FRACTURE RESISTANCE OF WEAKENED ROOT STRUCTURE REINFORCED WITH TWO TYPES OF COMPOSITE RESIN AND ENDODONTIC SEALER

by

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Dedication

To my family, for every thing

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Ahmad Mahmood Ahmad

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SIGNED STATEMENT

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I gave consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

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KETAHANAN STRUKTUR AKAR YANG LEMAH TERHADAP FRAKTUR DAN DIPERKUAT OLEH DUA JENIS RESIN KOMPOSIT DAN BAHAN PENGAP ENDODONTIK

ABSTRAK

Tujuan kajian ini adalah untuk membandingkan ketahanan akar-akar gigi yang lemah terhadap fraktur dan diobturat dengan bahan pengap endodontik HA nano yang baru atau bahan pengap endodontik epoksi resin dan diperkuat oleh resin komposit polimeran auto atau polimeran cahaya. Seratus dua belas (112) batang gigi kacip maksila tengah manusia yang masih elok yang telah dicabut dipotong bahagian korona hingga hanya 13mm akar yang tinggal. Akar-akar tersebut telah diinstrumenkan menggunakan teknik undur belakang dan telah dibahagikan secara rawak kepada 2 kumpulan (Kumpulan 1 dan 2). Untuk kumpulan 1, AH 26 bebas perak (silver) (Dentsply De Trey Gmbh, Germany) telah digunakan sebagai bahan pengap endodontik, manakala bahan pengap hidroksiapatit nano (HA nano) yang masih dalam percubaan telah digunakan untuk kumpulan 2. Kedua-dua kumpulan telah diobturat dengan gutta-percha menggunakan teknik kondensasi lateral sejuk. Persediaan ruang untuk tiang (post) telah dimulakan menggunakan palam pemadat yang dipanaskan (Dentsply Maillefer, Switzerland) untuk menyingkirkan 8 mm gutta-percha, diikuti dengan gerudi Gates Glidden nombor 2, 3, 4 dan 5 (Dentsply Maillefer, Switzerland) untuk memastikan keseluruhan gutta-percha telah disingkirkan. Hanpis kelajuan tinggi dengan semburan air yang banyak telah digunakan untuk melemahkan hujung dinding akar dengan hanya meninggalkan 0.5 mm sehingga 0.75 mm sisa dentin pada kawasan servikal. Akar-akar pada setiap

kumpulan kemudiannya dibahagikan secara rawak kepada dua subkumpulan menjadikannya empat kumpulan (1A, 1B, 2C & 2D). Akar-akar pada kumpulan A dan C telah diperkuat menggunakan Z100 (3M, ESPE, USA), resin komposit polimeran cahaya manakala akar-akar dalam kumpulan B dan D telah diperkuat menggunakan Alpha-dent (Dental Technologies, USA), iaitu resin komposit polimeran auto. Tiang plastik licin yang memancarkan cahaya Luminex (Dentatus, USA) berdiameter 1.5 mm telah diukur kepada panjang 8 mm dan disalut dengan jeli petroleum (Vaseline, USA). Ia kemudiannya dimasukkan ke dalam pes resin di dalam kanal akar sehingga ia sampai pada dasar persediaan. Komposit yang berlebihan telah disingkirkan dengan berhati-hati dan diratakan agar ia sama rata dengan permukaan akar yang dipotong sebelum dipolimerkan pada kumpulan A dan C, manakala untuk kumpulan B dan D tiang plastik telah digunakan untuk pemiawaian ruang tiang. Tiang Titanium telah disimen dengan Nexus 2 (SDS Kerr, USA) dalam setiap ruang tiang dan indeks silikon polimeran cahaya telah dicat pada akar untuk menyerupai ligamen periodontal. Akar-akar ini kemudiannya telah ditanam dalam blok-blok resin untuk ujian mekanikal. Gigi-gigi ini dibebankan pada 130◦ dengan paksi panjang gigi di dalam mesin ujian universal, Instron 8874 (Instron Crop, Canton, Mass) yang berkelajuan 2 mm/min sehingga mesin menunjukkan fraktur yang dapat ditentukan melalui penurunan daya yang mendadak. Min beban kepada fraktur dan sisihan piawai (SD) dalam unit Newton untuk kumpulan A, B C dan D adalah 549.3 (95.44), 528.2 (123.80), 490.7 (110.37) dan 521.6 (99.42) selayaknya. Data telah dimasukkan ke dalam perisian SPSS dan dianalisis menggunakan ujian t tidak bersandar di mana $p<0.05$, secara saintifiknya telah dianggap signifikan. Tiada perbezaan yang signifikan didapati pada ketahanan fraktur di antara kumpulan-kumpulan, dimana nilai p ialah 0.283, 0.505, 0.338 dan

0.407 selayaknya. Resin komposit pempolimeran auto Alpha-dent boleh digunakan untuk menguatkan gigi-gigi yang lemah dan keputusannya sama dengan resin komposit polimeran cahaya Z100. HA nano mempunyai sifat yang setanding dengan AH 26 dari segi ketahanan fraktur untuk gigi yang lemah.

FRACTURE RESISTANCE OF WEAKENED ROOT STRUCTURE REINFORCED WITH TWO TYPES OF COMPOSITE RESIN AND ENDODONTIC SEALER

ABSTRACT

The aim of this study was to compare the fracture resistance of weakened roots obturated with a new nano HA endodontic sealer or an epoxy resin endodontic sealer and reinforced by either auto-cured or light-cured composite resin. A hundred and twelve (112) extracted sound human permanent maxillary central incisors were decoronated to create 13 mm roots. The roots were instrumented by using step back technique and randomly divided into two groups (1 & 2). In group 1, AH 26 silver-free (Dentsply De Trey Gmbh, Germany) was used as endodontic sealer, while the new experimental nano hydroxyapatite (nano HA) sealer was used for group 2. Both groups were obturated with gutta percha by using cold lateral condensation technique. Post space preparation was initiated with heated condensers (Dentsply Maillefer, Switzerland) to remove 8 mm of gutta percha followed by Gates Glidden drills number 2, 3, 4 and 5 (Dentsply Maillefer, Switzerland) to ensure complete removal of gutta-percha. A high speed handpiece with diamond bur (Prima classic, UK) and copious water spray was used to weaken the root walls ending by leaving 0.5 mm to 0.75 mm of the residual dentine at the cervical area. The roots in each group were randomly divided into two subgroups to give four groups (1A, 1B, 2C & 2D). Roots in group A and C were reinforced with Z100 (3M ESPE, USA), a light-cured composite resin while the roots in group B and D were reinforced with Alpha-dent (Dental Technologies, USA), an auto-cured composite resin. Light-transmitting

smooth plastic post, Luminex (Dentatus, USA) of 1.5 mm in diameter was measured at 8 mm length and coated with petroleum jelly (Vaseline, USA). It was inserted into the resin paste in the root canal until it reached the bottom of the preparation. Displaced excess composite was carefully removed and made level with the cut root surface before curing in groups A and C while in groups B and D the plastic post was used for post space standardization. Titanium posts were cemented with Nexus 2 (SDS Kerr, USA) in each post space and auto-cured silicon index was painted on the roots to simulate the periodontal ligament. Later the roots were mounted in resin blocks for mechanical test. The teeth were loaded in 130° degree with long axis of the tooth in the universal testing machine, Instron 8874 (Instron Crop, Canton, Mass) with head speed 2 mm/min. until the machine indicated the fracture which was determined by a sudden drop in the force. The mean load to fracture and standard deviation (SD) in Newton units for groups A, B, C and D were 549.3 (95.44), 528.2 (123.80), 490.7 (110.37) and 521.6 (99.42) respectively. Data was entered into SPSS software and analyzed using independent *t* test where $p < 0.05$ was considered statistically significant. No significant difference in the fracture resistance was found among the groups, where *p* values were 0.283, 0.505, 0.338 and 0.407 respectively. Alpha-dent auto-cured composite resin could be used to reinforce weakened teeth with similar results as Z100 light-cured composite resin. Nano HA sealer had comparable property in term of fracture resistance of weakened teeth as AH 26 sealer.

CHAPTER ONE

INTRODUCTION

1.1 Study Background

In clinical practice, endodontically treated teeth present restorative problems because of frequent insufficient sound coronal tooth structure to retain the restoration. Further loss of tooth structure as a result of endodontic treatment, will subject the teeth to fracture. The restoration of tooth with excessive dentine loss presents a challenge to clinicians. In such cases, the risk of fracture is higher because the strength of any tooth is directly related to the bulk of remaining dentine (Yoldas *et al*., 2005).

Many anterior teeth that require post retained restorations are severely weakened due to caries extending into the radicular dentine. In some cases, secondary caries around pre-existing posts may further complicate the matter. Other cases may involve necrotic young permanent teeth with large canal space prior to the completion of root formation. Other less common conditions include developmental anomalies such as fusion and germination, internal resorption and iatrogenic damage resulting in large access preparations. The resulting large, flared root canals with thin dentinal walls are too weak to withstand normal masticatory forces and prone to fracture. Such teeth may also have insufficient coronal tooth structure and give problem to the restorative dentist (Tait *et al*., 2005). Pontius and Hutter, (2002) suggested two methods for restoration of weakened roots canals which were conventional and intraradicular reinforcement methods.

1.1.1 Conventional Method

This method includes the use of posts or pins. These weakened roots are difficult to restore with these methods for a variety of reasons. Restoration with cast posts can cause wedging forces which may result in fracture of an already weakened root. Moreover, the wide and tapered geometry of the weakened root canal results in unretentive posts (Tait *et al.*, 2005). In these situations, if a prefabricated post is used, the excess space within the root canal would be taken up with a bulk of luting cement. This will result in a potentially weak area in the restoration. Placement of dentine pins to help retain the core is also not feasible because there is likely to be insufficient dentine present at the coronal portion of the root. Thus, these conventional methods of restoration are unsatisfactory and often result in extraction of the tooth (Lui, 1999).

1.1.2 Intraradicular Reinforcement

As an alternative to the conventional methods, restoration of such weakened roots is commonly accomplished by using intraradicular reinforcement with adhesive materials for protection and reinforcement. Later, the prefabricated posts will be placed for the retention of the crown or a fixed partial denture (Lui, 2001; Tait *et al.*, 2005).

The intention for the use of adhesive materials for root reinforcement is to increase the fracture resistance by increasing the internal thickness of the root. A study by Freedman, (2001) indicated that the strength of the remaining tooth structure is directly related to the bulk of the remaining dentine and the fracture resistance is increased by increasing the dentine thickness.

1.1.3 Sealer

On the other hand, an important cause of failure after post placement is root fracture. It is still controversial whether or not root canal sealers will affect the strength of the root (Lertchirakarn *et al*., 2002).

Recently, the School of Dental Sciences, USM, has prepared a new experimental nano HA-filled epoxy resin based endodontic sealer. Hydroxyapatite (HA) which has the formula of $Ca_{10}(PO4)_6(OH)_2$ is the main component of the bone and teeth. It is considered by most researchers as a biocompatible, bioactive, osteoconductive and non inflammatory material (Alshakhshir, 2007). The HA nano crystals were synthesized at the School of Chemical Sciences, USM (Masudi *et al*., 2007). The composition of this experimental sealer was similar to that of various sealers of the epoxy resin based sealer type but with different additive. This additive (nano HA) was assumed to improve the periapical healing process (Gambarini and Tagger, 1996; Masudi *et al*., 2007) and to produce a hermetic apical seal (Alshakhshir, 2007). However, little is known regarding the reinforcement ability of this new material when used as a sealer in endodontic therapy as compared to commercialized product.

The material was prepared at nano level and nano HA particles size are believed to have several advantages over normal HA particles size in its use in hard tissue formation. This is due to its greater surface area and consequently higher reactivity which offers better cellular response. In addition, nano sized HA is useful as an effective surface modification agent for binding numerous biological molecules (Ong *et al*., 2004).

These nano structured HA-based materials are therefore a promising material that may have a future prospect and considerable clinical dental applications. The materials are biocompatible, reactive and have capability to adhere to the dentinal tubules. The smaller the particle size, the lower will be the gravity cohesion and higher intermolecular physical bonding (van-der Walls Forces) which leads to the higher surface activity (Roberson *et al*., 2002).

1.2 Statement of the Problem

Many adhesive materials including composite resin have been used for intraradicular reinforcement of weakened root structure. However, no studies had been done about the use of auto-cured composite resins for the reinforcement.

In addition, Goncalves *et al.*, (2006) recommended for further investigation to compare between light-cured composite resins and auto-cured composite resins since these materials were commonly used within root canals and post space.

The experimental nano HA-containing sealer is still new and little is known about its potential effects when used in reinforcing the weakened roots.

1.3 Justification of the Study

Successful usage of composite resin especially the auto-cured type in reinforcement of severely weakened root will widen the scope of materials available for dental practitioners to treat such cases. Many more weakened teeth could be strengthened and saved, thus decreasing the number of teeth that need to be extracted. Patients will have more natural teeth kept until their older age.

This study will also add value to the properties of the new locally-produced nano HA-based endodontic sealer. Successful development of this product will lead to its usage in clinical practice and commercialization. The material will be an alternative to the currently available materials. As the material is locally-produced, the cost should be lower than its imported counterparts. This will help to reduce the overall cost of treatment for patients and at the same time reduce the country import.

The result of this study will help the clinicians in selecting suitable materials at a more competitive cost.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The majority of endodontically treated single rooted teeth with lack of coronal tooth structure can be restored by using posts and cores. However, many anterior teeth that require post-retained restorations are severely weakened as a result of recurrent caries extending into the radicular dentine around pre-existing posts or the fact that the pulp has become necrotic prior to the completion of the root formation in a young patient. Other less common conditions include developmental anomalies such as fusion and gemination, internal resorption and iatrogenic damage resulting in large access preparation. The resulting large and flared root canals have thin dentinal walls, leaving the tooth too weak to withstand normal masticatory forces and prone to fracture. Such teeth may also lack sufficient coronal tooth structure and pose a problem to the restorative dentist (Lui, 2001; Tait *et al.*, 2005).

These compromised teeth are difficult to restore with conventional restorative methods for a variety of reasons. Placement of a retentive pin is not possible because of the lack of dentine substance at the coronal portion of the root. Placement of a cast metal post can cause wedging forces at the already thin and weakened portions of the root which may result in irreversible failure. The geometry of the flared canal also results in a very wide, tapered, and unretentive post. In these situations, if a prefabricated post is used, the excess space within the root canal would be taken up by a bulk of luting cement. This results in a potentially weak area in the restoration. Thus, these traditional methods of restoration are unsatisfactory and often result in fracture of the root and followed by extraction of the teeth (Tait *et al.*, 2005). The development of an alternative technique, the “Reinforcement Technique” could be implemented for the treatment of such teeth (Lui, 1994; Lui, 1999).

2.2 Differences between Sound and Endodontically –Treated Teeth

There are ample evidence stating that endodontically-treated teeth differ from vital teeth in many aspects. These differences include changes in physical properties, biomechanical behaviour under stress and chemical compositions of the teeth (Llena-Puy *et al.*, 2001; Fennis *et al.*, 2002; Kahler *et al.*, 2003; Ferrari *et al.*, 2004).

Dentine from endodontically treated teeth has been shown to exhibit significantly lower shear strength and toughness than vital dentine. In 1976, Tidmarsh described that the structure of an intact tooth permits deformation when loaded occlusally and elastic recovery after removal of the load (cited by Cohen and Burns, 2002). Cohen and Burns, (2002) also described about the direct relationship between tooth structure removed during tooth preparation and tooth deformation under the load of mastication.

The tooth structure that remains after endodontic treatment has been undermined and weakened by all of the previous episodes of caries, fracture, tooth preparation, restoration and endodontic treatment. Endodontic access preparation into the pulp chamber destroys the structural integrity provided by the coronal dentine of the pulpal roof and allows greater flexing of the tooth under function. Furthermore, changes in collagen cross-linking will affect the strength of the tooth. Rivera *et al.*, (1988) stated that the effort required to fracture the dentine may be less when teeth are endodontically treated because of potentially weaker collagen intermolecular cross-links. On the other hand, loss of moisture content or dehydration of the dentine results in a 14% reduction in strength and toughness of endodontically treated molars (Cohen and Burns, 2002).

Kinney *et al.*, (2003) showed that dehydration of human dentine increases its Young's modulus. Young's modulus is the resistance of the body to deformation by an applied force. Dentine specimens from endodontically treated teeth generally showed lower modulus of elasticity (tendency of the body to be deformed elastically non-permanently when a force is applied to it) and lower proportional limit (the greatest stress that a material is capable of sustaining without any deformation in compression) than those of normal teeth.

In a study using a method of collagen dissolution, the results showed that the percentage of collagen present in crown and root dentine decreases after root canal treatment. The percentage of collagen in crown dentine of healthy teeth was 21.7%. The value was reduced to 20.1% in teeth that had been endodontically treated for 2 years, and was further reduced to 16.8% in teeth that had been endodontically treated for 10 years. In root dentine the percentages are 25.5%, 23.5% and 19.3% respectively (Hashimoto *et al.*, 2000).

These findings were further confirmed in a study using Transmission Electron Microscopy by Ferrari *et al.*, (2004) which showed that a decrease in the distribution of the collagen fibrils within root dentine 3 to 9 years after endodontic treatment.

Another possible cause of weakness of endodontically-treated teeth might be due to the loss of pressure receptors or pressoreceptors (receptors in the vascular system) which are sensitive to the stretch of the vessel walls in the dental pulp. However, there is no clear evidence about this factor. Loss of pressoreceptors in blood vessels of the pulp or an elevated pain threshold allows heavier loads onto endodontically treated teeth without triggering a protective response (Ingle and Bakland, 2002). This will lead to increased risk of fracture. Many other studies on the reflex control of human jaw-closing muscles suggested the role of periodontal and gingival receptors as potential pressoreceptors (Louca *et al.*, 1998). Lack of these receptors in endodontically treated teeth may also allow heavier load that will lead to fracture.

In conclusion, the general loss of tooth structure in the non-vital tooth together with the alterations in collagen distribution may simultaneously contribute to the increased susceptibility of endodontically-treated teeth to fracture under loading. A further reduction in micro-hardness can be induced by the use of irrigating solutions during endodontic treatment (Ari *et al.*, 2004; Slutzky-Goldberg *et al.*, 2004). The loss of water and gutta-percha condensation procedures may also contribute to the weakness reported in endodontically-treated teeth (Saleh and Ettman, 1999; Goldsmith *et al.*, 2002).

2.3 Root Fracture

2.3.1 Root Fracture and Posts

For many years, the concept of using posts in restoration of endodontically-treated teeth was based upon the philosophy that the post could “reinforce” the tooth, in addition to their function in retaining the coronal restorations. The concept that says post was generally placed in an attempt to strengthen the tooth has “passed”. Post does not strengthen the root, but serves solely to improve retention of the core (Trope *et al.*, 1985; Morgano, 1996; Lui, 1999).

It is a common belief now that the likelihood of survival rate and resistance to fracture of the non-vital tooth is directly related to the thickness of remaining root dentine especially in the bucco-lingual direction (Cohen *et al.*, 1996; Lui, 1999).

There are three basic types of clinical studies which are able to provide information on the incidence of posts and root fracture. These include the surveys of extracted teeth with fractured roots, retrospective studies on the fracture rate of posts restored teeth and prospective studies on the fracture rate of certain types of restorations for endodontically-treated teeth. But the majority of studies available on the root fractures are retrospective in nature and unfortunately no prospective studies are available to definitely validate all the aspects analyzed. A significantly higher incidence of fractures in premolars and molars was found in these studies (Hansen and Asmussen, 1990; Hansen *et al*. 1990; Walton, 1999).

In these three basic types of clinical studies several factors have been identified, which affect the fracture resistance and failure modes of post-core restorations (Morgano and Brackett, 1999; Stockton, 1999).

One of the important factors is the type of tooth and its position in the dental arch. It was found that half of the fractured post-retained teeth were maxillary second premolars (27.2%) and mesial roots of the mandibular molars (24%). The susceptibility of these teeth to root fracture increased when the residual sound tooth structure was less than 1-2 mm in thickness (Pilo and Tamse, 2000).

Moreover, oval shaped canals are more prone to root fracture as there are more spaces that have to be filled with luting cements. As the cement dissolves, spaces are inadvertently created for the post to move inside the dowel space. These micro-movements may eventually result in dislodging of the post, fatigue of the tooth and root fracture (Chapman *et al.*, 1985; Tait *et al.*, 2005).

2.3.1.1 Post Length

Post length is important as well. Many different recommendations have been given to the clinicians regarding this issue (one half, two thirds, three quarters of the root, below the cemento-enamel junction, as long as possible). A study of teeth with vertical root fracture by Fuss and colleagues (2001) reported that two-thirds of the posts associated with vertically fractured teeth were extremely short or terminating in the cervical third of the roots. An *in vitro* biomechanical study also suggested that better stress distribution occurs with longer posts (Yang *et al.*, 2001).

Besides the length, the diameter of the post is also important. This is related to the remaining tooth structure because an increased in post diameter will mean that more dentine will be removed and exposed to higher risk of root fracture. Conservation of remaining tooth structure by avoiding the use of posts with a large diameter has been recommended (Guzy and Nicholls, 1979; Standlee *et al.*, 1980).

The geometry of posts has an influence on fracture resistance where the parallel-sided posts with an amalgam or resin composite core recorded the highest success rate. The tapered posts and core displayed a higher failure rate and less retentive than teeth treated with parallel-sided posts. On the other hand, failure of parallel-sided posts cause reversible failures while tapered posts failure cause irreversible root failures and extractions of teeth (Mendoza *et al.*, 1997).

2.3.1.2 Ferrule Effect

Post in a pulpless tooth can transfer occlusal forces intraradicularly and expose the root to vertical fracture. If the artificial crown extends apical to the margin of the core and encircles sound tooth structure for 360º, the crown serves as a reinforcing ring or ‘‘ferrule’’ to help in protecting the root from vertical fracture (Morgano *et al.*, 2004). A number of studies have reported the improvement of fracture resistance for pulpless teeth restored utilizing the ferrule effect (Zhi-Yue and Yu-Xing, 2003; Akkayan, 2004; Morgano *et al.*, 2004).

Ferrule was also found to help in protecting the integrity of the cement seal of the artificial crown (Morgano *et al.*, 2004). The most commonly accepted guideline for this ferrule is a minimal height of 1.5 to 2 mm of intact tooth structure above the cervical margin for 360º surrounds the circumference of the tooth preparation (Morgano and Brackett, 1999).

2.3.2 Root Fracture and Endodontic Sealer

Root fractures occasionally occur in endodontically treated teeth. The prevalence of root fracture is not equally distributed over the different tooth types (Tamse *et al.*, 1999). It is generally accepted that the removal of excessive amounts of radicular dentine compromises the root and the amount of dentine remaining is directly related to the strength of the root (Lertchirakarn *et al.*, 2002). It is also important to establish which procedures in the endodontic therapy that may increase the risk of root fracture and develop a new root filling materials that can strengthen the root (Wu *et al.*, 2004).

However, root fracture can occur before, during or after obturation of the root canal system. One of the indications for crown placement is to prevent unfavourable fractures after obturation. However, in some cases even properly restored teeth may also fracture. It would be advantageous if the root canal obturation, in addition to providing an adequate seal, could decrease the incidence of root fracture (Apicella *et al.*, 1999).

In addition to fracture resistance, a number of studies have investigated the effects of different cements on post retention. Schwartz *et al*., (1998) reported higher retentive values with resin cement than zinc phosphate or glass ionomer cements. Other authors have reported similar findings (Bergeron *et al.*, 2001; Boone *et al.*, 2001).

AH 26 is an epoxy amine resin–based sealer. Epoxy resin sealers have comparatively good sealing properties and it showed good mechanical properties as well as excellent adhesion and adaptation to dentine. After initial volumetric expansion, the sealer showed some shrinkage when tested at longer intervals. In general, epoxy resin sealant material showed good sealing properties *in vitro* and *in vivo* than with any sealer tested (Bergenholtz *et al*., 2003).

The setting reaction of AH 26 lasts about one to two days at body temperature and it involves a polymerization process during which formaldehyde is released, but the concentration is more than 300-fold less than that of formaldehyde–releasing zinc oxide eugenol formulation (Bergenholtz *et al*., 2003).

In addition, AH 26 shows antibacterial activity (Al-Khatib *et al*., 1990; Heling and Chandler, 1996). Al-Khatib *et al*., (1990) founds that AH 26 was the most active against *Bacteroides endodontalis*. Heling and Chandler, (1996) also found AH 26 within the dentinal tubules, which shown to have the strongest antimicrobial effect over three other well-known sealers (Pulp Canal Sealer EWT, Sealapex, AH 26, and Ketac-Endo).

Moreover, in reviewing the literature, AH 26 sealer have shown good sealing ability even when used as the sole filling in a root canal (Wu *et al.*, 1994). It had been reported that the long setting time and material fluidity resulted in no cracking or rapid separation from dentinal walls (De Gee *et al.*, 1994). AH 26 also have the ability to solidify in a wet medium. It is bioinert and during penetration into lateral canals it showed a contraction of less than 0.5% (Miletic *et al.*, 1999; Yucel *et al.*, 2006).

Miletic *et al.*, (1999) studied the apical sealing ability of five root canal sealers, and reported that AH 26 silver free was an effective sealing material that had a satisfactory sealing ability. Yucel *et al.*, (2006) found similar results for his study about the coronal sealing ability of four root canal sealers including AH 26 silver free sealer.

Bergeron *et al.*, (2001) reported a significant increase in post retention when AH 26 sealer was used compared with Roth's sealer (zinc-oxide and eugenol sealer) regardless of cement type. It is possible that the constituents of the unset sealers may have an effect on the retention of the posts cemented with resin cements when compared with set sealers. This may be important because many endodontic sealers contain eugenol, which has been shown to inhibit the polymerization of resins.

Schwartz *et al*., (1998) reported that there was no significant difference in post retention using resin cement after post-space preparation when either AH 26 or Roth's 801 sealers were used.

Clinicians have long sought to reinforce remaining tooth structure. Coronal reinforcement has been demonstrated through bonded restorations. Adhesive dental materials are now available that may offer an opportunity to reinforce the endodontically treated tooth through the use of bonded sealers in the root canal system. Interests in reinforcing the root canal system have lead to the development of an adhesive root canal sealer with the potential to increase resistance to root fracture (Boone *et al.*, 2001).

Glass ionomer cements were first described in the dental literature by Wilson and Kent (Wilson and Kent, 1972). A survey of the literature provided several case reports describing the use of glass ionomer root canal sealer to increase the tooth fracture resistance (Barkhordar, 1991; Trope and Rosenberg, 1992). A glass ionomer-based sealer, Ketac-endo (ESPE-Premier, Norristown, USA) was introduced for use as an endodontic sealer with the potential to increase resistance to root fracture (Lertchirakarn *et al.*, 2002). Ketac-endo sealer has been shown to have favourable manipulation characteristics, excellent radiopacity and good flow and adaptation to the canal walls. Once mixed, the sealer placed into the canal along with a single gutta-percha point which largely facilitate the retreatment if necessary (Johnson *et al.*, 2000).

Trope and Rosenberg, (1992) reported that Ketac-Endo has the potential for root reinforcement. Canals obturated in conjunction with glass ionomer sealer exhibited a higher resistance to fracture than canals instrumented but not obturated or those obturated with gutta-percha and Roth’s 801 sealers.

Ulusoy *et al*., (2007) concluded that the use of AH 26 and gutta-percha increased the fracture resistance of instrumented root canals compared with Epiphany (resin based sealer) and Resilon (new synthetic alternative material to gutta percha) and Ketac-Endo Aplicap (glass ionomer root canal sealer) and gutta-percha.

2.3.2.1 Nano HA Sealer

Hydroxyapatite (HA) which has the formula of $Ca_{10}(PO_4)_6(OH)_2$, is the main component of the bone and teeth. It is considered by most researchers as a biocompatible, bioactive, osteoconductive and non inflammatory material (cited by Alshakhshir, 2007).

Recently, a new synthetic HA material was introduced to mimic the mineral component and the microstructure of natural bone and teeth, which would play a significant role in various biomedical applications such as bone substitute materials, constituent implants and dental materials. The material was prepared at nano level (1 – 100 nm) and nano HA particles size are believed to have several advantages over normal HA particles size in its use in hard tissue formation. This is due to its greater surface area and consequently higher reactivity, which offers better cellular response. In addition, nano sized HA is useful as an effective surface modification agent for binding numerous biological molecules (Ong *et al.*, 2004).

These nano structured HA-based materials are therefore a promising material that may have a future prospect and considerable clinical dental applications. The materials are biocompatible, reactive and have capability to adhere to the dentinal tubules. The smaller the scale of the material would better decrease its gravity cohesion, but increases the intermolecular physical bonding (*van-der Walls* Forces) that leads to the higher surface activity. This phenomenon explains that the nano structured HA are more reactive and adhesive compared to micro structured HA. Nano structured HA, which is completely similar to that of dentine and enamel, can protect the dentine from acid attack by creating an acid-resistant layer inside and outside the dentinal tubules (Alshakhshir, 2007).

A study have shown that nano HA materials are biocompatible due to their chemical and physical nature. The nanometer-sized grains have also been found to increase the osteoblast adhesion, proliferation and mineralization (cited by Alomari, 2008).

Nowadays, the application of nano HA has extended into dental applications. New HA based sealers, such as Sankin HA (Shanghai Second Medical University, Shanghai, China), have been introduced into the market (Alshakhshir, 2007).

2.4 Reinforcement Technique for Weakened Root

As stated in the literature, fracture resistance of pulpless teeth depends on the remaining tooth structure. Moreover, using posts does not strengthen or reinforce the tooth but may weaken it and increase the risk to fracture. For that reason and to ensure a better prognosis, a technique called “Reinforcement Technique” by internally strengthening the thin dentinal wall of pulpless teeth, was introduced (Cohen and Burns, 2002).

Many *in vitro* studies and case reports used Reinforcement Technique with different type of materials and all of them found that the technique was effective in strengthening weakened root structure and provided better prognosis (Goldberg *et al.*, 2002; Tait *et al.*, 2005; Bonfante *et al*., 2007).

2.4.1 Materials for Reinforcement Technique

2.4.1.1 Composite Resin

The use of direct composite resin materials has become an active part of contemporary Operative Dentistry. The aesthetic appearance associated with conservative cavity preparations and the constantly improved properties have made these materials the main choice for many restorations. However, resin composites are like other dental materials which undergo deterioration and degradation in the oral environment, technique-sensitive and failure at the tooth-restoration interface (Finer and Santerre, 2004).

The introduction of materials which are capable of bonding to dentinal tooth structure has created potential for reconstitution and rehabilitation of lost dentinal tissue in order to salvage severely damaged teeth which otherwise would be extracted. When the weakened root is internally rebuilt with suitable adhesive dental materials, the root is dimensionally and structurally reinforced to support and retain a post and core for continued function of the tooth (Lui, 1994).

Weakened teeth restored with composite resin reinforcement technique have been shown to be 50% more resistance to fracture than those without composite resin reinforcement (Saupe *et al.*, 1996). Pene *et al.*, (2001) found that composite resin increased the fracture resistance of immature tooth.

Composite resin reportedly absorbs and distributes forces in a more uniform manner when compared to metal materials. This will increase resistance to fracture and provide better prognosis. Composite resins have been advocated as a reinforcing build-up material for badly damaged endodontically treated teeth with flared canals (Bitter and Kielbassa, 2007). Adhesive interfaces of bonded restorations transmit and distribute occlusal forces to the remaining tooth structures homogeneously, potentially strengthening the restored tooth and increasing its resistance to fracture (Lui, 1999).

On the other hand, interfaces of materials with different modulus of elasticity represent weak point in the restorative system as the toughness/stiffness mismatch between dentine and restorative materials do influence the stress distribution. Thus, the strength of weakened root structure is affected by the material as well as the design of the post and core system (Assif and Gorfil, 1994).

Mendoza *et al*., (1997) assumed that weakened root systems restored with dentine bonding cement are more resistant to fracture than root systems that use zinc phosphate as a cementing medium.

Carvalho *et al*., (2005) concluded that the reinforcements with zirconium fibre post or composite resin can increase the structural resistance of the weakened root significantly and decrease the risk of fracture.

Moosavi *et al*., (2008) found that Reforpin® (Angelus, Brazil) can be used as an alternative to resin composite for internal reinforcement of weakened roots (Reforpin is a system of thin flexible prefabricated posts made from glass fibers embedded in epoxy resin). It is used for intraradicular reinforcement and to fill the space between the main post and canal walls found in the oval shaped canals. Reinforcement of flared canals using fibre posts along with Reforpin® or composite resin proved to have higher fracture resistance when compared to teeth without reinforcement.

Up to date, there is still no agreement regarding the best composite for direct coronal reinforcement or core build up of endodontically treated teeth (Ferrari *et al.*, 2000; Monticelli *et al*., 2004). Many manufacturers today claim that their adhesive root reinforcement systems can actually strengthen the root and prevent fracture. Few studies (Heydecke *et al.*, 2001; Yamada *et al.*, 2004) support the idea that composite resin do afford the weakened root structure with some additional retention and resistance forms and it is possible that those root systems restored with dentine bonding system are strengthened and root fracture resistance was increased.

Amalgam and composite resin were found to be superior to glass ionomer for core build up after post cementation (Gateau *et al*. 2001; Nagasiri and Chitmongkolsuk 2005). Seow *et al*., (2003) found in a survey study that amalgam was the popular core build up material in United Kingdom and United States. On the other hand, composite resin was more popular than amalgam as a core build up material in Germany. While composite resin and amalgam are recommended as core materials, conventional glass ionomer and resin modified glass ionomer were found to be unsuitable, especially for large defects without hard tissue support (Cohen *et al*., 1996).

Many types of composite resin materials have been proposed for core build up (Goracci *et al*., 2005; Ferrari *et al*., 2006). Microhybrid and flowable composite resin materials in the self-curing, dual-curing or light-curing formulation which are characterized by different strength, stiffness and elasticity could affect the longevity of the restoration (Asmussen *et al*., 1999). Luxacore (DMG, Germany) is a world wide successful composite resin that comes in self-cure or dual-cure. It was especially developed for core build up and post cementation. This material is closely matching the dentine properties with excellent compressive strength.

On the other hand, another core build up material Paracore (Coltene/Whaledent, USA) which is a dual-cure with extraordinary strength for long-term restorations and fluoride release is also available. However, up to date, there is still no agreements regarding the best material for direct core build up (Ferrari *et al*., 2000; Monticelli *et al*., 2004).

2.4.1.1.1 Configuration Factor (C-Factor)

The C-factor was defined as the ratio of bonded to unbonded surface areas of the cavities (Fig. 2.1). When composite resins are bonded to opposing walls, the volumetric shrinkage that occurs in polymerization creates stresses as high as 17 to 20 MPa on the bonded walls in box-like cavities or in thin parallel-walled spaces such as between dentine and the walls of inlays or crowns. The geometrically determined contraction stress has been described as the C-factor (configuration factor) (Yoshikawa *et al.,* 1999).

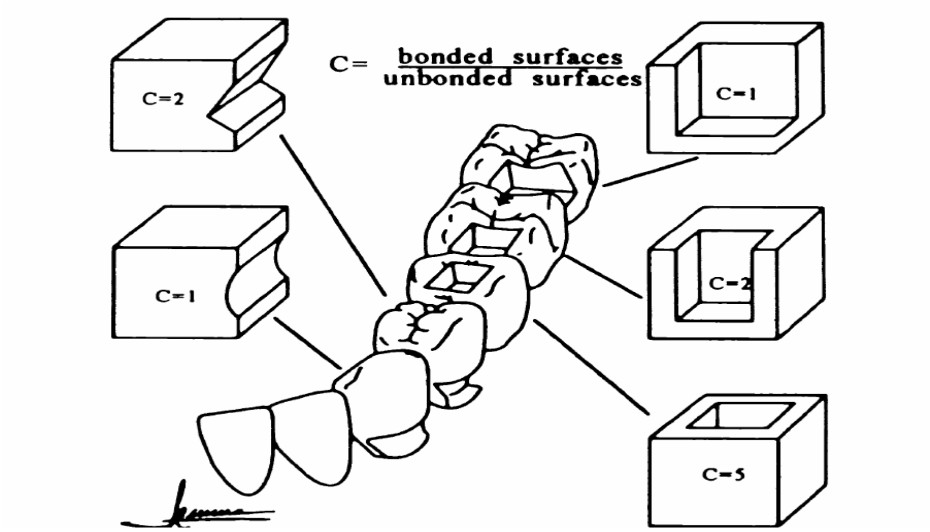

Figure 2.1 C-Factor & its classifications (Pashley *et al.*, 2003)

High C-factors can lead to debonding from one wall during light curing, which may lead to dentine sensitivity due to fluid shifts across unsealed dentin or micro leakage which may lead to secondary caries. The lower the C-factor, the less likely that polymerization shrinkage can stress the bonded interface (Bouillaguet *et al.,* 2001). *In vitro* studies showed that the C-factors is highly unfavourable in root canals, where it can range from 20 to 200 MPa and this is considered worse or too high when compared to the C-factor for the complex cavities which range from 17 to 20 MPa (Morris *et al.*, 2001; Pashley *et al.*, 2002).

It is important to optimize the bond strengths between the resin and dentine, and between the resin and the post material. It is desirable to use unfilled resins because they are softer and more easily removed if retreatment is required. However, all methacrylate-based resins shrink when polymerized. If the resin is light-cured, the shrinkage occurs so rapidly that a polymerization force develops (up to18-20 MPa) which can pull the resin off the dentin. However, if the resin is allowed to flow during polymerization shrinkage by using auto-cured composite resin, the stresses can be greatly lowered (Pashley *et al.*, 2002).

The amount of resin flow that occurs during polymerization is also determined by the C-factor. Only the unbonded, free surface of the material can flow during polymerization. The polymerization stress could be increased by increasing the ratio of bonded to unbonded surfaces. Bonded resin to a saucer-shaped class V cervical cavity creates a C-factor of approximately 1, because the bonded area is approximately equal to the free-surface area. The extreme C-factor could be found in a box-like, class I cavity with five bonded walls and only one free surface. If all of the surface areas are equal, this would create a C-factor of 5, which is associated with the development of very high polymerization stresses (Pashley *et al.*, 2002).