EFFECT OF THE FERRULE ON FRACTURE RESISTANCE OF TEETH RESTORED WITH PREFABRICATED POSTS AND COMPOSITE CORES

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A minithesis submitted in partial fulfilment of the requirements for the degree of M Sc (Dent) Cons Dent in the department of Conservative Dentistry, Faculty of Dentistry, University of the Western Cape

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Key Words:

Endodontically treated teeth

Fracture resistance

Preformed Post

Composite core

Ferrule design

Ferrule effect

Ferrule length

Shoulder

Bevel

Contra-bevel

ABSTRACT

EFFECT OF THE FERRULE DESIGN ON FRACTURE RESISTANCE OF TEETH RESTORED WITH PREFABRICATED POSTS AND COMPOSITE CORES

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The treatment objectives in the restoration of an endodontically treated tooth are maximum retention of post and core and to create a design in which the tooth is preserved when the restoration fails.

The ferrule effect in root treated teeth requiring cast post and core has been studied extensively and has been shown to greatly improve fracture resistance (Gluskin et al 1995, Libman & Nicholls, 1995. Hemmings et al, 1991. Barkhordar et al, 1989. Rosen & Partida-Rivera, 1986). Studies have also shown that in the case of cast post and core, the longer the ferrule, the greater the fracture resistance (Libman and Nicholls, 1995).

The use of the new bonding agents, composite resin cements and core materials, have led to a more conservative approach to post and core restorations.

However few studies have considered the effect of different ferrule designs on prefabricated post and composite core systems (Volwiler et al 1989, Al Hazaimeh and Gutteridge 2001). There is little information as to whether the ferrule is of additional value in providing reinforcement in these restorations.

This study investigated the effects of different ferrule designs on the fracture resistance of teeth incorporating prefabricated posts and composite cores. In addition teeth restored with a composite core but with no prefabricated post were included in the study to assess the necessity of a post in the restoration of endodontically treated teeth.

Sixty extracted maxillary incisors (centrals and laterals) and canines were randomly assigned into three groups and restored. Two groups had a prefabricated post and composite core with varying ferrule designs. A third group had a core with composite packed into the root canal but no post. All teeth were restored with cast crowns to simulate the clinical situation. A Zwick universal testing machine was used to apply compressive loads progressively on the restored teeth until failure occurred as a result of either root, tooth or post fracture. Failure loads, modes of fracture, post and core systems and tooth preparation were recorded and statistically analysed.

The results showed no significant difference in the amount of force needed to break the teeth in the different groups irrespective of whether the teeth had a ferrule or not. They also showed no significant difference in the amount of force needed to break the teeth in the different groups irrespective of whether the teeth had a post or not.

DECLARATION

I,………………………………………………………

(A.Kutesa-Mutebi)

declare that this minithesis entitled

Effect of the ferrule design on fracture resistance of teeth restored with prefabricated posts and composite cores

is my own work it has never been submitted before for any degree or examination in any other University and that all sources I have quoted have been indicated and acknowledged by means of references.

Signed……………………………………………

DEDICATION

This minithesis is dedicated

to my father, Hannington, husband, Joseph, and

my son, Jacob for their love, encouragement and support throughout

ACKNOWLEDGEMENTS

I wish to acknowledge my sincere gratitude to the following individuals for their assistance in this research project.

- Prof Y.I. Osman for guidance and assistance in making this study possible
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CONTENTS

CHAPTER ONE

1. INTRODUCTION

There are a number of treatment options for the management of endodontically treated teeth and these include; cast posts and cores, coronal-radicular core build-ups, pin-retained core build-ups and prefabricated posts and cores (Shillingburg, 1997). The use of prefabricated posts with amalgam, composite resin or reinforced glass ionomer core build-ups has become very popular (Christensen, 1998). This is due to the reduced chair time and ease of manipulation for the clinician compared to cast posts and cores, and the reduced costs and visits to the patients.

Successful restoration of endodontically treated teeth requires, an effective coronal seal, protection of the remaining tooth structure, and the restoration of function and aesthetics. Factors that may affect the success of this treatment have been studied, amongst, which is crown design (Aquaviva & Gauri, 2001). The design of the final restoration has been considered to have an effect on the prognosis of the restored tooth. Laboratory constructed crowns have been shown to alter the distribution of forces to the roots and provide a bracing or casing action to the tooth. This bracing action has been referred to as the ferrule (Desort, 1983).

A ferrule has been defined as a metal ring or cap intended for strengthening the end of a stick or tube (Pollard & Liebeck, 1994). The word has been thought to originate from combining the Latin for iron (ferrum) and bracelets (viriola) (Stankiewicz & Wilson, 2002). The dental ferrule has been defined by Libman & Nicholls (1995) as a metal band or ring used to fit around the root or crown of a tooth. The ferrule or encircling band of cast metal around the coronal surface has been suggested to reinforce the coronal aspect of the dowel preparation and acts as an antirotatory device (DeSort, 1983).

However, various forms of ferrule designs have been used in laboratory studies and these include, a contrabevel around the occlusal surface of the preparation (Sorensen and Engelman, 1990), and parallel walls of the preparation above the finish line (Libman and Nicholls, 1995).

However, most of the studies investigating the ferrule effect have used cast posts and cores, few studies have considered a ferrule effect or design on prefabricated posts and composite core systems (Volwiler et al 1989, Milot & Stein 1992, Al Hazaimeh & Gutteridge 2001). There is little information as to whether the ferrule effect and design are of any additional value in providing reinforcement in these restorations. Al Hazaimeh and Gutteridge (2001) in an in-vitro study found the addition of a ferrule preparation for prefabricated posts and composite core systems did not add any benefits in terms of fracture resistance.

1.1 AIM:

The aim of this study was to investigate the effects of different ferrule designs on the fracture resistance of teeth incorporating prefabricated posts and composite cores. In addition the teeth would be compared to teeth incorporating a composite core without any post.

1.2 HYPOTHESIS:

1. There is no significant difference in fracture resistance of endodontically treated teeth with or without the ferrule when using prefabricated posts and composite cores.
2. In teeth with at least 2mm of remaining coronal dentinal walls for a ferrule effect, there is no difference in fracture resistance when these teeth are restored with or without a post

1.3 OBJECTIVES:

- Measure the fracture resistance of endodontically treated teeth restored with prefabricated posts and composite cores incorporating different ferrule designs
- Determine the importance of the ferrule on prefabricated post and composite cores
- Determine the importance of the ferrule on teeth that are not restored with a post and core.

1.4 CLINICAL RELEVANCY:

There is a shift in clinical practice towards restoring endodontically treated teeth with prefabricated posts and composite cores to cut down on costs and treatment time (Christensen, 1998). If however, the incorporation of a ferrule into the design will increase fracture resistance of these restored teeth it will make this treatment modality for the restoration of endodontically treated teeth even more attractive for the clinician and the patient.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 INTRODUCTION

The endodontic literature contains repeated references to the widely held clinical perception that endodontic treatment weakens teeth resulting in increased brittleness (Rosen and Partida-Rivera 1986, Aquaviva and Gauri 2001). This results in an increase in the likelihood of fracture of the treated tooth during function. The weakened state has been attributed to loss of tooth structure following trauma, caries, endodontic access, decreased moisture content and instrumentation (Rosen and Partida-Rivera 1986). However other researchers have come up with contradictory findings. Sedgley and Messer (1992) found that the biomechanical properties of endodontically treated teeth and their vital contra-lateral pairs were similar. Papa et al (1994) showed that the moisture content of endodontically treated teeth compared to their vital contra-lateral teeth was comparable. Ross (1980) carried out a cross-section study on endodontically treated teeth, treated five years and more before the study and found that the teeth were functional with no evidence of fracture whether an internal device had been used or not.

2.2 RESTORATION OF ENDODONTICALLY TREATED TEETH

Posts are advocated to retain the cores that replace the lost coronal tooth structure in the restoration of endodontically treated teeth with extensive tooth destruction (Shillingburg et al, 1997). There are two main categories of post systems exhibiting different design characteristics, the custom cast post reproduces the morphology of the post space, and the standardised prefabricated post which offers a round cross section. The treatment objectives in the selection of a post system are maximum retention of the post and core, and the creation of a design, which preserves the tooth when the restoration fails.

Aquaviva and Gauri (2001) reviewed factors that influence the successful restoration of an endodontically treated tooth amongst which were post length, surface configuration, post diameter, post design, core material, and amount of remaining dentine. Studies (Colley et al. 1968, Standlee et al. 1978) have shown that for maximum retention, a post should be parallel, serrated or threaded with sufficient length. Tapered posts have been found to produce high stress concentrations when cemented and loaded, and are therefore more prone to tooth fracture when compared to parallel sided posts (Sorensen and Engelman 1990B, Aquaviva and Gauri 2001). The fractures have been attributed to the wedging effect that the tapered post exerts on the root.

Many varieties of prefabricated posts have been developed, to be used with direct restorative materials. Both in-vitro, and clinical studies have shown that these systems perform as well as or even better than the cast post and core (Tjan & Whang. 1983, Sorensen & Martinoff. 1984, Milot & Stein 1992). When a prefabricated post is used, the coronal section is fabricated intraorally. Core build-up materials for the coronal section are usually amalgam, composite resin or reinforced glass ionomer (Shillingburg et al, 1997).

Composite resin cores have gained popularity and this can be attributed to bonding strength, ease of manipulation and rapid setting time, which allows for immediate preparation after post placement (Jacobs, 2002). With the advent of dentin bonding agents, composite resins also offer the advantage of being adherent to tooth structure (Jacobs, 2002). The bonding agents have led to a more conservative approach to post and core restorations. Adhesive materials and techniques are used for intra-radicular reinforcement of teeth with thin roots. The internal dimension of the remaining root structure is reinforced with a resin bonded to dentin (Lui 1994). The composite resin increases the diametral thickness of the root; it also reduces the likelihood that the metal post will show through a thin root wall to darken the overlying gingival tissues (Stewardson 2001). Composite resin cement and core materials have been shown to be particularly suited when restoring compromised roots by increasing their fracture resistance. Saupe et al (1996) found that when root and dentinal support are compromised, the luminex resin reinforced dowel system could offer up to 50% more resistance to fracture than a conventional morphologic cast post and core. They concluded that the use of this system and post adhesion with resin cements could eliminate the requirement of a ferrule in these roots.

2.3 THE FERRULE

The restoration of teeth with no remaining coronal structure is costly and the risk of failure is high. Sorensen and Engelman (1990A) reported the importance of maintaining parallel walls of dentine coronal to the shoulder of the preparation to increase the tooth's strength. They recommended surgical crown lengthening or orthodontic extrusion when existing clinical crown height did not permit the placement of a crown over coronal dentinal walls.

They suggested that this "ferrule effect" be defined by a 360-degree metal crown collar surrounding parallel walls of dentine and extending coronal to the shoulder of the preparation. Libman and Nicholls (1995) defined it as a metal band or ring used to fit the root or crown of a tooth. Libman and Nicholls (1995) suggested that to achieve the full benefits of the ferrule effect it should be a minimum of 1.5 mm in height and have parallel dentine walls, totally encircle the tooth, end on sound tooth structure and avoid invasion of the attachment apparatus of the tooth.

2.4 IMPORTANCE OF THE FERRULE

The ferrule effect on endodontically treated teeth requiring cast posts and cores, has been shown to greatly improve fracture resistance (Gluskin et al, 1995. Libman & Nicholls, 1995. Hemmings et al, 1991. Barkhordar et al, 1989. Rosen & Partida-Rivera,1986). In addition Libman & Nicholls (1995) also showed that the longer the ferrule the greater the fracture resistance.

Loney et al (1990) studied the effects of the metal collar on stress distribution with cast posts and cores using photo elastic models and found that the collar had a significant effect on stress distribution. They suggested that the ferrule may help to unite different portions of the tooth. It has also been suggested to act as an antirotatory device (DeSort, 1983).

It has been proposed that the use of a ferrule as part of the core or laboratory manufactured crown may be of benefit in reinforcing root-filled teeth. A protective, or ferrule effect occurs due to the ferrule resisting stresses such as functional lever forces, wedging effect of tapered posts, and the lateral forces exerted during the post insertion (Gluskin et al 1995, Sorensen & Engelman 1990). It also maintains the integrity of the cement seal.

2.5 REVIEW ON FERRULE DESIGNS

Ferrule designs vary greatly. There is no standard preparation design for the ferrule in the literature. The ferrule can either be on the core or the crown, every investigator has used their own design. Some of the designs mentioned in the literature are;

Libman and Nicholls (1995) considered the ferrule as tooth structure at different heights apical to the core.

Saupe et al (1996) and Gluskin et al (1996) used a 2.0 mm ferruled collar with a 3 degree taper on the root wall. Barkhordar et al (1989) used a 2.0 mm collar preparation with approximately 3 degrees of taper with a total of 6 degrees of convergence.

Rosen and Partida-Rivera (1985) used a 2.0mm ferrule collar with an angle of convergence of 6 degrees and a short bevel apical to the shoulder. Milot and Stein

(1992) used a 1.0 mm circumferential bevel apical to the shoulder. Hemmings et al (1991) used a 45-degree bevel at the periphery of the root face.

Sorensen and Engelman (1990) investigated different ferrule designs using a cast post and core system and concluded that 1mm of coronal tooth structure above the crown margin increased fracture resistance whereas a contra-bevel at either the tooth-core junction or the crown margin was ineffective.

2.6 REVIEW OF STUDIES ON FRACTURE RESISTANCE AND THE FERRULE EFFECT

Barkhodar et al (1989), used twenty maxillary central incisors restored with cast posts and cores to compare the effect of a metal collar on the fracture resistance of these teeth. Teeth with the metal collar required a higher force to fail compared to the ones without the collar.

Saupe et al (1996) used forty maxillary central incisors to compare the fracture resistance of structurally compromised roots restored with either the cast post and core system or the prefabricated post and composite core system. They had four groups in which each post system had a ferruled and an unferruled group. All the posts were cemented using a resin cement. Their results showed no statistically significant difference in fracture resistance between the two post systems nor in the groups with or without a ferrule. They attributed their results to the use of a resin reinforced system which was used to cement the posts as all the posts were cemented with a resin cement.

Al Hazaimeh and Gutteridge (2001) used thirty five extracted central maxillary incisors to investigate the effect of the ferrule on fracture resistance of teeth incorporating prefabricated posts and composite cores. They had two groups of ten teeth, where one group had a ferrule and the control group had no ferrule. They found that the addition of a ferrule preparation did not add any benefits in terms of fracture resistance.

Milot and Stein (1992) used forty eight standardised plastic analogues to investigate the resistance to root fracture of endodontically treated teeth. They used both cast posts and prefabricated posts and composite cores with and without a ferrule. They found that the ferrule increased the resistance to fracture.

2.7 SUMMARY

Successful restoration of root treated teeth requires an effective coronal seal; protection of the remaining tooth structure and the restoration should be aesthetically pleasing. A post-retained crown may be indicated to fulfil these requirements. However, root treated teeth commonly fail due to root fracture. Therefore the crown and post design features that reduce the chance of root fracture would be advantageous. The ferrule effect with cast posts and cores has been found to reinforce root treated teeth and increase their resistance to fracture.
Advances in adhesive dental technology have led to improved and stronger bond strengths developed between the tooth structure and restorative materials. This has led to the increased use of prefabricated posts and composite cores. However, few

studies have considered a ferrule effect or design on prefabricated posts and composite core systems. There is little information as to whether the ferrule effect and design are of any additional value in providing reinforcement in these restorations.

CHAPTER THREE

3 RESEARCH DESIGN AND METHODOLOGY

3.1 <u>Ethical Statement:</u>

This study used only extracted teeth, which were collected from the UWC dental clinic, Guguletu clinic and Makerere dental clinic (Uganda). The teeth were extracted for reasons other than the study. At the end of the study the teeth would be disposed off according to the recommended guidelines for medical waste disposal of the faculty of Dentistry (University of the Western Cape).

3.2 <u>Study sample:</u>

Sixty extracted maxillary incisors (centrals & laterals) and canines were collected from the UWC dental clinic, Guguletu clinic and Makerere dental clinic (Uganda). Two extra teeth were added to the study sample to act as replacements in case a specimen was discarded during tooth preparation. Hard and soft deposits were removed with hand scaling instruments. The teeth were visibly inspected and only those with minimal caries were included in the study. Teeth with fractures or cracks were excluded. The teeth were stored in a thymol solution at room temperature to prevent bacterial growth during the entire time of the study.

3.3 **Endodontic preparation:**

Endodontic treatment was completed for all the teeth using the standardised technique. Each tooth was instrumented according to clinical guidelines in relation to its size. Access cavities were prepared in the conventional manner. Reamers were used to remove the pulp, and K-files were used to instrument the canals. The working length for each tooth was determined by inserting a No 15 K-file into the canal until it appeared at the apex of the root and the length was noted. One millimeter was then subtracted from this measurement to provide the working length. Each tooth was instrumented at this working length. The canals were instrumented two sizes beyond the first file that bound against the dentinal walls of the canal. During instrumentation, copious irrigation was performed with saline. The canals were dried with air and absorbent paper points. They were then obturated using gutta percha points by lateral condensation with the aid of a finger spreader. The technique used was to simulate the clinical situation as far as possible.

Tubliseal (De trey/ Dentsply) a root canal cement, which contains eugenol, was used as the sealer. The teeth were grouped according to the different tooth types that is; canines, central and lateral incisors. They were then numbered for identification and randomly assigned into three groups of twenty teeth each. The two extra teeth were assigned to group 1.

The teeth were stored in a thymol solution for a week until the cement had set. Using a Gates Glidden bur the gutta percha was removed from groups 1 and 2 leaving at least 4-5mm to create an apical seal. Teeth in group 3 had only 4mm of gutta percha removed from the coronal part of the canal.

3.4 **Tooth measurements:**

The coronal tooth structure was measured at points indicated using a pair of dividers (*Figure 1*). The measurements included the mesial-distal and bucco-lingual diameters, the remaining dentine width after post channel preparation, and the thinnest wall was also measured and recorded.

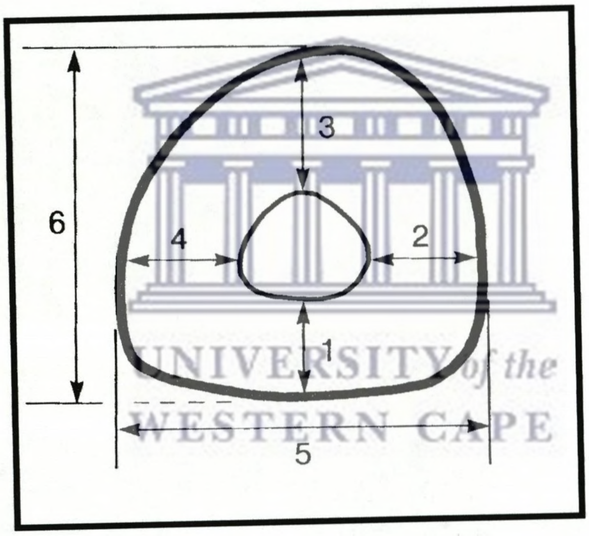


Figure 1, Occlusal view of tooth structure measurements

Key to measurements

- 1, 2, 3, & 4 represent measurements from the canal wall to the periphery of the root on the buccal, lingual, mesial and distal root surfaces
- 5 Mesial-distal diameter
- 6 buccal-lingual diameter

3.5 **Teeth groupings :**

The teeth were decoronated 2mm (proximal surface) above the cemento-enamel junction perpendicular to their long axis using a model trimmer with a continuous water coolant.

All teeth had a crown preparation with a 90^0 shoulder 0.5mm in width following the cemento-enamel junction to simulate the clinical situation. The shoulder margin was prepared using a conventional high-speed handpiece with a flat-ended fissure diamond bur.

The ferrule for groups 2 and 3 was prepared by marking off 1mm of the root apical to the root core junction and a contrabevel was prepared. It was prepared using a conventional hand-piece with a chamfer diamond bur.

Group 1: This group had twenty two decoronated teeth with prefabricated posts. They had a 90° shoulder and a 2mm coronal dentinal extension on the proximal surface. A butt joint configuration was prepared at the tooth core junction (fig 2).

Group 2: This group had twenty decoronated teeth with prefabricated posts. They had a 90° shoulder and a 2mm coronal dentinal extension. A 1mm wide contra-bevel was prepared at the tooth core junction (figure 3).

Group 3: This group had twenty decoronated teeth with no posts. They had a 90° shoulder and a 2mm coronal dentinal extension. A 1mm wide contra-bevel was prepared at the tooth core junction. The composite core extended 4 mm inside the root canal instead of a post (figure 4).

THE THREE TOOTH-CORE JUNCTION DESIGNS REPRESENTED DIAGRAMATICALLY

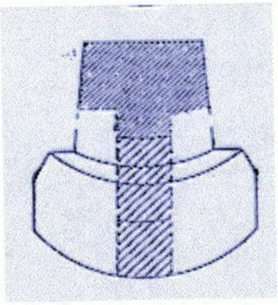


Figure 2,
Group 1, teeth with a post and a butt joint at the tooth-core junction

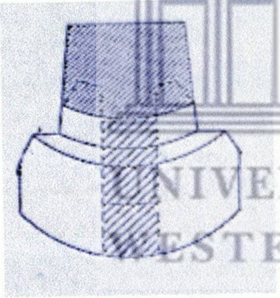


Figure 3,
Group 2, teeth with a post and a ferrule at the tooth -core junction

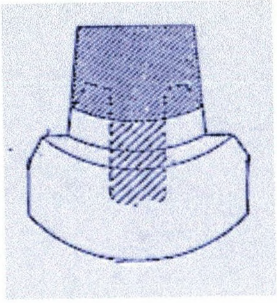


Figure 4,
Group 3, teeth with no post, but with a ferrule at the tooth-core junction

3.6 Post-space preparation:

Post channels were prepared following clinical guidelines adopted in the UWC crown and bridge clinics (figure 5). The length of the post to be used was first determined and prepared with gates glidden burs. The width of the post space was prepared using the parapost system (Coltene/Whaledent Inc, USA); a drill that fits snugly after removal of gutta percha was used for the preparation of the channel for each tooth under constant irrigation with saline in a conventional slow speed handpiece. A new parapost drill was used for each group of five specimens. All teeth in groups 1 and 2 had at least 4mm of remaining gutta percha apically except teeth in group 3 which had much more gutta percha remaining. An anti-rotational notch measuring at least 1.0mm occluso-apically and 1.0mm bucco-lingually was placed at the greatest bulk of dentine for all the posts and core systems.

Figure 5, decoronated teeth after post channel preparation

3.7 Post cementation:

The canals were irrigated with water and dried with paper points and compressed air. Preformed titanium paraposts (Coltene/Whaledent Inc, USA) were fitted that matched the last drill size, which was used to prepare the post space. The posts were cemented with an acid modified resin cement Dyract Cem (Caulk/ Dentsply), a dual-cure acid modified resin crown and bridge cement. It was mixed and used according to the manufacturer's instructions. The cement was spun down the channels using a spiral paste filler (Lentulo, Dentsply) with some cement placed on the post and the post firmly seated with finger pressure until the cement had set.

3.8 Core build-up:

All the cores were prepared freehand to a 7 mm height using a composite resin (TPH, Dentsply/ L.D. Caulk) for all the teeth. The width and diameter for each preparation varied according to the tooth diameter. The teeth were etched using 37% phosphoric acid gel for 15 seconds and then rinsed with water for 30 seconds. They were dried but not dessicated, a layer of prime and bond (TPH, Dentsply/ L.D. Caulk) (a dentine bonding system) was applied according to the manufacturers' instructions and cured for 10 seconds. The composite was inserted in layers of approximately 2 mm and light cured for 60 seconds after each increment using a visible light curing unit (Dentsply) from the buccal, lingual and occlusal aspects. In all cases the posts were completely covered by the core material.

3.9 Crown fabrication:

Metal copings were used and these were fabricated in the laboratory by two technicians. They were made using wax patterns directly moulded onto the teeth. The technicians used the dip wax technique to obtain an even axial thickness of the pattern of 0.5 mm and an overall height of 8mm. The wax patterns were sprued, removed, invested and cast in non-precious metal.

The copings were luted to the teeth with Dyract Cem (Dentsply, USA) mixed according to the manufacturers' instructions (Figure 6). They were seated using finger pressure with the excess cement being removed after complete setting of the cement.

Figure 6, sample of specimen cemented with a metal coping

Mounting procedure:

The teeth were embedded in individual autopolymerising acrylic resin blocks in a plastic tubing (Figure, 7). The plastic tubing used provided a flat surface and was shaped to fit into the retention device of the Instron testing machine. Care was taken to ensure that the long axis of the post channel was parallel to the side of the tube. This was achieved by using a specially fabricated instrument (Figures, 8-10). The roots were embedded to a level of 2mm below the cemento-enamel junction. This procedure was followed to simulate the natural biological width.

Figure 7, Plastic tubing

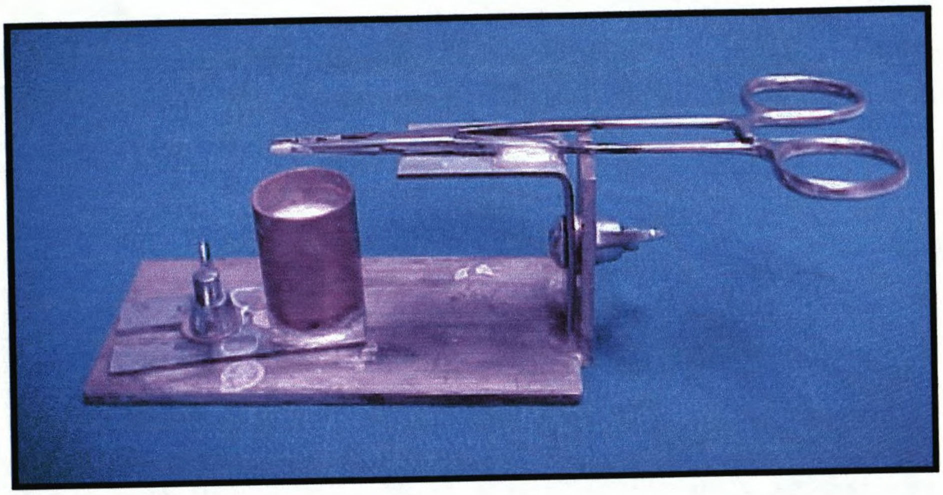


Figure 8, fabricated instrument used for mounting teeth in acrylic

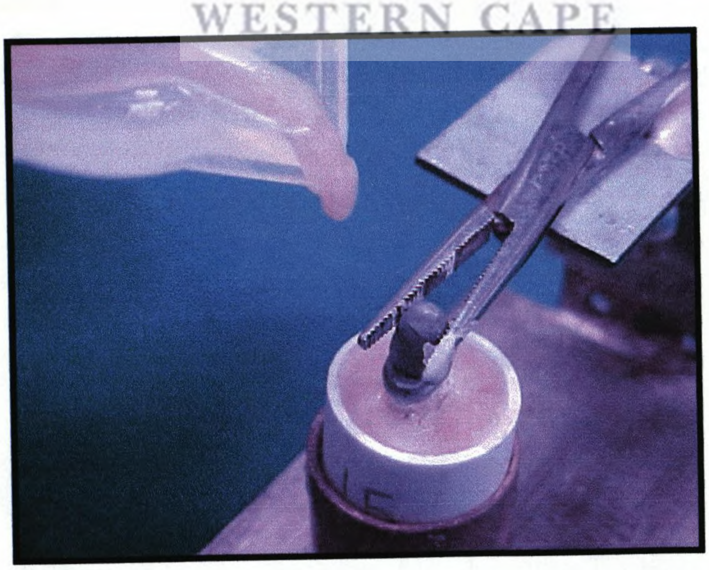


Figure 9, Tooth being mounted in acrylic

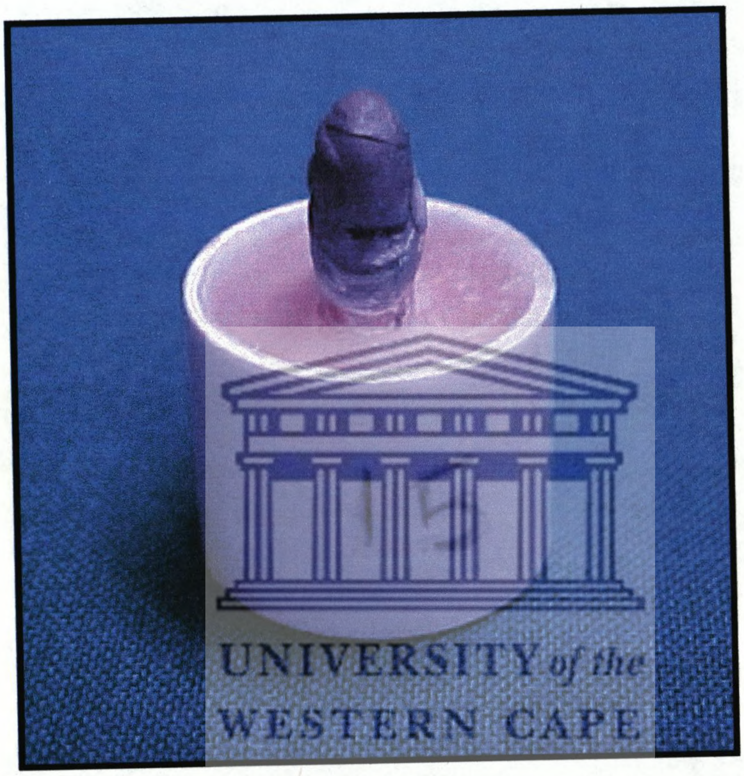


Figure 10, mounted specimen in plastic tubing

Testing procedure:

The Zwick testing instrument (Figure 11) model Zwick/Material prufung 1446, (zwick GmbH and Co., postf. 4350, D-7900u/m, Germany) was used to apply a compressive load progressively onto the teeth at a crosshead speed of 0.5millimeter per minute. The mounted specimens were fixed in a special device (Figure, 12), which ensured a loading angle of 135^0 to the long axis of the teeth. This angle was selected since it simulates the average angle of contact between maxillary and mandibular incisors in an Angle's class I occlusion and has been used by other investigators and reported in the literature previously (Barkordar et al 1989, Libman & Nicholls 1995, Saupe 1996). The force was directed from the lingual to the labial aspect on the coping. The coping had a notch made 2.5 mm from the cemento-enamel junction to receive the test load in an identical location for all specimens. These markings were made by a high-speed handpiece with a diamond bur. The magnitude of the load was continually recorded by the machine until failure occurred. The failure that occurred was recorded as either a result of root fracture, post fracture, or crown displacement (cement failure).

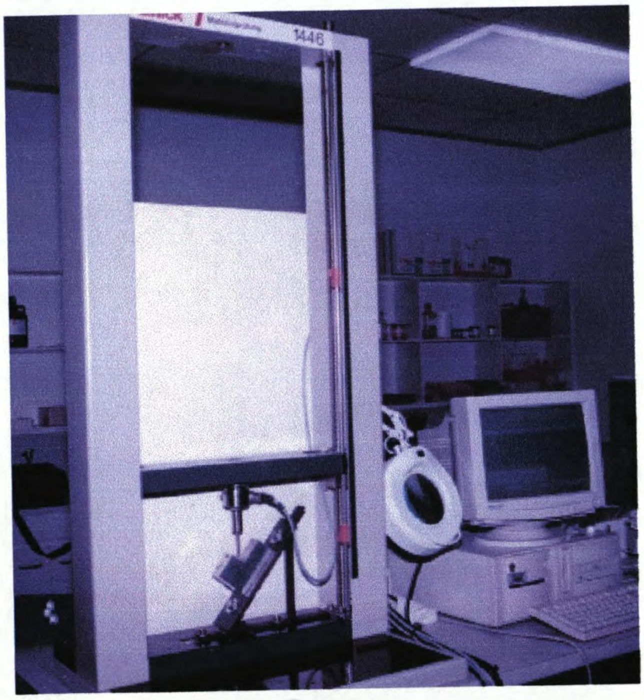


Figure 11, Zwick testing machine linked to a computer to record results

Fig 12, Specimen locked in a special device ready for testing

CHAPTER FOUR

4 RESULTS

Variables evaluated

The failure threshold was defined as the maximum load a sample could withstand until fracture. Failure loads, modes of failure, and tooth preparation (ferrule design) were recorded and statistically analysed for significant correlations between design and failure loads. The mesio-distal and bucco-lingual tooth dimensions and the remaining dentine width were also correlated with the fracture loads

Statistical analysis

Descriptive statistics including the mean, standard deviation, median and range were calculated for each of the 3 groups tested. The data was entered using the excel Microsoft programme. It was analysed using the SPSS system. The one-way analysis of variance (ANOVA) was used to determine whether the fracture resistance differed significantly among the three groups, and whether differences in the other variables were significant. The level of significance was predetermined at the $p<0.05$ level of confidence. The results of the force needed to fracture the teeth were recorded in newtons and are reflected in tables 4, 5 and 6 (Appendix 1, 2 & 3).

Samples discarded

Results from two specimens were discarded due to errors caused by the testing machine (Zwick machine). Two other specimens were discarded because of a mix-up of their markings in the laboratory by the technicians who made the metal copings for the teeth. Therefore eighteen specimens were evaluated for both groups 2 & 3. Group 1 had twenty two specimens.

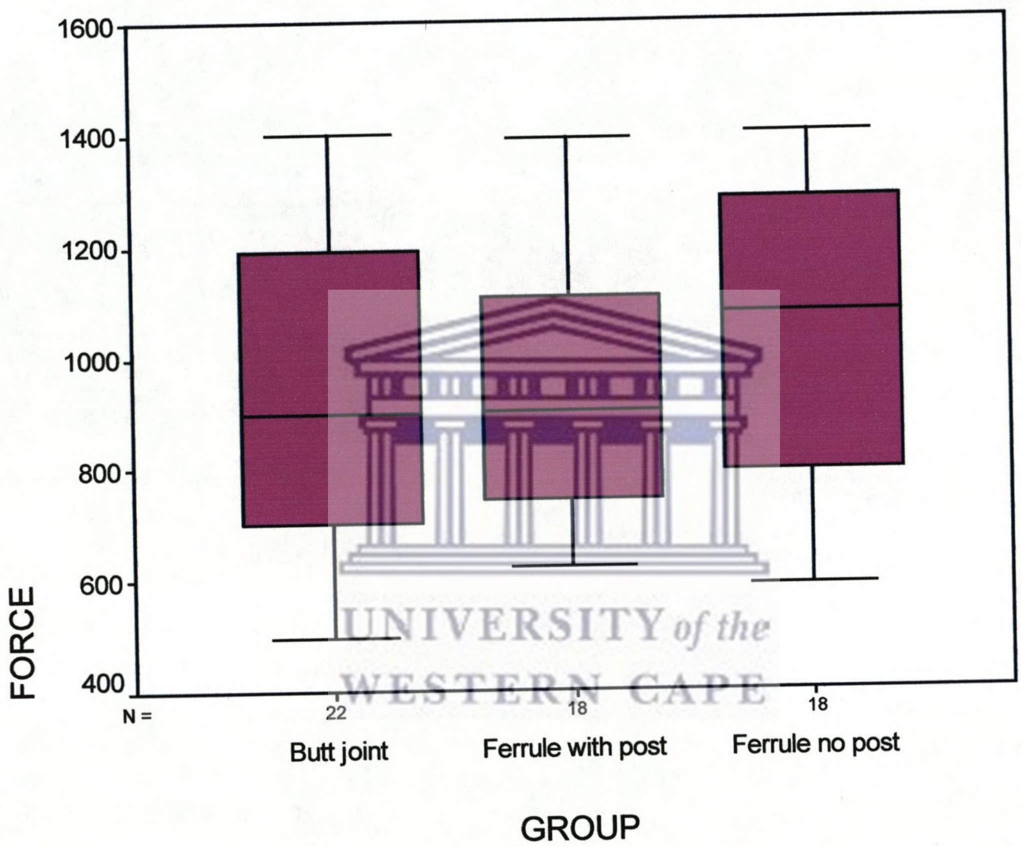
Mode of fracture

All the specimens failed by fracturing of the root except one sample, which failed by cement failure. The mode of fracture was either a vertical or horizontal fracture. However there was no statistical difference between the two types.

Table 1. Descriptive statistics in newtons comparing the mean force needed to break teeth in the different groups

Group	Mean	Numbers	Std	Median
Butt joint	931.3005	22	282.83492	899.0150
Ferrule with post	930.5489	18	241.90164	899.8800
Ferrule no post	1035.7461	18	268.76516	1075.3200
All teeth	963.4814	58	266.19414	909.4050

The analysis of variance (ANOVA tables, appendix 5) showed that there was no significant difference amongst the three groups as regards fracture resistance, although teeth in group 3 required a much higher mean force (1036N, std ±269) to fracture as compared to teeth in the other two groups. Group 1 required a mean force of (931N, std ±283) and group 2 required a mean force of (931N, Std ±242) as presented in table 1. These results are also shown in a bar graph form in figure 12.



(Figure 13) Graph showing the force needed to break teeth between the groups

The graph shows that the group with the butt joint (group 1) had the highest distribution. The group with the ferrule with a post had the least distribution. The group with no post but with the ferrule (group 3) needed the greatest force to fracture.

Table 2. Descriptive statistics in newtons comparing the mean force needed to break the different tooth types within the groups.

Group	Centrals	Laterals	Canines
Butt joint	978.1990	770.8414	1062.1460
Ferrule with post	937.4567	892.8550	948.2700
Ferrule no post	985.1167	850.2133	1271.9083

The analysis of variance (ANOVA tables, appendix 8) showed a statistically significant ($p<0.011$) difference in the amount of force needed to break the different tooth types within group 3. Canines required 1272 N, Std ±269, centrals required 985 N, Std ±304 and laterals required the least force 850 N, Std ±139 as presented in table 2. The teeth in groups 1 and 2 showed no statistically significant difference (ANOVA tables, appendix 6 & 7), however, in all 3 groups canines required the highest amount of force to break irrespective of whether they had a post or not.

Table 3. Descriptive statistics in newtons comparing the mean force needed to break teeth with different thickness of remaining dentine

Dentine wall (mm)	Mean	Number	Std deviation	Median
1.0	858.6300	20	222.59824	819.1300
1.5	1055.5948	21	292.22161	1100.4300
2.0	973.0488	17	248.75283	908.2900
Total	963.4814	58	266.19414	909.4050

The analysis of variance (ANOVA tables, appendix 4) results indicated that there was a significant difference ($p<0.05$) in the amount of force required to break the teeth with differing amounts of the remaining dentinal wall. Teeth with 1.5mm and 2mm of remaining dentine required a higher force of 1056N, Std ±292 and 973N ±249 respectively to break compared to teeth that had 1.00mm or less of the remaining dentinal wall, which required 859N, Std ±223 as presented in table 6.

However an unexpected finding was that teeth with 1.5mm of remaining dentine needed a greater force to break than teeth with 2mm of remaining dentine.

CHAPTER FIVE

5 DISCUSSION

5.1 MATERIALS USED

A variety of solutions and chemicals have been used as storage media for extracted teeth amongst which are normal saline, distilled water, and thymol solution (Tjan & Whang 1985, Standlee et al 1978). Thymol solution has been used by many researchers (Al Hazaimeh & Gutteridge 2001) as a storage agent because of its antifungal activity. Thymol solution was used in this study since the teeth had to be stored for an extended period as collection of the specimens proceeded.

When selecting a root canal post, the smallest diameter post that fits the prepared canal accurately without excess removal of dentine should be chosen. In addition, the post must have sufficient rigidity and retention to resist occlusal forces. The Parapost system has a long record of clinical success (Sorensen, 1984) and has been known to represent the industry standard for prefabricated posts. It satisfies the general criteria of a good post system being parallel, serrated and vented (Standlee, 1978). It is the first choice with regard to the important properties of rigidity and retention. It has been found to have high retention values compared to cast posts (Torbjorner et al 1995). It was therefore used in this study for preparing the post channels and the prefabricated post used

Acid modified resin cement was chosen in the study because it has been shown to produce high and consistent retentive values. Passively cemented parallel sided posts are the most retentive with least stress transmitted to the root structure. Cementation with resin cement can enhance the retention of the parallel sided post and increase fracture resistance (Mendosa et al 1997). This may be due to the dentine bonding provided by these cements. In this study "Dyract Cem" was used to cement the posts. Composite resin was chosen as the core material in this study because composite cores have been found to have a higher fracture resistance as compared to amalgam and glass ionomer cores (Kovarik et al 1992, Tjan et al 1993). The requirements for a composite core build-up material are radiopacity, highly filled with glass filler for strength, pigmented to demarcate the extent of the core and easy to use (Christensen, 1998).

Aquaviva (2001) suggested that laboratory studies must have some degree of clinical correlation in order to be practically applicable. Therefore the teeth in this study were restored with laboratory made crowns so as to simulate the clinical situation as far as possible. However many in-vitro studies (Tjan & Whang 1985, Barkhodar et al 1989, Loney et al 1990) have used forces applied directly either to the post head or core. This has limited significance clinically because teeth with posts and cores are commonly restored with laboratory made crowns.

2mm was used in the study as the coronal dentine extension for all the groups because it has been recommended as the minimum length, which can compensate for the difficulties of intraoral tooth preparations (Stankiewicz & Wilson, 2002). It is also the minimum ferrule length necessary for long term clinical success of endodontically treated teeth. Although Libman & Nicholls (1995), found the minimum effective ferrule length to be 1.5mm of coronal dentine extending beyond the preparation margin.

5.2 FRACTURE RESISTANCE

- The results showed no significant difference in the amount of force needed to break the teeth in the different groups irrespective of whether the teeth had a ferrule or not.

- The results also showed no significant difference in the amount of force needed to break the teeth in the different groups irrespective of whether the teeth had a post or not.

Posts in some parts of the mouth are subjected to rotational forces. Anti rotational features are placed to counteract these forces. These features can be placed in tooth roots by slotting the most coronal internal position of the post channel or by placing pot hole channels or retentive pins in the dentin mesially and distally to the post channel. The most important anti rotatory feature for posts and cores is placement of a ferrule effect (Hemmings, 1991) circumferentially around the build-up and remaining root stump by extending the crown preparation margins at least 1-2 mm apically to the composite tooth structure interface.

In-vitro studies have shown that the ferrule effect significantly reduces the incidence of fracture in non-vital teeth by reinforcing the tooth at its external surface and redistributing applied forces (Loney, 1990).

However, this study showed no significant difference in the forces needed to break teeth with or without the ferrule. This finding is in agreement with the findings of Al-Hazaimeh & Gutteridge (2001) and Saupe et al (1996).

The study had a high mean failure load of the specimens in the ferruled group compared to the non ferruled group whereas other studies (Al-Hazaimeh & Gutteridge 2001, Saupe et al 1996) had a high mean failure load for the non ferruled group compared to the ferruled group.

The mean failure loads of the specimens in the study occurred at 931N for the non-ferruled group (group 1), and at 931N (group 2) and 1035N (group 3) for the ferruled groups (table 1). Al-Hazaimeh & Gutteridge (2001) had a mean failure load of 1218N for the ferruled group and 1407N for the non ferruled group. Saupe et al (1996) had a mean failure load of 173.3 kg (1698) for the non ferruled and 170.5 kg (1671) for the ferruled group.

In general the mean failure load values of this study and of Al-Hazaimeh & Gutteridge (2001) and Saupe et al (1996) were high compared to findings by previous studies; Volwiler et al (1989) had 21.6 kg (212 N), and Sorensen and Engelman (1990A) had 65.3 kg (640 N).

The high forces in this study are probably due to the use of the "Dual" cured resin modified cement (Dyract cem, dentsply) and the cements ability to chemically bond to the dentine and micro-mechanically bond to the post.

The results showed a statistically significant difference ($p<0.011$) in the amount of force needed to break the different tooth types in group 3 (table 2, appendix 3). The canines required the highest force to break. This was across all the groups while the lateral incisors required the least force as expected. This was probably due to the larger width of the canines compared to the lateral incisors.

The results showed no statistically significant difference regarding the amount of force needed to fracture teeth with and without posts in this study. However, teeth without posts required (1036 N) a higher amount of force to fracture than the teeth that had posts (931 N) (table 4, figure 13). These findings are related to the findings of Sorensen and Martinoff (1984). They carried out a retrospective study and found that there was no significant increase in fracture resistance gained with intracoronal reinforcement.

The relatively lower values required to break teeth restored with posts in this study were probably due to weakening of the tooth structure during post channel preparation. When insufficient tooth structure exists to prepare for coronal coverage, a composite resin coronal-radicular core may be appropriate instead of a post and core build-up in the restoration of anterior teeth, if there is sufficient dentinal wall to act as a ferrule.

The results indicated a significant difference ($p<0.05$) in the amount of force required to break the teeth with differing amounts of remaining dentinal width. Teeth with 1.5mm or more of remaining dentine width required a higher force to break compared to the teeth that had 1.00mm or less. Teeth with 1.5mm and 2mm or more of remaining dentine required forces of 1056 N and 973 N respectively to break and teeth with 1mm or less of remaining dentine width required 859 N (table 3).

Post channels are prepared by removal of gutta percha. The safest technique has been the use of heated instruments, however the commonest and fastest method is by use of rotary instruments. All the procedures involved that is; root canal instrumentation, initial post space preparation by Gates Glidden and final preparation by specific post drills have the potential to reduce the remaining dentine thickness (Pilo & Tamse, 2000). The reduction in the remaining dentine thickness is a predisposing factor for root fracture. Tjan and Whang (1985) in their study found that all teeth with only 1mm of the remaining dentine wall failed by root fracture other than cement failure. They suggested that when the buccal wall at the entrance of the post channel is 1mm or less, a parallel-sided dowel form should be avoided. Therefore the use of posts should be avoided when they are not required to provide retention for the core.

5.3 Limitations of the study

When evaluating the results of this investigation, it should be noted that there may be limitations to the direct application of in vitro results to clinical situations. Some of the limitations encountered included; variations among the specimens within the groups which is inherent with these types of studies because of the natural variation among the teeth that are used. One way to reduce these variations is to try to collect similar teeth of the same dimensions. Technical difficulties encountered included, ensuring that the long axis of the post channel was parallel to the side of the plastic tubing during mounting, making a uniform contrabevel reduction for all the teeth and building a uniform composite core. Lack of a periodontal ligament such that the teeth were embedded in acrylic resin, which showed resilience such that the specimens were displaced for a short distance within the material (acrylic) when a load was applied at the time of testing.

The sample size in this study was small. This made comparisons between the smaller subgroups difficult for a conclusion to be made. Therefore in many instances it was necessary to collapse some of the groups in order to assess associations.

6 CONCLUSIONS

This study evaluated the resistance to fracture of endodotically treated teeth restored with prefabricated posts and composite cores with and without a ferrule effect, and teeth restored with a ferrule effect but with no post. Two major conclusions came out of this study and they are;

In the restoration of an anterior endodontically treated tooth with a prefabricated post and composite core having 2mm or more of remaining dentine, a ferrule effect provides no statistically significant improvement if a prefabricated post and core is used.

In the restoration of an anterior endodontically treated tooth with a prefabricated post and composite core having 2mm or more of remaining dentine, a post provides no statistically significant improvement in fracture resistance.

BIBLIOGRAPHY

Al-Hazaimeh N. Gutteridge DL. An in-vitro study into the effect of the ferrule preparation on the fracture resistance of crowned teeth incorporating prefabricated post and composite core restorations, *Int Endod J*, 2001; **34** (1): 40-46

Aquaviva SF. Gauri SD, Factors affecting the fracture resistance of post-core reconstructed teeth; A review, *Int J Prosthodont,* 2001; **14:** 355-363

Barkhordar RA. Ryle R. Jan A, Effect of metal collars on resistance of endodontically treated teeth to root fracture, J Prosthet Dent, 1989; **61**:676-8

Christensen GJ, Posts and cores: State of the art, *JADA*, 1998; **129**: 96-97

Colley IT. Hampson EL. Lehman ML, Retention of post crowns. An assessment of the retentive efficiency of posts of different shapes and sizes, *BDJ,* 1968; **124**: 63-69

DeSort KD, The prosthodontic use of endodontically treated teeth: Theory and biomechanics of post preparation, *J Prosthet Dent*, 1983;**49**(2): 203-206

Gluskin AH, Radke RA, Frost SL, Watanabe LG, The mandibular incisor: Rethinking guidelines for post and core design, *J Endodont*, 1995; **21** (1): 33-37

Hemmings KW, King PA, Setchell DJ, Resistance to torsional forces of various post and core designs, *J Prosthet Dent*, 1991; **66**: 325-9

Jacobs DJ, Steele JG, Wassell RW, Crowns and extracoronal restorations: Considerations when planning treatment, *BDJ*, 2002; **192**(5): 499-509

Libman WJ, Nicholls JI, Load fatigue of teeth restored with cast posts and cores and complete crowns, *Int J Prosthodont*, 1995; **8**: 155-161

Loney RW, Kotowicz, McDowell, Three-dimensional photoelastic stress analysis of the ferrule effect in cast post and cores, *J Prosthet Dent*, 1990; **63**: 506-12

Lui JL, Composite resin reinforcement of flared canals using light-transmitting plastic posts, *Oper Dent*, 1994; **25**: (5): 313-319

Mendoza DB, Eakle WS, Kahl EA, Ho R, Root reinforcement with a resin bonded preformed post, *J Prosthet Dent*, 1997; **78** (1): 10-14

Milot P, Stein. RS, Root fracture in endodontically treated teeth related to post selection and post design, *J Prosthet Dent*, 1992; **68**: 428-35

Papa J, Cain C, Messer HH, Moisture content of vital versus endodontically treated teeth, *Endod Dent Traumatol*, 1994; **10**: 91-93

Pilo R, Tamse A, Residual dentine thickness in mandibular premolars prepared with Gates Glidden and ParaPost drills, *J Prosthet Dent*, 2000; 83 (6): 617-623

Pollard E, Liebeck H, *The Oxford paperback Dictionary,Oxyford* University press, Fourth edition, 1994

Rosen H, Partida-Rivera M, Iatrogenic fracture of roots reinforced with a cervical collar, *Oper Dent*, 1986; **11**: 46- 50

Ross FI, Fracture susceptibility of endodontically treated teeth, *J Endod*; 1980; **6**: (5): 560-565

Saupe WA, Gluskin AH, Radke RA, A comparative study of fracture resistance between morphologic dowel and cores and a resin reinforced dowel system in the intra-radicular restoration of structurally compromised roots, *Quintessence International*, 1996; **27**: (7): 483-491

Sedgley CM, Messer HH, Are endodontically treated teeth more brittle? *J Endod*, 1992; **18**: (7): 332-335

Shillingburg HT, Hobo S, Whitsett LD, Jacobi R, Bracket SE, *Fundamentals of Fixed Prosthodontics*, third edition, Quintessence Publishing Co., 1997.

Sorensen JA, Martinoff JT, Clinically significant factors in dowel design, *J Prosthet Dent*, 1984; **52**: 28-35

Sorensen JA. Engelman MJ, Ferrule design and fracture resistance of endodontically treated teeth, *J Prosthet Dent*, 1990A; **63**: 529-36

Sorensen JA. Engelman MJ, Effect of post adaptation on fracture resistance of endodontically treated teeth, *J Prosthet Dent*, 1990B; **64**: 419-24

Standlee JP. Caputo AA. Hanson EC, Retention of endodontic dowels: effects of cement, dowel length, diameter and design, *J Prosthet Dent*, 1978; **39**: 401-405

Stankiewicz NR, Wilson PR, The ferrule effect: a literature review, *Int Endod J*, 2002; **35**: 575-581

Stewardson DA, Non metal post systems, *Dental update*, 2001; **28**: 326-336

Tjan AHL. Whang SB, Resistance to root fracture of dowel channels with various thickness of buccal dentin walls, *J Prosthet Dent*, 1985; **53**: 496-500

Tjan AHL. Whang SB, Retentive properties of some simplified dowel-core systems to cast gold dowel and core, *J Prosthet Dent*, 1983; **50**: 203-206

Tjan AHL, Dunn JR, Lee JKY, Fracture resistance of amalgam and composite resin cores retained by various intradentinal retentive features, *Quintessence Int*, 1993; **24** (3): 211-217

Torbjorner A, Karlsson S, Odman PA, Survival rate and failure characteristics for two post designs, *J Prosthet Dent*, 1995; **73**: 439-44

Volwiel RA, Nicholls JI, Harrington GW, A comparison of three core build-up materials used in conjunction with two post systems in endodontically treated anterior teeth, *J Endod*, 1989; **15**:(8): 355-361

8 APPENDIX

Appendix (1)

Table 4. Results for teeth in group 1 which had a post and a butt joint between the tooth and the core

Tooth	Group	Tooth type	Force (N)
A1	1	Central incisors	1341.03
A2	1	Central incisors	1166.80
A3	1	Central incisors	731.23
A4	1	Central incisors	1053.88
A5	1	Central incisors	1400.56
A6	1	Central incisors	640.32
A7	1	Central incisors	902.44
A8	1	Central incisors	725.86
A9	1	Central incisors	555.46
A10	1	Central incisors	1264.41
A11	1	canines	1400.37
A12	1	canines	702.83
A13	1	canines	1190.19
A14	1	canines	895.59
A15	1	canines	1321.75
A16	1	Lateral incisors	688.58
A17	1	Lateral incisors	1100.58
A18	1	Lateral incisors	1100.43
A19	1	Lateral incisors	985.92
A20	1	Lateral incisors	705.33
A21	1	Lateral incisors	495.54
A22	1	Lateral incisors	594.55

Appendix (2)

Table 5. Results for teeth in group 2, which had a post with a contrabevel (ferrule) at the tooth-core junction

Tooth	Group	Tooth type	Force (N)
B1	2	Central incisors	817.32
B2	2	Central incisors	623.33
B3	2	Central incisors	1301.13
B4	2	Central incisors	1107.35
B5	2	Central incisors	1181.14
B6	2	Central incisors	574.18
B7	2	Central incisors	625.31
B8	2	Central incisors	1247.68
B9	2	Central incisors	910.52
B10	2	canines	752.12
B11	2	canines	891.47
B12	2	canines	991.76
B13	2	canines	1391.43
B14	2	canines	714.57
B15	2	Lateral incisors	1089.89
B16	2	Lateral incisors	908.29
B17	2	Lateral incisors	740.92
B18	2	Lateral incisors	832.32

Appendix (3)

Table 6. Results for teeth in group 3, which had no post but a composite core and a contrabevel (ferrule) at the tooth-core junction

Tooth	**Group**	**Tooth type**	**Force (N)**
C1	3	Central incisors	1372.79
C2	3	Central incisors	1246.56
C3	3	Central incisors	588.73
C4	3	Central incisors	1106.89
C5	3	Central incisors	774.79
C6	3	canines	1401.64
C7	3	canines	1344.84
C8	3	canines	1084.74
C9	3	canines	1400.28
C10	3	canines	1120.68
C11	3	canines	1280.36
C12	3	canines	820.94
C13	3	Lateral incisors	968.32
C14	3	Lateral incisors	793.81
C15	3	Lateral incisors	681.31
C16	3	Lateral incisors	883.54
C17	3	Lateral incisors	1065.85
C18	3	Lateral incisors	708.45

Appendix (4)

Table 7: ANOVA tables for the force needed to break teeth with differing amounts of remaining dentine

	Sum of squares	df	Mean square
Between groups (Combined)	399614.73	2	199807.363
Within groups	3639366.5	55	66170.299
Total	4038981.2	57	

	F	Sig
Between groups (Combined) Within groups Total	3.020	0.57

Appendix (5)

Table 8: ANOVA tables for the force needed to break teeth between the different groups

	Sum of squares	df	Mean square
Between groups (Combined)	136304.79	2	68152.395
Within groups	3902676.4	55	70957.753
Total	4038981.2	57	

	F	Sig
Between groups (Combined) Within groups Total	0.960	0.389

Appendix (6)

Table 9: ANOVA tables showing force needed to break teeth of the different types in group 1

	Sum of squares	df	Mean square
Between groups (Combined)	287827.21	2	143913.606
Within groups	1392080.3	19	73267.382
Total	1679907.5	21	

	F	Sig
Between groups (Combined)	1.967	0.168
Within groups		
Total		

Appendix (7)

Table 10: ANOVA tables showing force needed to break teeth of the different types in group 2

	Sum of squares	df	Mean square
Between groups (Combined)	7682.962	2	3841.481
Within groups	987095.87	15	65806.391
Total	994778.83	17	

	F	Sig
Between groups (Combined) Within groups Total	0.058	0.944

Appendix (8)

Table 11: ANOVA tables showing force needed to break teeth of the different types in group 3

	Sum of squares	df	Mean square
Between groups (Combined)	556550.08	2	278275.042
Within groups	671440.01	15	44762.667
Total	1227990.1	17	

	F	Sig
Between groups (Combined) Within groups Total	6.217	0.011