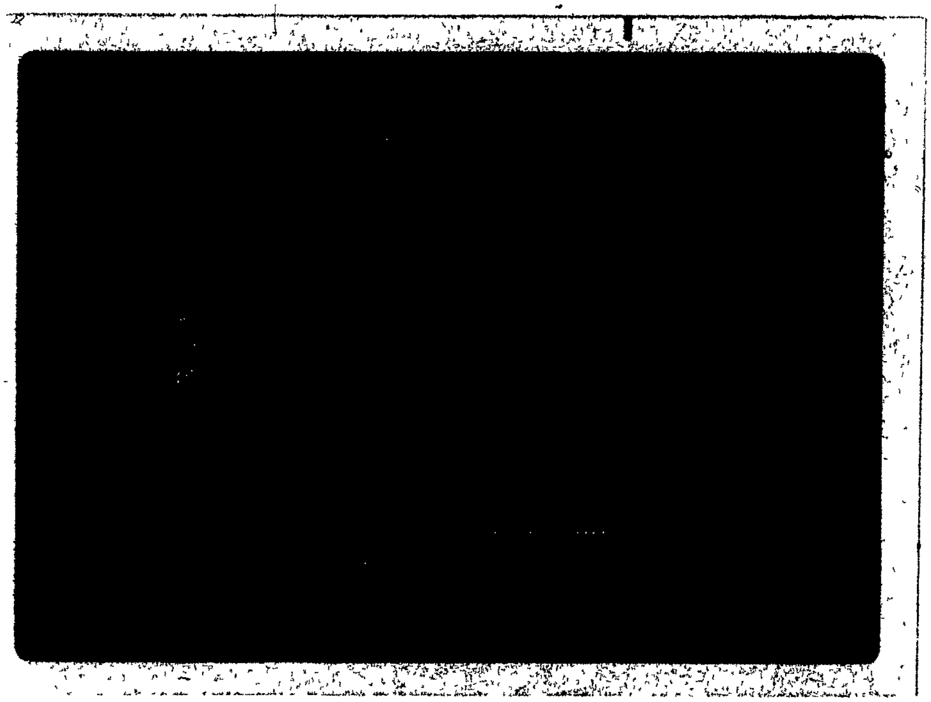

Fig. 3 *Kurer crown saver system including reamer, tap, post and wrench.*

Every kit comprises the following instruments:

1) An engine reamer: it is used to finalize the preparation of the root canal in order to match its diameter with that of the tapping device. This instrument deepens the canal to the desired length.

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* Cottrell & Company. London, England.

[redacted]

2) A tap: this instrument matches the reamer and is used to form the thread in the canal. The thread is accomplished by rotating the tap 3/4 turn forwards and 3/4 turn backwards.

3) A driver: it is used to screw the post passively into the root canal.

The most commonly used screw posts, the Dentatus and the Kurer, were selected for this investigation.

Specimen selection, preparation and storage

The lateral incisor was selected for this study because it is a narrow tooth and the pulp canal diameter is such that it could receive a 1.60 mm diameter post without excessively widening the post space. Narrow teeth were deliberately selected as they are more prone to fracture.

Three hundred and thirty teeth with intact crowns were stored in a solution of water and zephiran chloride immediately after the extraction to prevent desiccation and to inhibit bacterial growth. The specimens were kept in the solution at all times during preparative procedures. Large samples of teeth were needed to reduce the effect of variations in pulp chamber and pulp canal dimensions, degree of calcification and water content.

The teeth were randomly assigned to one of 19 test groups. The periodontal membrane was removed from each root using a No. 15 scalpel blade. The coronal portion of the tooth was then severed with a diamond bur using a spray of water. The cut was made perpendicular to the long axis of the tooth at a level of 1.5 mm coronal to the cemento-enamel junction. The pulp was then removed with broaches.

Each tooth was painted now with a surface crack detection dye (Dector)*, to ensure that no crack was present in the root prior to conducting the experiment. The following steps were undertaken according to the dye manufacturers instructions:

1) The tooth was dried with a blast of air.
2) The surface of the root was coated with dye using a cotton pellet.
3) The dye was allowed to remain on the tooth for two minutes.
4) The dye was wiped from the surface of the root with dry cotton. A blue line became visible on the surface of the root wherever a crack or discrepancy existed.
5) Dector solvent was applied to the surface of the tooth to remove the dye, and the tooth finally was rinsed with water.

Not more than 1% of all the teeth tested (330) showed surface cracks *(Fig. 4)*. These teeth were excluded from the sample.

The preparation of the root canal was initiated on each sound root. Holding each root with a 2 x 2 in humid gauze swab, the access to the root canal was prepared in a conventional manner. Each canal was enlarged to accommodate a No. 50 file, 3 mm short of the apex. The canals were widened then with Gates Gliden drills** and finally prepared to receive their respective posts with the corresponding reamer. The entire procedure was performed with engine reamers rotating at very slow speed.

During root canal preparation and after the final reaming of the canal, debridement was carried out by irrigating it with saline solution.

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* Den-Mat Inc., Santa Maria, CA.

** Union Broach Co., Long Island City, N.Y. 11101.

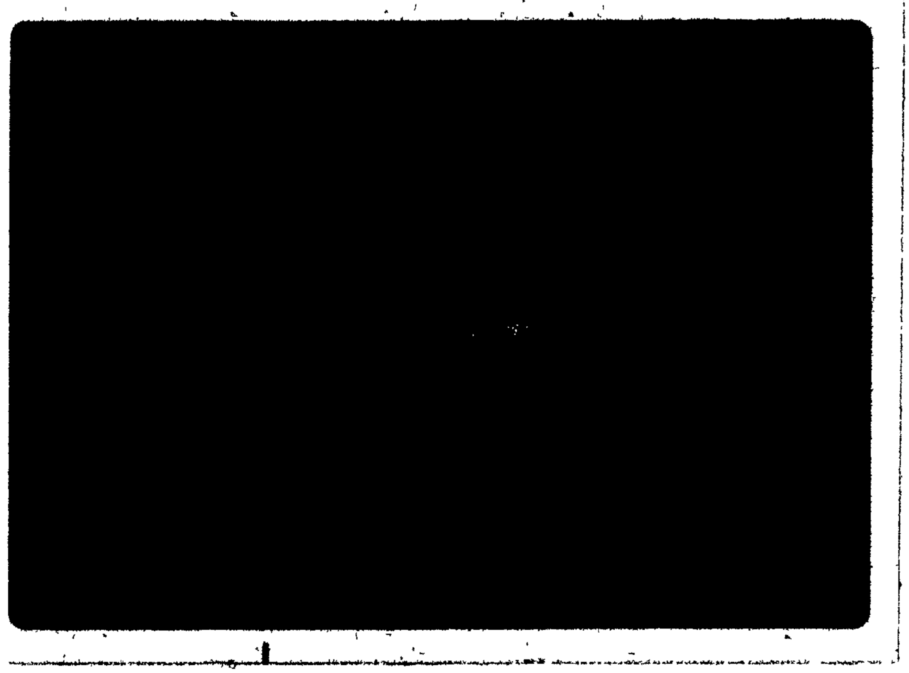

Fig. 4 Blue line revealing a crack using detection dye (Dector).

A torque adjustable screwdriver* (converted to a torque wrench) was used for both the Dentatus and the Kurer screw post experiments. *(Fig. 5)*. The torque screwdriver was used as follows:

1) Setting the torque: this was done by pulling the lock collar toward the handle and turning the adjusting knob to the desired setting. The torque setting is the sum of the readings of the major scale and the minor scale. The lock collar was released to lock the setting.

2) Inserting and removing the bits: the torque wrench holds bits with 1/4 inch male hex drive. The Kurer tap and Dentatus wrench were modified by machining in order to fit the chuck of the torque wrench *(Fig. 6 and 7)*.

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* Torque Control Inc., Utica, Orangeburg S.C. 29115.

3) Torqueing: the torque screwdriver was used as any regular screwdriver. Care was taken to engage the bit fully in the chuck. The final torque was applied with a slow rotary motion. The handle was turned steadily until the internal clutch was released and the screwdriver turned freely for 20^{0} - 30^{0}.

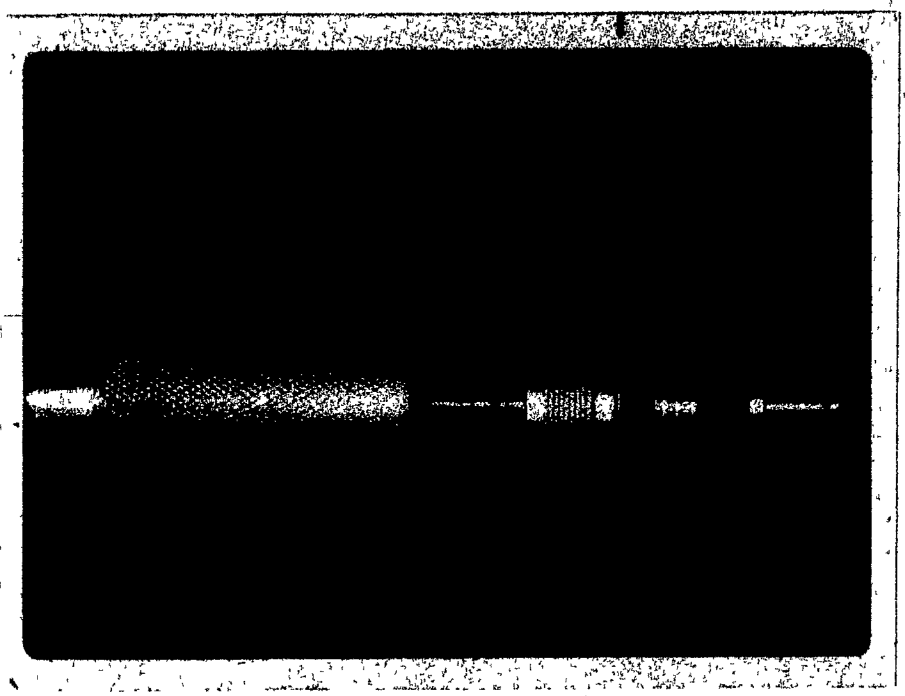

Fig. 5 *Torque wrench.*

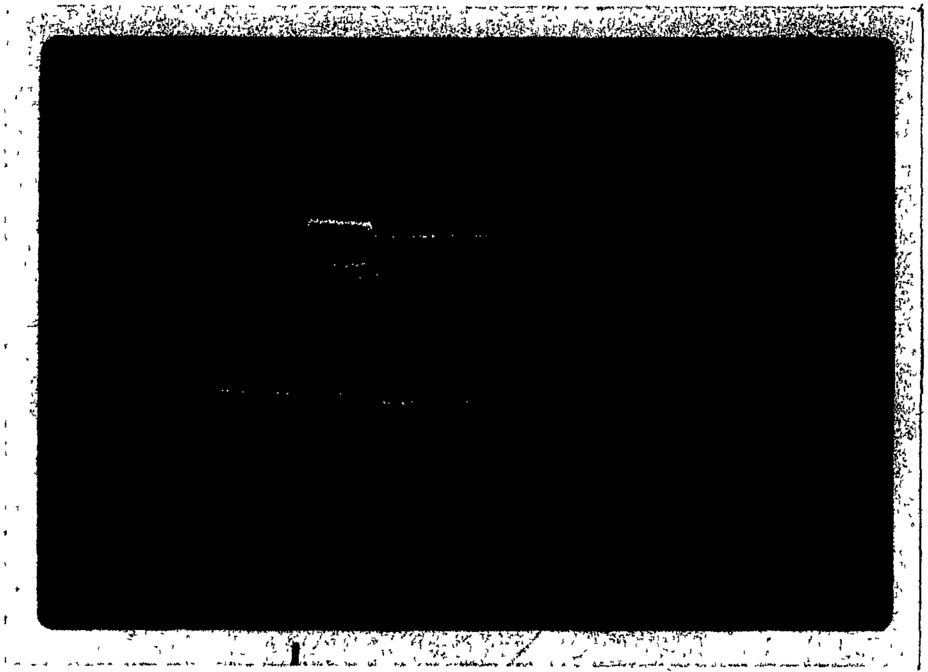

Fig. 6 *Kurer tap and its modification.*

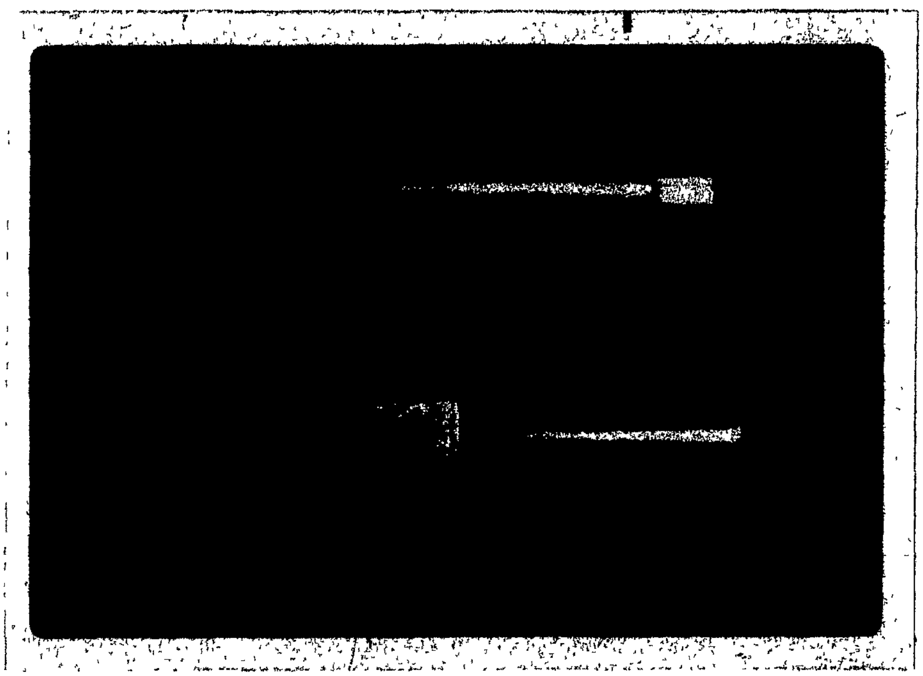

Fig. 7 *Dentatus wrench and its modification.*

The range of the torque wrench is from 0 to 100 ounce inches (Ozf in). It is adjustable by increments of 2 ozf in of increasing or decreasing force.

The wrench was set at 24 ozf in to screw in each Dentatus post, or tap the thread for each Kurer post. In a previous laboratory study Calderón-Durney and Rosen[74] showed that 24 ozf in of torque produced actual root fracture. The torque was reduced by 4 ozf in for each consecutive sample of Dentatus post insertion or Kurer tapping procedure until 16 ozf in. It was subsequently reduced by 2 ozf in for each consecutive sample until 4 ozf in was reached.

Experiment No. 1 Dentatus Post Insertion

A sample of 160 upper lateral incisors were used for the insertion of Dentatus screw posts. They were divided into nine sample groups:

Sample No.	Sample size	Torque applied to insert Dentatus Post
1	20	24 ozf in
2	20	20 ozf in
3	15	16 ozf in
4	15	14 ozf in
5	15	12 ozf in
6	15	10 ozf in
7	20	8 ozf in
8	20	6 ozf in
9	20	4 ozf in

The No. 15 long Dentatus post was selected for this study because it approximated the size of the extra-small Kurer crown saver post. Both were considered suitable for upper lateral incisors. The matching No. 4 Dentatus reamer was used to finalize the preparation of the post space,avoiding any eccentric movement of the engine reamer while providing continuous cooling with water. Upon completion of the preparation, each canal was carefully cleaned by irrigating it with peroxide and saline.

The torque wrench was set at 24 ozf in for sample No. 1 to screw each post into its corresponding preparation within the root canal with a slow rotary motion. The torque was decreased to 20, 16, 14, 12, 10, 8, 6 and 4 ozf in for subsequent sample groups. The post was screwed to place as firmly as was possible with the torque selected for that sample.

Experiment No. 2: Kurer Post Insertion

The 150 upper lateral incisors, prepared for this experiment were divided into nine sample groups:

Sample No.	Sample size	Torque applied to tap threads
10	20	24 ozf in
11	20	20 ozf in
12	20	16 ozf in
13	15	14 ozf in
14	15	12 ozf in
15	15	10 ozf in
16	15	8 ozf in
17	15	6 ozf in
18	15	4 ozf in

The Kurer post selected for this experiment was No. 0 (Extra-small), which the manufacturer claims to have a diameter of 1.60 mm. The initial cleaning and shaping of the canal was achieved with hand instruments. Final preparation of the root canal was performed with an engine reamer that matched the diameter and length of the tapping device. The engine reamer was introduced into the root with slow rotary speed using water as an irrigant and coolant. The reaming extended to 5 mm from the apex. Each canal was carefully cleaned by irrigating it with peroxide and saline.

The tap included in the Kurer kit was used to cut the thread into the walls of the canal. The post space was moistened with water before the tip of the tap was introduced into it. The tap was rotated in a clockwise direction, 3/4 turn forwards, 3/4 turn backwards. This procedure was repeated until the length of the prepared root was threaded and 24 ozf in torque was reached for the first sample group. Subsequently, all the sample groups were tapped by decreasing the torque applied to 20, 16, 14, 12, 10, 8, 6, and 4 ozf in.

It was impossible to tap to the bottom of the prepared canal using torques of 4 ozf in. It was also impossible to reach the bottom of the prepared canal with the 6 ozf in torque unless the tap was cleaned of clogged debris. At 8 ozf in and above, it was possible to cut the threads in the canal without cleaning the tap and get the post to seat fully. All these procedures were accomplished with slow rotary motion.

After cleaning and drying the canal, the post was inserted with the Kurer screwdriver modified to be used with the torque wrench, set at 5 ozf in.

Embedding the teeth

Small cylindrical copper bands containing Buehler Castolite Resin* were prepared to embed each sample tooth immediately after the posts were inserted *(Fig. 8)*. The transparent resin material was allowed to set for more than six hours. The plastic cylinder containing the root was removed from the copper band and stored in a plastic container *(Fig. 9)*.

Fig. 8 *Teeth ready to be embedded in resin.*

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* Buehler Ltd., Evanston, Ill. 60204.

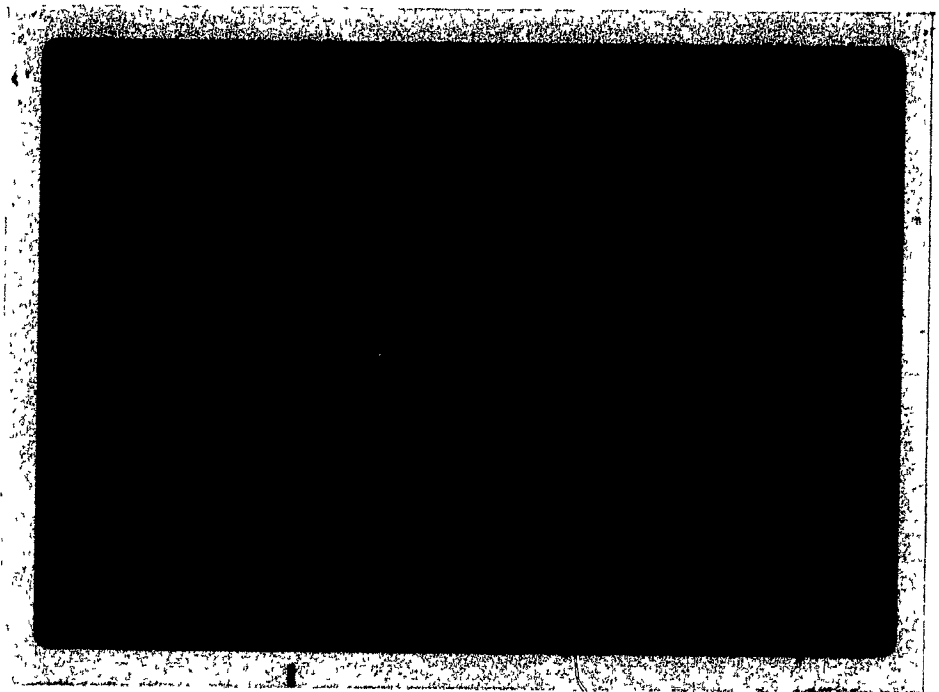

Fig. 9 Plastic cylinder containing the root removed from copper band.

Sectioning

Every cylinder block containing a tooth was cemented with cyanoacrylate* onto a plastic mounting plate of the Bronwill sectioning machine.** Four cylinder blocks were luted onto each mounting plate. The sectioning was done along the horizontal plane of the root at three different levels (cervical - α) (middle - β)-(apical third - γ) in order to observe any craze lines occurring at various levels of the root *(Fig. 10)*. Each one of these sections was approximately 1.5 mm thick. The thickness of each slide was determined by adjusting a

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* Krazy Glue Inc., Chicago Ill. 60634.

** Hamco Machine & Electronics. Model 503 Rochester, N.Y.

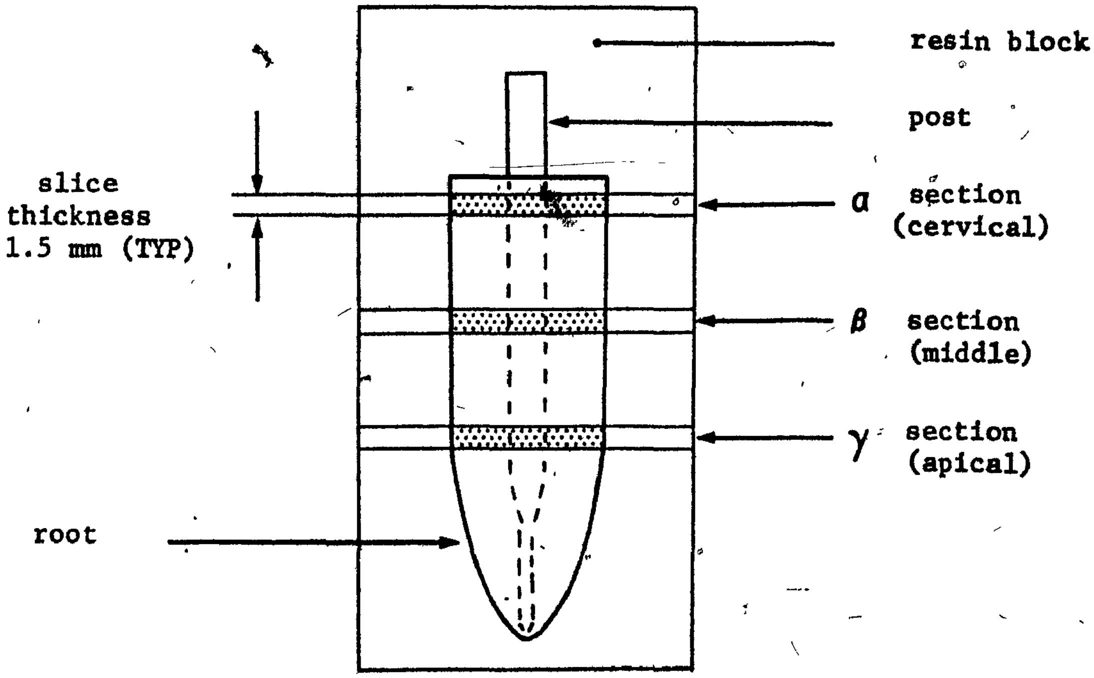

Fig. 10

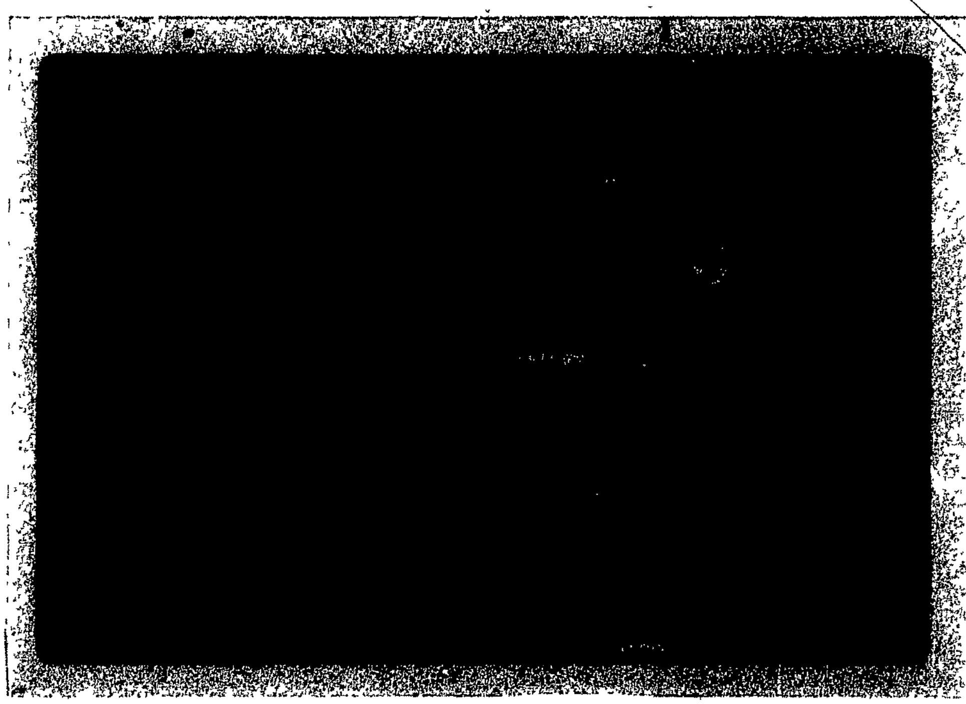

Fig. 11 Bronwill sectioning machine.

micrometer attached to the sectioning machine. The cutting was done under water coolant using a 320 grit diamond wheel of 200 μ width and 4 in diameter *(Fig. 11)*.

After each root was sectioned, the selected slides were identified by engraving the torque applied, the corresponding level (α, β, γ) and the number of the tooth in the sample group on the plastic surrounding the section *(Fig. 12)*. The slides corresponding to the three levels for each tooth were stored in a separate compartment of a plastic container.

A solution of zephiran chloride covered the sections to keep them moistened and to inhibit bacterial growth. Nine hundred and ninety sections were ultimately studied.

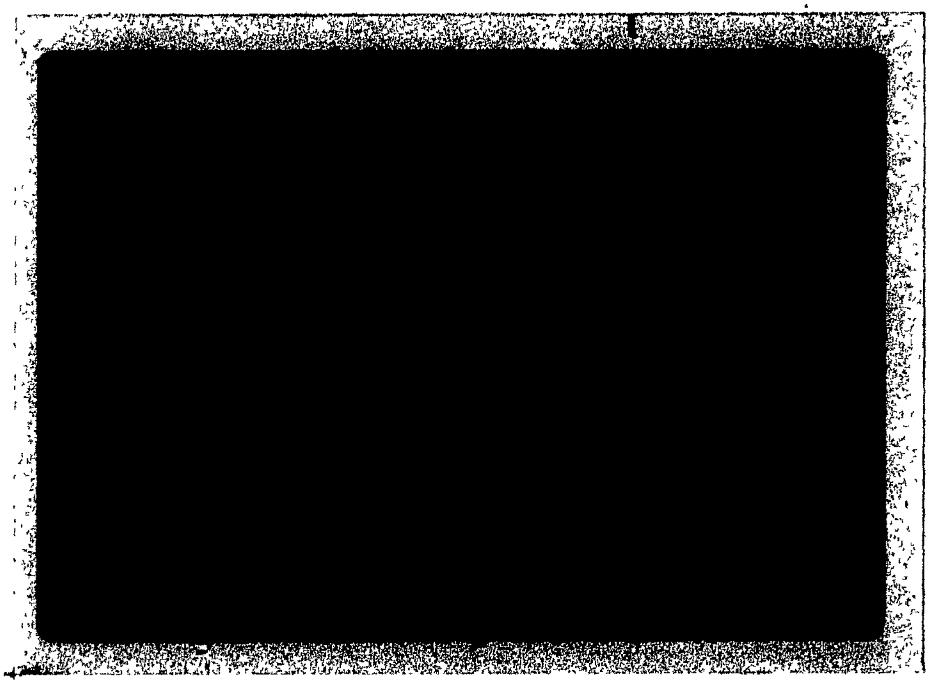

Fig. 12 *Section of one root.*

One group of 20 teeth, left as control without posts, was sectioned and stored in the same manner to be examined microscopically to determine whether the sectioning process could in itself produce fracture of the specimens.

Crack detection

Fluorescent dye materials have been used successfully by industry as a rapid and reliable means of detecting pores, cracks or craze lines in various manufactured articles.

Many substances absorb short-wave light, and re-emit this energy as light of longer wave lengths. This phenomenon is known as fluorescence. The emitted light which differs in colour from the exciting light may be separated from it by using filters. Many substances show marked fluorescence in their natural state. This is termed primary fluorescence and is found, for example, in teeth (green fluorescence). Other materials are not self-fluorescent but will take up fluorescent dyes (fluorochromes) and are said to exhibit secondary fluorescence. Fluorochromes have the advantage over normal dyes in that their effects may be rendered visible even when much smaller concentrations are employed. The fluorescent dye penetration into any minute flaw and its visual inspection under an ultraviolet light microscope, seemed to offer a satisfactory means of revealing discontinuities in the tooth structure which may escape notice under ordinary illumination.

The following dye penetrants were used originally in this study with no success to detect dentinal craze lines:

- Eosin-γ appeared to be a very weak dye, thus it was discarded.

- Fluorescein isothiocyanate: this dye produced a green fluorescence which was very difficult to distinguish from the natural fluorescence of the tooth structure.

After considerable preliminary experimentation, a satisfactory technique was developed using 1% w/v solution of Rhodamine 6G* (tetramethyl rhodamine isothiocyanate) which produces a bright orange fluorescence.[75]

Application of Fluorescent Dye

The sections were immersed twice in acetone to remove any particles of abrasive or debris adhering to the surfaces. Each section was immersed in the fluorescent dye for two minutes. Excess dye was removed from the surfaces of each section with a thin cloth and dry-mounted on standard microscope slides, without a cover-slip.

Fluorescence Microscopy and Photomicrography of teeth sections

The sections were examined under a Leitz Orthoplan microscope *(Fig. 13)* equipped with a Ploem modified incident illumination set-up. All of the work was performed at 25x or 75x to detect any possible dentinal craze lines. The light source was fitted with a 490 nm. steep cut-off interference filter as the primary exciting filter with a 525-530 nm. Schott orange glass secondary filter. The primary filter was supplemented with an identical 490 nm. interference filter set at 45^{o} and thus acted as a light selecting dichroic mirror.

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* Anachemia Chemical Industries. Toronto, Canada.

Reading of the teeth sections was performed with ease as the red to orange fluorescence of the fluorochrome, filling the cracks, contrasted well with the naturally occuring green autofluorescence of the teeth sections when excited at 490 nm. or blue-light fluorescence.

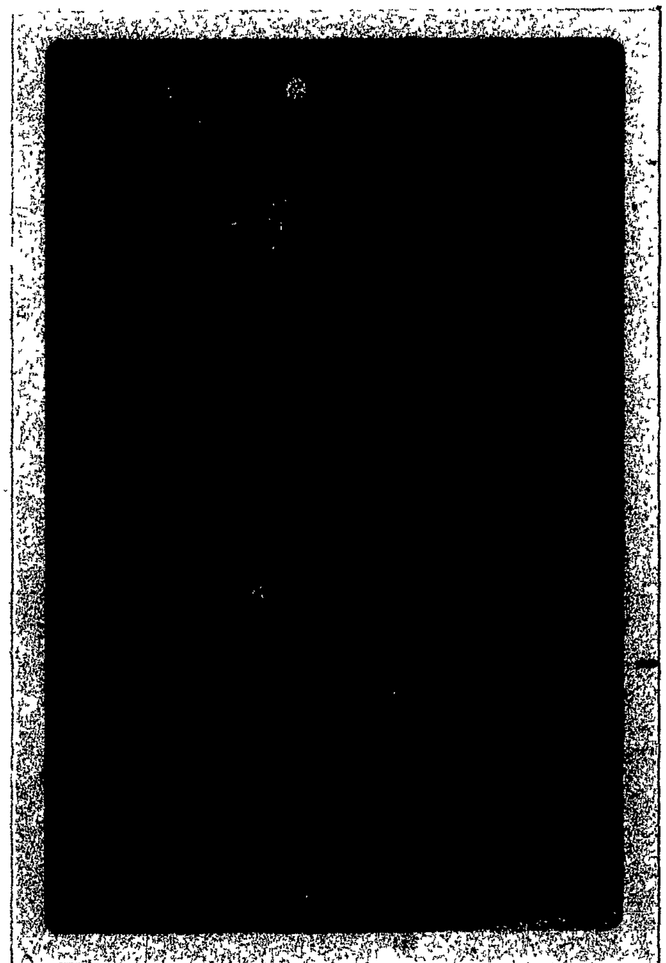

Fig. 13 *Leitz Orthoplan microscope.*

Photomicrography was performed using a 35 mm camera attached to the microscope, loaded with Ektachrome EHB 125 ASA color film.* The black and white photographs were obtained using a 35 mm camera attached to a binocular microscope** with high contrast Kodak panchromatic film (5069).*

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* Eastman Kodak Co., Rochester, N.Y. 14650

** Bausch and Lomb Co. Scarborough, Ontario, Canada.

RESULTS

The results of the experiment designed for the Dentatus posts are shown in samples 1 to 9.

SAMPLE 1

Torque Applied: 24 ozf in

Tooth No.	Sections α	β	γ
1	+	+	+
2	+	+	+
3	-	-	-
4	+	+	+
5	+	+	+
6	-	+	+
7	-	-	-
8	+	+	+
9	-	-	-
10	+	+	+
11	+	+	+
12	+	+	+
13	+	+	+
14	-	-	-
15	-	-	-
16	-	+	+
17	+	+	-
18	+	+	+
19	+	+	+
20	+	+	+

Sections Fractured:

α - 13

β - 15

γ - 14

Teeth Fractured: 15

SAMPLE 2

Torque Applied: 20 ozf in

Tooth No.	Sections α	β	γ
1	+	+	-
2	-	-	+
3	+	-	+
4	+	+	+
5	-	-	-
6	-	-	-
7	+	+	+
8	+	+	+
9	+	+	+
10	+	+	+
11	-	-	-
12	-	-	-
13	-	-	-
14	+	+	+
15	-	-	-
16	+	+	+
17	-	-	-
18	-	+	+
19	+	-	-
20	+	+	+

Sections Fractured:

α - 11

β - 10

γ - 11

Teeth Fractured: 13

+ denotes a crack

- no crack

DENTATUS

SAMPLE 3

Torque Applied: 16 ozf in

Tooth No.	α	β	γ
1	-	-	-
2	-	-	-
3	+	+	+
4	-	-	-
5	+	+	+
6	-	+	+
7	-	-	-
8	-	+	+
9	+	+	+
10	-	-	-
11	-	-	+
12	-	+	+
13	-	-	-
14	+	+	+
15	+	+	+

Sections Fractured:

α - 5

β - 8

γ - 9

Teeth Fractured: 9

SAMPLE 4

Torque Applied: 14 ozf in

Tooth No.	α	β	γ
1	+	+	+
2	+	+	+
3	-	-	-
4	-	-	-
5	-	-	-
6	+	+	+
7	-	-	+
8	-	-	-
9	-	-	-
10	-	-	-
11	+	+	+
12	-	-	-
13	+	+	+
14	+	+	+
15	+	+	+

Sections Fractured:

α - 7

β - 7

γ - 8

Teeth Fractured: 8

\+ denotes a crack

\- no crack

DENTATUS

SAMPLE 5

Torque Applied: 12 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	+	+	+
4	+	+	+
5	+	+	+
6	-	-	-
7	-	-	-
8	-	-	-
9	+	+	+
10	-	-	-
11	-	-	-
12	-	-	-
13	+	+	+
14	+	+	+
15	-	+	+

Sections Fractured:

α - 6

β - 7

γ - 7

Teeth Fractured: 7

SAMPLE 6

Torque Applied: 10 ozf in

Tooth No.	Sections α	β	γ
1	-	+	+
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	+	+	+
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-

Sections Fractured:

α - 1

β - 2

γ - 2

Teeth Fractured: 2

\+ denotes a crack

\- no crack

DENTATUS

SAMPLE 7

Torque Applied: 8 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	+	+	+
15	-	-	-
16	+	+	+
17	-	-	-
18	-	-	-
19	-	-	-
20	-	-	-

Sections Fractured:

α - 2

β - 2

γ - 2

Teeth Fractured: 2

SAMPLE 8

Torque Applied: 6 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-
16	-	-	-
17	-	-	-
18	-	-	-
19	-	-	-
20	-	-	-

Sections Fractured:

α - 0

β - 0

γ - 0

Teeth Fractured: 0

\+ denotes a crack

\- no crack

DENTATUS

SAMPLE 9

Torque Applied: 4 ozf in.

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-
16	-	-	-
17	-	-	-
18	-	-	-
19	-	-	-
20	-	-	-

Sections Fractured:

α - 0

β - 0

γ - 0

Teeth Fractured: 0

+ denotes a crack

- no crack

The results of the experiment designed for the Kurer posts are shown in samples 10 to 18.

SAMPLE 10

Torque Applied: 24 ozf in

Tooth No.	α	β	γ
1	+	-	+
2	-	-	+
3	-	-	-
4	+	+	+
5	-	-	-
6	-	-	-
7	+	+	+
8	+	+	+
9	+	+	+
10	+	+	+
11	+	+	+
12	+	+	+
13	-	-	-
14	-	-	-
15	-	-	-
16	-	-	-
17	-	-	+
18	-	-	-
19	-	-	-
20	+	+	+

Sections Fractured:

α - 9

β - 8

γ - 11

Teeth Fractured: 11

SAMPLE 11

Torque Applied: 20 ozf in

Tooth No.	α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	+	+	+
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	+	+	+
11	+	+	+
12	+	+	+
13	-	-	-
14	-	-	-
15	-	-	-
16	-	-	-
17	+	+	+
18	+	+	+
19	-	+	+
20	+	+	+

Sections Fractured:

α - 7

β - 8

γ - 8

Teeth Fractured: 8

+ denotes a crack

- no crack

KURER

SAMPLE 12

Torque Applied: 16 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	+	+	+
3	+	+	+
4	-	-	-
5	-	-	-
6	+	+	+
7	+	+	+
8	-	-	-
9	-	-	-
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	-	+	+
16	-	-	-
17	-	-	-
18	-	-	-
19	-	-	-
20	+	+	+

Sections Fractured:

α - 5

β - 6

γ - 6

Teeth Fractured: 6

SAMPLE 13

Torque Applied: 14 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	+	+
7	-	-	-
8	-	-	-
9	-	-	-
10	-	-	-
11	-	+	+
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-

Sections Fractured:

α - 0

β - 2

γ - 2

Teeth Fractured: 2

+ denotes a crack

- no crack

KURER

SAMPLE 14

Torque Applied: 12 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	+
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	-	-	-
11	-	+	+
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-

Sections Fractured:

α - 0

β - 1

γ - 2

Teeth Fractured: 2

SAMPLE 15

Torque Applied: 10 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	-	-
7	-	+	+
8	-	-	-
9	-	-	-
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-

Sections Fractured:

α - 0

β - 1

γ - 1

Teeth Fractured: 1

\+ denotes a crack

\- no crack

SAMPLE 16

Torque Applied: 8 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-

Sections Fractured:

α - 0

β - 0

γ - 0

Teeth Fractured: 0

SAMPLE 17

Torque Applied: 6 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-

Sections Fractured:

α - 0

β - 0

γ - 0

Teeth Fractured: 0

+ denotes a crack

- no crack

KURER

SAMPLE 18

Torque Applied: 4 ozf in

Tooth No.	Sections α	β	γ
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-
6	-	-	-
7	-	-	-
8	-	-	-
9	-	-	-
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	-	-	-

Sections Fractured:

α - 0

β - 0

γ - 0

Teeth Fractured: 0

\+ denotes a crack

\- no crack

SAMPLE 19

20 Control Teeth

No cracks detected after sectioning

TABLE 1

DATA SHEET

Torque ozf in	DENTATUS Sample size	DENTATUS Number of Fractured Teeth	DENTATUS Number of Fractured Sections α	β	γ	DENTATUS Total of Sections Fractured α+β+γ	KURER Sample size	KURER Number of Fractured Teeth	KURER Number of Fractured Sections α	β	γ	KURER Total of Sections Fractured α+β+γ
4	20	0	0	0	0	0	15	0	0	0	0	0
6	20	0	0	0	0	0	15	0	0	0	0	0
8	20	2	2	2	2	6	15	0	0	0	0	0
10	15	2	1	2	2	5	15	1	0	1	1	2
12	15	7	6	7	7	20	15	2	0	1	2	3
14	15	8	7	7	8	22	15	2	0	2	2	4
16	15	9	5	8	9	22	20	6	5	6	6	17
20	20	13	11	10	11	32	20	8	7	8	8	23
24	20	15	13	15	14	42	20	11	9	8	11	28

Total: 160 teeth (Dentatus)

Total: 150 teeth (Kurer)

TABLE 2

RESULTS

Torque ozf in	DENTATUS: Percentage of teeth Fractured	DENTATUS: Crack Distribution per tooth section (percentage of total sections fractured) α	β	γ		KURER: Percentage of teeth Fractured	KURER: Crack Distribution per tooth section (percentage of total sections fractured) α	β	γ	
4	0	0	0	0		0	0	0	0	
6	0	0	0	0		0	0	0	0	
8	10	33	33	33	100	0	0	0	0	
10	13	20	40	40	100	7	0	50	50	100
12	47	30	35	35	100	13	0	33	67	100
14	53	32	32	36	100	13	0	50	50	100
16	60	23	36	41	100	30	29	35	35	100
20	65	34	31	34	100	40	30	35	35	100
24	75	31	36	33	100	55	32	29	39	100

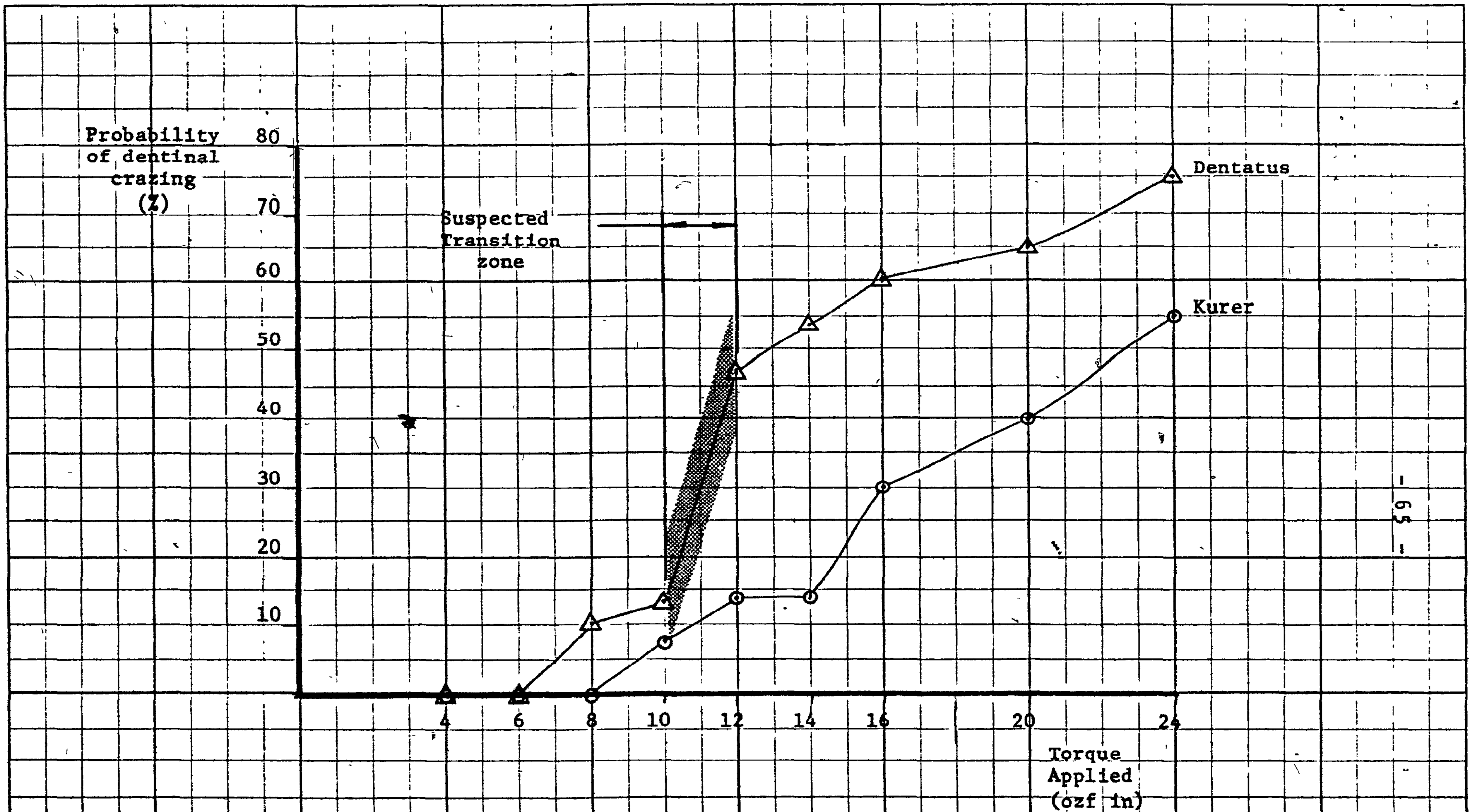

Fig. 14: Probability of dentinal crazing of Dentatus and Kurer Systems with different torques applied.

Description of the Test Results:

A) Dentatus: The general behavior of the Dentatus post was as follows:

1. Under 6 ozf in torque, no cracks were observed.
2. Between 6 ozf in and 10 ozf in torque, 13% of the teeth exhibit fractures.
3. At 12 ozf in torque, considerably more cracks were observed, about 3.5 times more than at 10 ozf in.
4. When increasing the torque from 12 ozf in, the percentage of cracked teeth increases linearly to 75% at 24 ozf in.

B) Kurer: The general behavior of the Kurer post was as follows:

1. Under 8 ozf in torque, no cracks were observed.
2. At torques higher than 8 ozf in, the percentage of cracked teeth found per sample increases approximately linearly with the torque applied to a maximum of 55% at 24 ozf in.

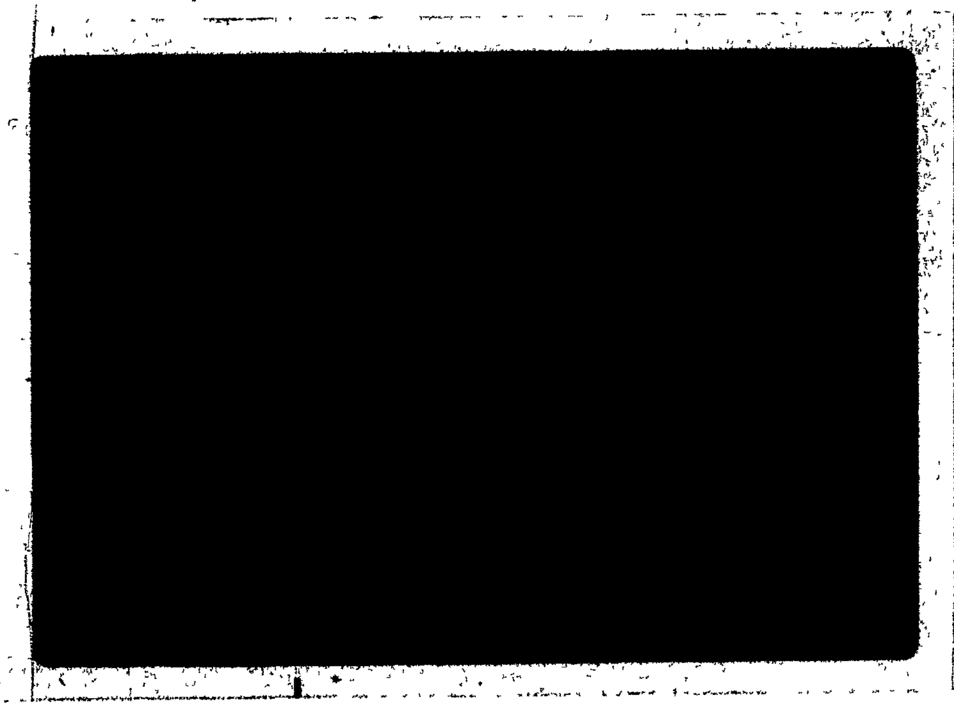

Fig. 15 Dentinal crack produced by Dentatus post X75 magnification.

Fig. 16 Dentinal crack produced by Dentatus post X75 magnification.

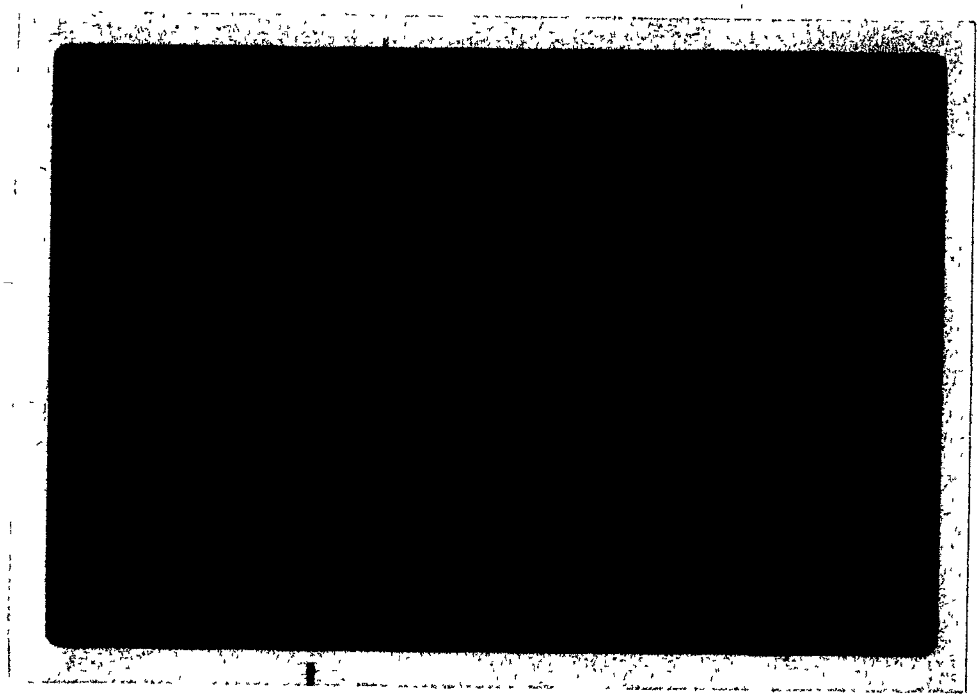

Fig. 17 Dentinal crack produced by Kurer tap
X75 magnification.

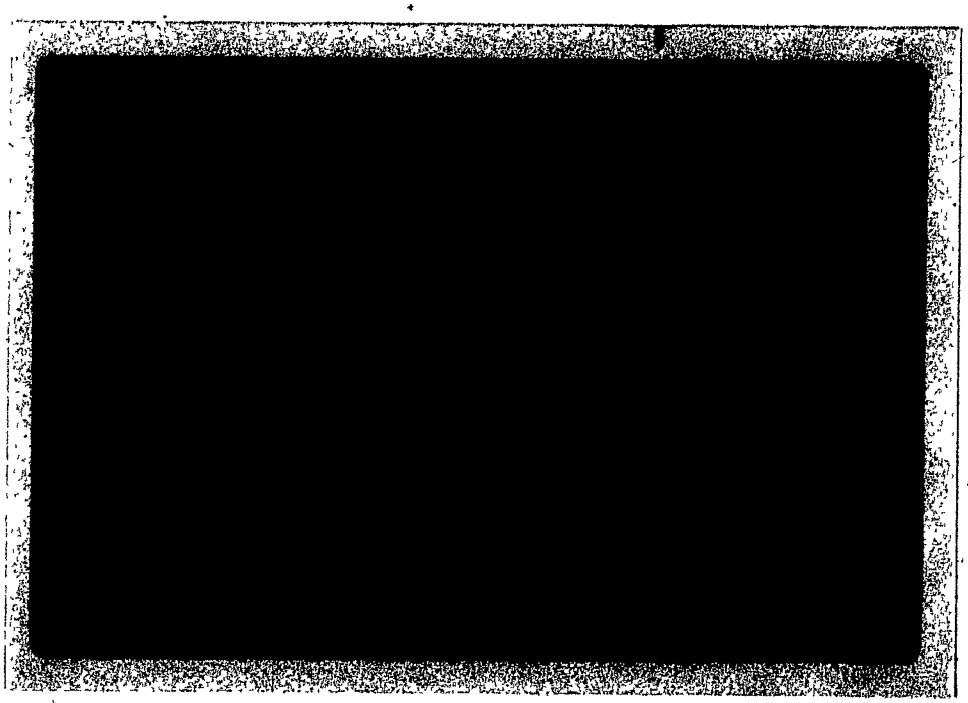

Fig. 18 Dentinal crack produced by Kurer tap
X75 magnification.

Fig. 19 and 20 Examples of completely fractured roots at high torques.

DISCUSSION

The significance of crazing of the dentin induced by the insertion of screw posts has never been determined previously, although failures in teeth restored with screw posts have been reported by dentists. Markley [76] stated that "craze lines may be a first indication of weakening of the tooth structure and that years later failure may occur". The mere insertion of a post may result in pre-stressing or crazing of the root dentin. Functional forces, when superimposed, may ultimately induce further crazing or total fracture. This may occur soon after, or years after the initial insertion of the post.

This study did not only corroborate the suspicions of many authors that such craze lines may indeed be introduced, but even revealed cracks of substantial size. It demonstrated also a relationship between the probability of dentinal cracks and the torque being applied during insertion of the screw posts.

The use of fluorescent dye to detect dentinal crazing and cracks was found to be extremely valuable, as was shown in similar studies done with pins by Dilts and co-workers[8] and Standlee and co-workers[9].

Comparison of both techniques

Most dentists routinely do not apply more than 6 ozf in of torque when manipulating Dentatus wrenches, and 8 ozf in torque when manipulating Kurer wrenches with finger pressure. Operator dexterity and clinical accessibility are obvious variables. A dentist with strong fingers can exert a torque of up to 20 ozf in with the Dentatus wrench and up to 24 ozf in with the Kurer wrench.

No cracks were observed at torques of 6 ozf in or less with the Dentatus system. Ten percent of the teeth demonstrated dentinal cracks at a torque of 8 ozf in. If the head of the post is not fully seated, it may induce the operator to exert more torque, increasing the probability of dentinal cracks.

No cracks were observed at torques of 8 ozf in or less with the Kurer system. Thirteen percent of the teeth demonstrated dentinal cracks at a torque of 12 ozf in.

Calderón-Durney and Rosen[74] reported that an average of 6.2 ozf in torque was required to cut the threads if the tap was cleaned after two turns, compared to 11.2 ozf in torque when the tap was removed to be cleaned. In this experiment, only 8 ozf in torque was required to cut the threads without cleaning the tap.

The mechanism of insertion of the Dentatus post could produce high stresses along the length of the root canal. This happens because the drilled hole is not tapped and the tapered post wedges against the inner root wall as it engages the dentin. Therefore, the probability of crack generation can exist at any point along the root canal.

The Kurer post, which possesses a flat seat and is the same diameter for its total length, produces an increasing stress distribution in an apical direction. These stresses are significantly lower than those produced by the Dentatus post. In the Kurer system, a tap cuts the dentin to form a thread for the post. The technique of thread tapping is regarded as technologically sound.[7] The upper portion of the tooth is submitted to more cutting than the lower portion (the top of the tooth is in contact with more cutting tool than the bottom). The tangential stresses on the wall of the root canal are higher than the tangential stresses on the outer surface of the tooth.[77] In the α, β, and γ slices, cracks which did not propagate fully, had their starting point at the inner wall of the root canal. Lame's equation and the maximum shear theory of failure[77] states that, when cylinders are submitted to internal expansion pressure, the tangential stress of the inside surface is higher than that on the outside.

There is some suggestion (Table 2) that there is a greater probability of crack initiation near the apical end of the root for both systems. Lame's equation on interference fits states that, on cylinders with the same inner diameter (root canal) the tangential stresses on the inner wall increase as the outer diameter (conical profile of the tooth) decreases. This equation explains the greater probability of crack generation near the apex of the tooth.

Failures with screw post systems are due to overmanipulation. To avoid such a problem in clinical use, the manufacturer should provide a wrench with a clutch which disengages at torques above 6 ozf in for the Dentatus system and 8 ozf in for the Kurer system. Dentists should also be instructed to turn Dentatus posts slowly and delicately without leverage and, if they bind, to enlarge the post hole by reintroducing the reamer or drill. In the Kurer system, the tapping procedure is critical in minimizing the hazards of root fracture. The tap should be withdrawn and cleaned as soon as resistance to further tapping is encountered.

The graph plotted for the Dentatus system *(Fig. 14)* demonstrates a marked transition zone from 10 ozf in to 12 ozf in of torque, in which the probability of crazing increases very rapidly until it reaches a less steep and more stable slope. A similar phenomenon is barely suggested by the Kurer system from 14 ozf in to 16 ozf in torque. The transition zone is probably related to the first stage of engagement of the Dentatus post into the prepared canal. The highest point of the transition zone may indicate an almost fully engaged condition. A similar situation (transition zone) would be less obvious with the Kurer system *(Fig. 14)* since the threads are already pre-cut. The disparities could also be explained by the difference in the shape of the posts. This corroborates the results of a study by Chan and Svare[42] where the dentinal crazing ability of retention pins and machinist's taps were compared. Fifty-four percent of the retention pins produced dentinal crazing whereas only twenty percent of the taps produced crazing.

Screw-posts should be used only for canals that are narrow and not too tapering. Such canals should be round or almost round in cross section. The remaining root dentin should be thick and a well-designed crown restoration should brace the root.

CONCLUSIONS

Based on the findings of this study, the following conclusions can be made:

1) Dentinal crazing or microscopic fracture can be observed as a function of the torque applied with the Dentatus screw post and the Kurer crown saver system in roots that do not demonstrate fracture when examined with the naked eye.

2) There is a considerably higher probability of dentinal crazing with the Dentatus screw post system than with the Kurer crown saver system.

3) The probability of dentinal crazing at torques of 6 ozf in or less is extremely small, if not negligible, with the Dentatus system. The torque required to seat Dentatus posts ranges from 4 to 6 ozf in.

4) The probability of dentinal crazing at torques of 8 ozf in or less is extremely small, if not negligible, with the Kurer crown saver system. The torque required to cut the threads with Kurer tap is 8 ozf in if the tap is not cleaned periodically during tapping, and 6 ozf in if it is.

5) Both systems are relatively safe when care is exercised. The dentist must determine for each case whether the additional retention provided by a screw post system justifies the risk of possible root fracture.

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