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Reconstruction of endodontically treated teeth

A Project Submitted to The College of Dentistry, University of Baghdad, Department of Restorative & Esthetic Dentistry in Partial Fulfillment for the Bachelor of Dental Surgery

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بسم الله الرحمن الرحيم

يرفع الله الذين آمنوا منكم والذين أوتوا العلم درجات

صدق الله العظيم

Certification of the Supervisor

I certify that this project entitled "Reconstruction of endodontically treated teeth " was prepared by the fifth-year student Manar Zuhal Abdulhamza under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Supervisor’s name: Asst.Prof.Samer Aun Thyab

Date :

Dedication

I humbly dedicate this project to my family (**Father** and **Mother** , my aunt **Neptune** , my aunt **Ala'a**) , who instilled in me a desire to learn and made sacrifices so I would have access to high quality education from an early age.

" الى رفاق الخطوه الاولى و الخطوه ما قبل الاخيره , الى من كانوا خلال السنين العُجاف سحاباً مُمطراً "

To my second family , **Amna , Zainab Mustafa** and **Zainab hamid**.

Also, this is dedicated to all my close friends who have always supported me since I went for dental school , especially **Tasnim** and **Hashw**.

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Introduction

The completion of root canal treatment does not signal the end of patient management. The endodontically treated tooth needs to be restored back to form, function and aesthetics. The quality of the coronal restoration will directly impact on the survival and success of the endodontically treated tooth. The provision of a restoration with a good coronal seal has been suggested to reduce the risk of failure of a root canal treated tooth by reducing bacterial microleakage into the recently cleaned, shaped, and filled root canal system.(saunders, 1994)

Additionally, provision of a well-executed restoration will return the tooth to form and function, re-establish proximal contacts and occlusal stability as well as protecting the tooth from future breakdown, both non-carious (fracture) and carious. The restoration of endodontically treated teeth has changed in recent years. The availability of adhesive techniques has increased the clinician's repertoire in terms of restoring teeth. Amalgam cores and cast metal posts are being replaced by direct composite and fibre-posts, all ceramic crowns and composite resin crowns are often chosen because of their superior aesthetic outcome.

Aim of the study

The aim of the study of reconstruction of endodontically treated teeth is to restore the functional and aesthetic properties of the tooth after root canal therapy. This includes repairing any damage or decay, rebuilding the tooth structure, and placing a suitable restoration such as a crown or filling. The goal is to maintain the integrity and longevity of the tooth while also improving its appearance and function. Additionally, the study aims to evaluate different techniques and materials used in the reconstruction process to determine their effectiveness and success rates.

CHAPTER ONE

(REVIEW OF LITERATURE)

1.1.Root canal treatment :

Root canal treatment is a dental procedure used to treat infected tooth pulp which would be otherwise extracted, Root canal treatment is required when the dental pulp is irreversibly damaged and involves both coronal and apical pulp. Root canal treatment can also be carried out on teeth with doubtful pulpal state before placing post-retained crowns and overdentures , Root canal therapy is not only performed when pain relief from an infected or inflamed pulp is required. It is also done to prevent adverse signs and symptoms from the surrounding sequelae and promote the healing and repair of the surrounding periradicular tissues. An example of which is if there is trauma to a front tooth which has caused it to be avulsed from the bony socket; endodontic treatment is required following re-implantation to preserve the aesthetics and function of the tooth, even though there may be no adverse symptoms of the dental pulp, or pain present at the time**.(Carrotte and Peter, 2006 ; Ricketts, David, et al., 2011 ; Anderson, Lars, et al., 2012 ; Garg, Nisha, et al., 2013)**

1.2.Special features of endodontically treated teeth :

Once endodontic therapy is completed, the tooth must be adequately restored. Indeed, given the large impact that poor or missing restorations have on the survival of endodontically treated teeth, one could make the argument that the restoration is actually the last step of endodontic therapy. However, it isimportant to realize that endodontically treated teeth are structurally different from nontreated vital teeth. Major changes following treatment include altered tissue physical characteristics, loss of tooth structure, and possibly discoloration.Research has analyzed these tissue modifications at different levels, including tooth composition, dentin microstructure, and tooth macrostructure**.(Louis, Berman Kenneth, et al., 2021)**

1.3.Aesthetic changes in nonvital and endodontically treatedteeth:

Several aesthetic changes may also occur in nonvital or endodontically treated teeth. For example, color change or the darkening of nonvital teeth is a common clinical observation . In addition, incomplete endodontic treatment can contribute to discoloration. For instance, inadequate cleaning and shaping can leave necrotic tissue in coronal pulp horns, resulting in tooth darkening. In addition, root canal filling materials (gutta-percha and root canal sealer cements, MTA-like materials) retained in the coronal aspect of anterior teeth can detract from the aesthetic appearance**. (Dahl and Pallesen, 2003)**

Opaque substances also adversely affect the color and translucency of most uncrowned teeth. Biochemically altered dentin modifies tooth color and appearance. It is generally accepted that organic substances present in dentin (e.g., hemoglobin) might play an important role in this color change and also food and drink pigment penetration triggered by the absence of pulpal pressure. However, the respective contribution of these two phenomena and precise physicochemical mechanisms leading to discoloration are poorly understood or described**.(Hattab, et al., 1999 ; Plotino, et al., 2008)**

Endodontic treatment and subsequent restoration of teeth in the aesthetic zone require careful control of procedures and materials to retain a translucent, natural appearance. It is therefore strongly recommended that one avoid the use of potentially staining endodontic cements and clean all material residues left in the pulpal chamber and access cavity**.(Louis, Berman Kenneth, et al., 2021)**

1.4.Treatment planning and restorative principles :

Many authors have highlighted the need to adequately restore endodontically treated teeth. Weine' claimed that more endodontically treated teeth are lost due to poor restoration than to subse- quent endodontic failure. Swam, Skidmore and Griffin2 found the failure rate of endodontically treated teeth was almost double in cases without adequate restoration. Therefore, for restorative therapy to be considered a success, there must be:

(a) sound endodontic therapy; and (b) the tooth should be adequately restored to enable protection of remaining tooth structure, whilst returning the tooth to occlusal function and satisfying the aesthetic demands of the patient.

To achieve this, basic principles of restorative dentistry must be understood and applied**.(Louis, Berman Kenneth, et al., 2021)**

1.5.Restorative materials and options

Endodontic treatment, particularly excessive access preparations, can result in significant loss and weakening of tooth structure. Tooth structure lost during endodontic treatment increases the risk of crown fracture, with fatigue mechanisms mediating the fracture of roots over time. Restorations of endodontically treated teeth are designed to (1) protect the remaining tooth from fracture, (2) prevent reinfection of the root canal system, and (3) replace the missing tooth structure. **(Louis, Berman Kenneth, et al., 2021)**

According to the amount of tissue to be replaced, restorations of endodontically treated teeth rely on different materials and clinical procedures. As a general rule, most structurally damaged teeth should be restored with an artificial crown. Although the use of a crown built on post and core is a traditional approach, others have advocated the use of direct composite resins for restoring small defects in endodontically treated teeth. More recently, indirect restorations, such as overlays or endocrowns made of composite resins or ceramics, have also been used. The selection of appropriate restorative materials and techniques is dictated by the amount of remaining tooth structure. This is far more relevant to the long-term prognosis of endodontically treated teeth than any properties of post, core, or crown materials**.(Louis, Berman Kenneth, et al., 2021)**

1.5.1.Direct composite restorations

When a minimal amount of coronal tooth structure has been lost after endodontic therapy, a direct resin composite restoration may be indicated. Composite resins are a mixture of a polymerized resin network reinforced by inorganic fillers. When properly cured, resin composites are highly aesthetic, exhibit high mechanical properties, and can reinforce the remaining tooth structure through bonding mechanisms.Typically, 500 to 800 mW/cm2 of blue light for 30 to 40 seconds is necessary to polymerize an increment of composite that must be 1 to 3 mm thick. Unfortunately, the shrinkage that accompanies polymerization of contemporary composite resins remains a significant problem to the long-term success of these restorations. The use of an incremental filling technique, which helps to reduce shrinkage stresses during polymerization, is highly recommended**.(Daidson and Feilzer, 1997 ; Powers and Sakaguchi, 2003).**

In other words, a direct composite restoration may be indicated when only one proximal surface of the tooth has been lost; using an incremental filling technique is mandatory.

Classically, direct composite restorations have been placed in anterior teeth that have not lost tooth structure beyond the endodontic access preparation. In such cases, the placement of a direct composite restoration offers an immediate sealing of the tooth, which prevents coronal leakage and recontamination of the root canal system with bacteria. In vitro studies have demonstrated that the fracture resistance of small bonded restorations is nearly as great as that of intact teeth.**(Gelb, Barouch, et al., 1986 ; Yoshikawa, Sano, et al., 1999)**

Although direct composite resins may also be used for small restorations in posterior teeth, they are contraindicated when more than a third of coronal tissue has been lost. In one study, it was reported that the resistance to fracture of endodontically treated teeth is reduced by 69% in cases where MOD cavities are present. Under such conditions, a direct composite restoration may not be appropriate to prevent the tooth structure from fracture and reinfection. Furthermore, resin composite materials may require the use of reinforcing in vitro fibers to increase their mechanical resistance. Although most studies on the clinical performance of direct composite restorations were conducted on vital teeth, one clinical report indicates that direct in vitro fiber-reinforced composite restorations may represent a valuable alternative to conventional restorations of endodontically treated teeth. On the contrary, inserting an in vitro fiber post in the root canal of an endodontically treated tooth before bonding a direct MOD restoration significantly reduces its fracture resistance compared to the same composite restoration without a post.**(Reeh, Douglas, et al., 1989 ; Reeh, Messer, et al., 1989 ; Soares, Soares, et al., 2008)**

1.5.2.Indirect restorations:

1.5.2.1.Composite or ceramic onlays and overlays

Ceramic or resin composite onlays and endocrowns can also be used to restore endodontically treated teeth. Whereas overlays incorporate a cusp or cusps by covering the missing tissue, endocrowns combine the post in the canal, the core, and the crown in one component. Both onlays and endocrowns allow for conservation of remaining tooth structure, whereas the alternative would be to completely eliminate cusps and perimeter walls for restoration with a full crown.Onlays and overlays are generally constructed in the laboratory from either hybrid resin composite or ceramics. Ceramics are a material of choice for long-term aesthetic indirect restorations because their translucency and light transmission mimic enamel. **(Gohring and Peters, 2003 ; Rocca and Bouillaguet, 2008 ; Kreici, Lutz, et al., 1992)**

New materials either are variations of feldspathic porcelains (e.g., In-Ceram, Cerec, IPS Empress) or may be fabricated from other ceramic systems, including alumina, zirconia, or silica. Among these newer compositions is lithium disilicate, which offers high strength, high fracture toughness, and a high degree of translucency. Physical properties of these materials have improved to the point where they can survive high stress-bearing situations such as posterior restorations in endodontically treated teeth. Onlays, overlays, and endocrowns can also be fabricated from resin composites processed in the laboratory. **(Denry, 1996 ; Drummond, King, et al., 2000 ; Anusavice, 2003 ; Holand, Rheinberger, et al., 2006)**

1.5.2.2.Full crowns

When a significant amount of coronal tooth structure has been lost by caries, restorative procedures, and endodontics, a full crown may be the restoration of choice. In a few cases, the crown can be directly built on the remaining coronal structure, which has been prepared accordingly . More frequently, the cementation of a post inside the root canal is necessary to retain the core material and the crown. The core is anchored to the tooth by extension into the root canal through the post and replaces missing coronal structure. The crown covers the core and restores the aesthetics and function of the tooth. An additional role of the post and core is to protect the crown margins from deformation under function and thereby to prevent coronal leakage. Because most endodontic sealers do not completely seal the root canal space, the coronal seal provided by the placement of a post and core will positively influence the outcome of the endodontic treatment. The post's ability to anchor the core is also an important factor for successful reconstruction, because the core and the post are usually fabricated of different materials. Finally, the luting material used to cement the post, the core, and the crown to the tooth will also influence the longevity of the restoration. The post, the core, and their luting or bonding agents together form a foundation restoration to support the future crown.**(Saunders and Saunders, 1994 ; Morgano and Brackett, 1999 ; Summit, Robbins, et al., 2006)**

The foundation restoration: General considerations

Although many materials and techniques can be used to fabricate a foundation restoration, no combination of materials can substitute for tooth structure. As a general rule, the more tooth structure that remains, the better the long-term prognosis of the restoration. The coronal tooth structure located above the gingival level will help to create a ferrule. **(Barkhoder, Radke, et al., 1989 ; McLean, 1998 ; Pierrisnard, Hohin, et al 2002)**

The ferrule is formed by the walls and margins of the crown, encasing at least 2 to 3 mm of sound tooth structure. A properly executed ferrule significantly reduces the incidence of fracture in endodontically treated teeth by reinforcing the tooth at its external surface and dissipating forces that concentrate at the narrowest circumference of the tooth. A longer ferrule increases fracture resistance significantly. The ferrule also resists lateral forces from posts and leverage from the crown in function and increases the retention and resistance of the restoration.**(Libman and Nicholls, 1995 ; Wu, Pehlivan, et al., 1998)**

To be successful, the crown and crown preparation together must meet five requirements: **(Louis, Berman Kenneth, et al., 2021)**

1. The ferrule (dentin axial wall height) must be at least 2 to 3 mm.

2. The axial walls must be parallel.

3. The restoration must completely encircle the tooth.

4. The margin must be on solid tooth structure.

5. The crown and crown preparation must not invade the attachment apparatus.

Root anatomy can also have significant influence over post placement and selection. Root curvature, furcations, developmental depressions, and root concavities observed at the external surface of the root are all likely to be reproduced inside the root canal. Within the same root, the shape of the canal will vary between the cervical level and the apical foramen. As a result, severe alteration of the natural shape of the canal is often necessary to adapt a circular post inside the root. This increases the risk of root perforation, especially in mesial roots of maxillary and mandibular molars that exhibit deep concavities on the furcal surface of their mesial root.**(Bower, 1979 ; Kuttler, McLean, et al., 204 ; Grandini, Goracci, et al., 2005)**

The tooth is also weakened if root dentin is sacrificed to place a larger-diameter post. A study using three-dimensional electronic speckle-pattern interferometry (ESPI) evaluated the effects of root canal preparation and post placement on the rigidity of human roots. ESPI has the major advantage of being able to assess tooth deformation in real time and can be used repeatedly on the same root because of the nondestructive nature of the test. Study results indicate that root deformability increases significantly after the preparation of a post space. Thus preservation of root structure is also a guiding principle in the decision to use a post, the selection of the post, and the preparation of the post space. This is a reason why not every endodontically treated tooth needs a post and why more conservative approaches that do not rely on the use of a post are currently being developed. However, a post may be used in the root of a structurally damaged tooth in which additional retention is needed for the core and coronal restoration. Posts should provide as many of the following clinical features as possible:

■ Maximal protection of the root from fracture

■ Maximal retention within the root and retrievability

■ Maximal retention of the core and crown

■ Maximal protection of the crown margin seal from coronal leakage

■ Pleasing aesthetics, when indicated

■ High radiographic visibility

■ Biocompatibility

From a mechanical point of view, an endodontic post should not break, should not break the root, and should not distort or allow movement of the core and crown. **(Lertchirakarn, Palamara, et al., 2004)**

1.5.3.Post and core

Requirements of a Tooth to Accept a Post and Core: **(Martinz-Insua, Da Silva, et al., 1998 ; Rosentritt, Furer, et al., 2000 ; Ottl, Hahn, et al., 2002)**

- Optimal apical seal
- Absence of fistula or exudate
- Absence of active inflammation
- No sensitivity to percussion
- Absence of associated periodontal disease
- Sufficient bone support around the root
- Sound tooth structure coronal to alveolar crest
- Absence of any fracture of root.

Conditions where post should not be given (Bower, 1993)

1. Any sign of endodontic failures are evident, i.e. tooth exhibits:

- Poor apical seal and poor quality obturation
- Active inflammation
- Presence of fistula or sinus
- Tender on percussion.

2. If adequate retention of core can be achieved by natural undercuts of crown.

3. If there are horizontal cracks in the coronal portion of the teeth.

4. When tooth is subjected to excursive occlusal stresses such as when there is presence of lateral stresses of bruxism or heavy incisal guidance

Component of post and core system (Calt and Serper, 2002)

1. Residual coronal and radicular tooth structure

2. Post

3. Core

4. Coronal restoration which protect tooth and restores function and esthetics

5. Luting cement

1.5.3.1.Post

It is relatively rigid restorative material placed in the root of a nonvital tooth. It extends coronally to anchor the core material which supports the crown.

Post Mainly Serves ***Two Functions***

• Helps in retaining the core

• Helps in favorable distribution of the stresses through the radicular dentin portion of the teeth to apex.

Earlier it was believed that posts strengthen or reinforce the teeth but it has been shown by various studies that posts actually weaken the tooth and increases the risk of root fracture. It has been suggested that endodontically treated teeth are more brittle and may fracture more easily than vital teeth. Subsequently post space preparation or placement of post can further weaken the root and may lead to root fracture. Therefore, a post should be used only when there is insufficient tooth structure remaining to support the final restoration. In other words the main function of post is retention of the core to support the coronal restoration. **(Caputo and Standlee, 1976)**

Ideal Requirements of a Post

A Post Should**: (Cohen and Burns, 2002)**

• Provide maximum protection of the root to resist root fractures

• Provide maximum retention of the core and crown

• Be easy to place

• Be less technique sensitive

• Have high strength and fatigue resistance

• Be visible radiographically

• Be biocompatible

• Be easily retrievable when required

• Be esthetic

• Be easily available and not expensive.

Posts can be classified as:

I. Prefabricated :

1. Metal prefabricated posts are made up of:

    • Gold alloy

    • High platinum alloys

    • Co-Cr-Mo alloys

    • Stainless steel

    • Titanium and titanium alloys

2. Carbon fiber post

3. Quartz fiber post

4. Zirconia posts

5. Glass fiber post

6. Plastic posts.

II. Custom made : They can be cast from a direct pattern fabricated in patient's mouth or indirect pattern fabricated in the lab.

Posts can also be classified as: (Cooney, et al., 1986)

1. Active post: Active posts mechanically engage the canal walls. They are retentive in nature but can generate stresses during their placement and functional loading.

2. Passive or cemented posts: Passive posts do not engage the canal walls. They are less retentive but also produce low stresses while placement and functional loading.

And According to post design

They can be :

• Smooth

• Serrated

• Parallel sided

• Tapered

• Combination of above

CUSTOM CAST METAL POST

The custom fabricated cast gold post and core has been used for decades as foundation restoration. Custom cast metal post is post of choice for single rooted teeth especially when remaining coronal tooth structure supporting the artificial crown is minimal. In such case, post must be capable of resisting the rotation which can be better achieved by custom cast posts. **(cruz, et al., 2008)**

Figure 1: To the left is a Dentatus screw post mounted in its driver and to the right is a radiograph of a Dentatus screw post in a lower single-rooted tooth. **(Ricketts, 2023)**

Advantages : (DeCleen, 1993)

1. Adaptable to large irregularly shaped canals

2. Very strong

3. Better core retention because core is an inherent part of the post

4. Better choice for small teeth

5. Beneficial in cases where angle of the core must be changed in relation to the post

Disadvantages : (DeCleen, 1993)

1. Requires more chair side time

2. Very rigid so lead to greater stress concentration in root causing root or post fracture

3. Poor aesthetics

4. Prone to corrosion

5. Risk of casting inaccuracy

6. Hypersensitivity in some cases because of Ni-Cr ions

ALL CERAMIC POST AND CORES

Advantages: (vire, 1991)

1. Excellent aesthetics

2. Biocompatibility

3. Good radiopacity.

Disadvantages: (vire, 1991)

1. Brittle, so not indicated in high stress conditions like bruxism

2. Very rigid, so more risk of root or post fracture.

PREFABRICATED POSTS

Indications of Prefabricated Posts (Dickey, et al., 1982)

1. Sufficient width and length of root structure is present.

2. Roots are of circular cross-section, for example, roots of maxillary premolars.

3. Gross undercuts in root canals make pattern fabrication for cast posts difficult.

Carbon Fiber Posts

Carbon fiber posts were introduced by Duret et al in 1996 based on the carbon fiber reinforcement principle. Carbon fiber post consists of bundle of stretched carbon fibers embedded into an epoxy matrix. This was the first nonmetallic post introduced to the dentistry. The original form of carbon post was black and unaesthetic. **(Fernandes, et al., 2001)**

Figure 2: Carbon fiber post in place. **(Sergio Rubinstein, 2007)**

Advantages: (Freedman, 2001)

1. Clinical procedure is less time consuming

2. Strong but low stiffness and strength than ceramic and metal posts

3. Easily retrievable

4. Modulus of elasticity similar to dentin

5. Biocompatible

6. Good retention.

Disadvantages: (Freedman, 2001)

1. Black in color, so unaesthetic

2. Radiolucent, so difficult to detect radiographically

3. Flexture strength decreases by 50 percent by moisture contamination

Glass Fiber Post

It was introduced in 1992. It consists of unidirectional glass fibers embedded in a resin matrix which strengthens the dowel without compromising the modulus of elasticity. **(Gelfand, et al., 1982)**

Figure 3: fibre post in place**. (Derek richards, 2016)**

Advantages: (Gutmann, et al., 1992)

1. Esthetically acceptable

2. Modulus of elasticity similar to dentin

3. Biocompatible

4. Distributes stresses over a broad surface area, thus increasing the load threshold

5. Easy to handle and place

6. Less time consuming

7. Favorable retention in conjunction with adhesive bonding technique

8. High resistance to fracture

9. Easy retrieval.

Disadvantages: (Gutmann, et al., 1992)

1. Poor radiographic visibility

2. Expensive

3. Technique sensitive.

Zirconia Post

These were introduced in dentistry in late 1980 by Christel et al. They are made from fine grained tetragonal zirconium polycrystals (TZP). **(Ingle, et al., 1999)**

Figure 4: Zirconia post-and-core in place. **(Ju-Hyoung Lee, 2018)**

Advantages: (Koutayas, et al., 1999)

1. For teeth with severe coronal destruction, zirconia posts provide adequate strength.

2. Smaller zirconia posts can be used for an all ceramic post and core construction for narrower canals.

Disadvantages: (Koutayas, et al., 1999)

1. Adhesion to tooth and composite is compromised which becomes a problem for retreatment.

2. They are brittle with high modulus of elasticity.

3. When used with direct composite resin build up, high stresses and functional forces may lead to microleakage and their deformation because of high polymerization shrinkage and high coefficient of thermal expansion of composites.

4. Expensive

Post Length

There are many guidelines available as suggested by various authors regarding the post length. It is obvious that longer the post in the canal, more retentive it is. But increased length also increases risk of root fracture and perforation. Generally, it is accepted that apical 3-6 mm of gutta-percha must be preserved to maintain the apical seal . **(Sauaia, et al., 2006)**

Accepted Guidelines for Determining Post Length

These include: **(Sauaia, et al., 2006)**

- Post should be equal to clinical crown length.
- Post should be equal to one-half to two-thirds of the length of the remaining root.
- Post should end halfway between the crestal bone and the root apex.
- Post should be as long as possible without disturbing the apical seal.

Post Diameter

It has been seen that post diameter has little difference in the retention of post, but increase in post diameter increases the resistance form but it also increases the risk of root fracture . Presently there are three different theories/philosophies regarding the post diameter. these are: **(Verissimo, et al., 200)**

<u>The conservationist</u>: It suggests the narrowest diameter that allows the fabrication of a post to the desired length. It allows minimal instrumentation of the canal for

post space preparation. According to this, teeth with smaller dowels exhibit greater resistance to fracture.

The preservationist: It advocates that at least 1 mm of sound dentin should be maintained circumferentially to resist the fracture.

The proportionist: This advocates that post width should not exceed one-third of the root width at its narrowest dimensions to resist fracture.

Post Design

Various types of post designs are available in the market, The posts can be: **(weine, 2004)**

- Tapered, smooth sided—least retentive
- Tapered, serrated type
- Parallel smooth sided
- Parallel serrated type
- Tapered notched
- Parallel threaded type
- Parallell notched type

*Generally parallel sided are more retentive than tapered ones. Threaded posts are more retentive than cemented ones.

Luting Agents

Commonly used dental cements for luting the posts are zinc phosphate, polycarboxylate, glass ionomer cement, resin based composite and hybrid of resin and ionomer. **(colly, et al., 1968)**

Luting Method

Luting method also affects the retention of post. Since luting agents are susceptible to moisture present in the canal, so canal should be absolute dry. **(colly, et al., 1968)**

Optimal method of cementation of posts is: (bower, 1983)

- Dry the canal
- Mix the cement according to instructions
- Uniformly place the cement in the canal
- Place the post into the canal with least possible force to reduce the stress
- Vents should be made to release the hydrostatic pressure when the posts thrust back.

1.5.3.2.Core

Core is the supragingival portion that replaces the missing coronal tooth structure and forms the center of new restoration. Basically it acts as a miniature crown.

Ideal Requirements for a Core Material (caputo, et al., 1976)

• Compressive strength to resist intraoral forces

• Biocompatibility

• Ease of manipulation

• Flexure strength to present core dislodgement

• Ability to bond to tooth structure and post

• Coefficient of thermal expansion similar to dentin

• Minimal water absorption

• Dimensionally stable

• No reaction with chemicals

• Easily available

Core material include composite resins, cast metal, ceramic, amalgam, glass ionomer resin materials.

Amalgam Core

Amalgam has been used as a buildup material, with well recognized strengths and limitations. It has good physical and mechanical properties and works well in high stress area. In many cases, it requires the addition of pins or other methods to provide retention and resistance to rotation. Placement can be clumsy when there is minimal coronal tooth structure, and the crown preparation must be delayed to permit the material time to set. Amalgam can cause esthetic problems with ceramic crowns and sometimes makes the gingival look dark. There is a risk of tattooing the cervical gingival with amalgam particles during the crown preparation. For these reasons, and potential concern about mercury, it is no longer widely used as a buildup material. Amalgam has no natural adhesive properties and should be used with an adhesive system for buildup.**(vire, 1991)**

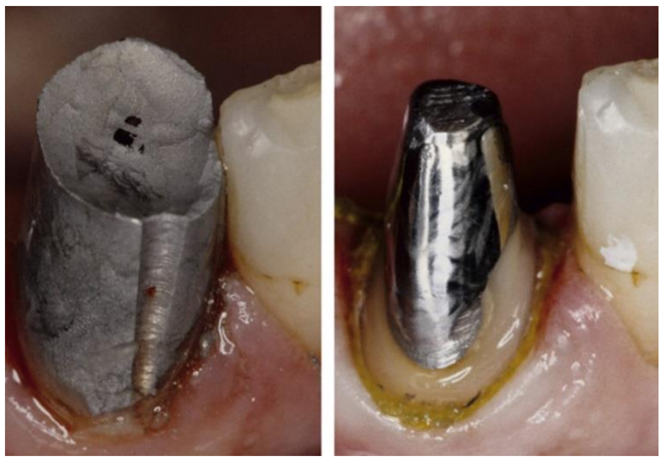

Figure 5: amalgam core. **(Victor Alonso de la Peña, 2016)**

Glass Ionomer Cements core

The glass ionomer materials, including resin-modified glass ionomer, lack adequate strength and fracture toughness as a buildup material and should not be used in teeth with extensive loss of tooth structure. It is also soluble and sensitive to moisture. When there is minimal loss of tooth structure and a post is not needed, GIC works well for block out such as after removal of an MOD restoration. **(Fernandes, et al., 2001)**

Composite Resins core

Composite resin is the most popular core material and has some characteristics of an ideal build up material.

Fig 6: Fabrication of fiber-reinforced composite resin post and core. **(Carlos Alberto Jurado, et al., 2022)**

Advantages: **(gutmann, 1992)**

• High tensile strength and the tooth can be prepared for a crown immediately after polymerization.

• It has fracture resistance comparable to amalgam and cast post and cores, with more favorable fracture pattern when they fail.

• It is tooth colored and can be used under translucent restorations without affecting the esthetic result.

Disadvantages: **(gutmann, 1992)**

• Composite shrinks during polymerization, causing gap formation in the areas in which adhesion is weakest. It absorbs water after polymerization, causing it to swell, and undergoes plastic deformation under repeated loads.

• Adhesion to dentin on the pulpal floor is generally not as strong or reliable as to coronal dentin. Strict isolation is an absolute requirement. If the dentin surface is contaminated with blood or saliva during bonding procedures, the adhesion is greatly reduced. Although composite resin is far from ideal, it is currently the most widely used buildup material.

Ribbond

Ribbond is a spectrum of 215 fibers with a very high molecular weight. First introduced to the market in 1992, Ribbond consists of bondable, reinforced ultra-high-strength polyethylene fibers11 with a high elasticity coefficient (117 GPa) that makes them highly resistant to stretch and distortion6 and a high resistance to traction that allows them to easily adapt to tooth morphology and dental-arch contours . **(Joseph, 1998)**

Clinical use of LWUHM (leno wave ultra high molecule) polyethylene fiber

Ribbond is a colorless and pliable material which adapts readily to tooth morphology and dental arch contour. Its translucency allows aesthetic restoration and it can be cured with light-cured composites. Three different forms of UHMW Polyethylene fiber Ribbond are commercially available: Original Ribbond, Ribbond THM and Ribbond Triaxial. Both Original Ribbond and Ribbond THM consist of cold plasma treated polyethylene fibers but the latter differ in shape and thickness. During applications in which the final fiber breaking strength is of primary concern, Original Ribbond is recommended. Its 0.35 mm thickness can be increased with the addition of filled composite over the fiber during the creation of direct adhesive restorations which do not require tooth preparation. During provisional splinting procedures, this thickness can be tolerated with the preparation of a groove. However in temporary splinting cases, this could cause an occlusion problem especially on the palatal surfaces of the upper incisor teeth.

Ribbond-THM was consequently developed with a higher concentration of thinner (0.18mm diameter) fibers. It was designed for use with applications in which thinness, adaptability, smoothness and a higher modulus were the primary concerns. The primary indications for Ribbond THM are the same as for Original Ribbond, i.e. periodontal splinting, conservative treatment of cracked tooth syndrome, the creation of fixed partial dentures, trauma stabilization, orthodontic fixed lingual retainers or space maintainers as well as directly bonded endodontic posts and cores. **(Strassler and Serio, 1997 ; Kama 2000 ; Belli and Özer, 2000 ; Karaman, 2002 ; Eskitascioglu, 2002 ; Eskitascioglu, et al., 2004)**

Ribbond Triaxial was developed subsequently. Its structure is a hybrid of unidirectional and braided fibers forming a double layered triaxial ribbon and consists of cold plasma treated polyethylene fibers. This material provides greater multidirectional fracture toughness and a greater modulus of elasticity than the other Ribbond products. Where fracture toughness is the primary concern, Ribbond-Triaxial is indicated. However the thickness of the material requires tooth preparation in order to conserve tooth contour. **(Hamza, et al., 2004)**

The use of Ribbond as a post-core material

Early post techniques were quick, inexpensive and simple. These posts were usually cast in a precious alloy or prefabricated in stainless steel, titanium or precious alloy. However, they did not take into account the individual shape of the root canal and, as a result, their adaptation was not ideal. A post core system should include components of differing rigidity. Because the more rigid component is able to resist forces without distortion, stress would be transferred to the less rigid substrate. The difference between the elastic modulus of dentin and that of the post material may therefore be a source of stress to the root structures. **(Kern, et al., 1984 ; Chan., et al, 1993)**

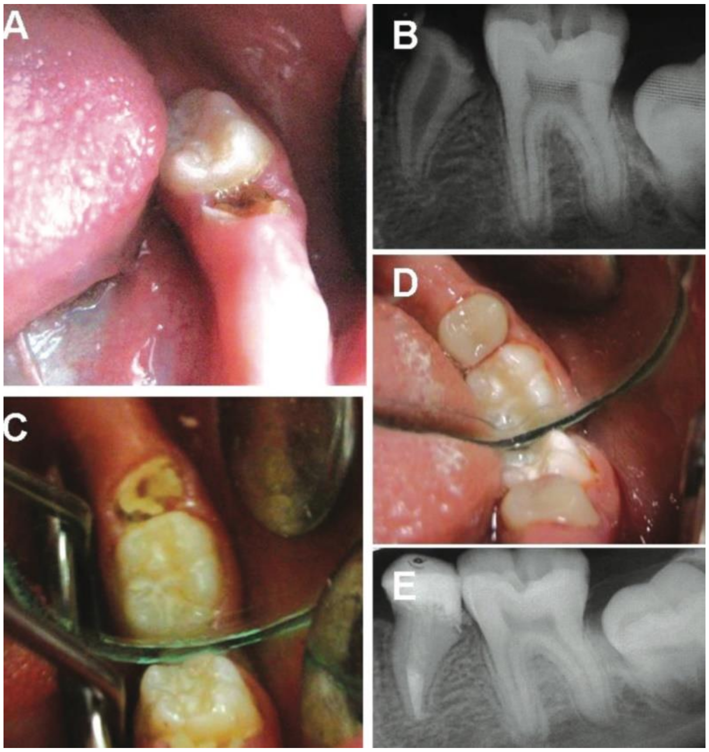

Figure 7: (A). Intraoral view of a hypoplasic mandibular left second premolar; (B). Radiographic appearance of hypoplasic mandibular left second premolar; (C). View of Case after Rib- bond has been inserted into the root canal; (D). Occlusal view of Case after completion of Ribbond-composite endodontic post and core; (E). Final radiographic appearance of hypoplasic mandibular left second premolar**.**

(Nuray, et al., 2019)

Fiber reinforced composite root canal posts with an elastic modulus close to that of dentin were introduced in the 1990's. They were found to reduce the incidence of root fracture, and, in the case of endodontic retreatment, they could be removed from the root canal with ease and predictability without compromising core retention. Glass fibre-supported resin dowel systems comprising unidirectional glass fibres in a resin matrix were introduced in 1992. These materials were able to distribute stress over a broad surface area thus increasing the load threshold at which the dowel began to show evidence of microfracture.**(King and Setchell, 1990 ; Goldberg and Burstone, 1992 ; Purton and Payne, 1996 ; Akkayan and Gülmez, 2002 ; Boschian Pest, et al., 2002 ; Pitel and Hicks, 2003)**

Post restoration technique with Ribbond THM

All carious dentin must be removed. A periodontal procedure is usually indicated when the cervical margin of the restoration is below the gingival tissue. In such cases, placement of rubber dam may be difficult and an opal dam will be helpful to avoid gingival contamination. Orthodontic extrusion of the root is an alternative treatment option. Following isolation of the tooth, gutta percha should be removed from the root canal with rotary instruments and with heated instruments or solvents until the desired length for the post is achieved, At least 4 to 5 mm of gutta percha should be left in situ in order to preserve the apical seal.**(Kwan and Harrington, 1981 ; Dickey, et al., 1982 ; Suchina and Ludington, 1985)**

Previously the length of the post was a critical factor due to a lack of adhesive properties of the post systems. Developments in adhesive dentistry now allow more conservative post space preparation as adhesive luting cements prevent adhesive failure and adhesive post systems prevent cohesive failure. **(Standlee, et al., 1978)**

The findings indicated that the post length should not be shorter than the clinical crown as this would cause an increase in stress accumulation at the cervical region. On the other hand, the post length does not need to extend beyond 2/3 of the root because as the post length increases, so stress moves through the apical area. Preservation of radicular dentin is also an important factor. Teeth restored with larger diameter posts are reported to have the least resistance to fracture with a decrease in the width of the remaining dentin. **(Trabert, et al., 1978 ; Adanir, et al., 2003)**

Short Fibre Reinforced Composite

In 2013, a short fibre-reinforced composite (SFRC) (everX Posterior, GC) was introduced to the market with the goal to substitute the missing dentin with a material having a similar behaviour; additionally, the material has clinically shown to be also able to mimic the stress absorbing properties of the DEJ simultaneously. Fibre-reinforced composites have been used in dentistry for the past 30 years but their true potential and function is just being realised. The reinforcing effect of the fibre these natural tissues to withstand a lifetime of mastication. Therefore, the DEJ might be considered a specialized tissue type of its own fillers is based on stress transfer from the polymer matrix to the fibres **(Garoushi S et al., 2013).**

which is influenced by the size of the fibres and the connection between the fibres and the matrix. The actual average size of the glass fibres in the SFRC material is 1-2 mm, thus exceeding the critical fibre length and making stress transfer possible.

Additionally the fibres are silanised and are therefore able to chemically connect to the matrix. As a consequence of these features, the SFRC is able to reinforce the dental structures even in case of extreme loading conditions. Since these fibres show random orientation, they can reduce the polymerisation stress generated by the composite resin in all directions **(Sailynoja E et al., 2013).**

This makes it possible to use the material in layers up to 4mm. However, the in vitro research carried out by the authors has shown that everX Posterior applied in 2-3mm thick layers with oblique layering gave the best results regarding the fracture resistance of posterior molar teeth among the restored groups **(Basaran EG et al., 2013).**

Furthermore, this technique showed the highest number of repairable fractures once fracture occurred. Thus this technique (2-3 mm thick layers with oblique layering) seems to be the most beneficial. When following the biomimetic restorative principles, the indications for the usage of everX Posterior are dentin substitution in medium and large cavities in posterior teeth, which means that in practice the surfaces of these modern direct restorations should be made of microhybrid or nanohybrid composite covering the SFRC “dentinal core” in at least 1 mm thickness everywhere. The other revolutionary indication of SFRC is in case of indirect restorations or repair of damaged restorations. The SFRC material contains a semi-interpenetrating polymer matrix (semi-IPN), which consists of both linear and cross- linked polymer phases. The linear phase can be dissolved if a suitable adhesive resin is added on its surface, thus enabling the reactivation of the material and also true chemical bonding to it **(Fráter M et al., 2014).**

CHAPTER TWO

(DISCUSSION)

Discussion

Posts and cores are commonly required with pulpless teeth. Custom-cast posts and cores are generally recommended for anterior teeth and most premolars, and prefabricated posts with direct cores are commonly preferred for molars. Complete crowns or onlays that cover all cusps are recommended for all posterior pulpless teeth regardless of the amount of remaining coronal tooth structure to reduce the chances of fracture of these teeth.

In general, the choice between direct or indirect composite restoration for endodontically treated teeth should be made based on the tooth's condition and the specific requirements of the restoration. Direct composite restorations may be preferred for small restorations or when conserving tooth structure is a priority. Indirect composite restorations may be preferred for larger restorations or when optimal strength and aesthetics are required.

There is no single "best" dental post choice that is suitable for all cases, metal posts is a good choice cause they have the advantage of being strong and durable, and they can be used in a variety of clinical situations. However, metal posts can be difficult to remove if necessary, and they may be visible through the tooth structure, which can affect the aesthetics of the final restoration. While fiber posts also a good choice and have become increasingly popular in recent years because they are biocompatible, esthetic, and have a similar modulus of elasticity to dentin. Fiber posts can be easily adjusted and removed if necessary, and they provide excellent retention for the core material but they are not as strong as metal. Zirconia posts can also be a good choice for patients with metal allergies or those who prefer metal-free restorations. Ultimately, the clinician should evaluate each case individually and choose the appropriate dental post based on the specific clinical situation.

The choice of dental core material for endodontically treated teeth depends on several factors such as the remaining tooth structure, occlusion, esthetics, and the clinician's experience and preference. In general, The choice of dental core material for endodontically treated teeth depends on several factors such as the remaining tooth structure, occlusion, esthetics, and the clinician's experience and preference.

Dental Ribbond and ever x are a useful materials for providing additional strength and support to weakened or damaged teeth, and is a good alternative to traditional reinforcement methods in certain cases.

CHAPTER THREE

(CONCLUSION)

Conclusion

1- A pulpless tooth has commonly lost substantial tooth structure as a result of previous restorations, dental caries, and the access preparation for endodontic therapy. Consequently, a pulpless tooth requires a restoration that conserves and protects the remaining tooth structure.
2- Although there are many new materials available for the restoration of pulpless teeth, the prognosis of these teeth relies primarily on the application of sound biomechanical principles rather than on the materials used for the restoration.
3- As a general rule, most structurally damaged teeth should be restored with an artificial crown.
4- the Ferrule Effect, According to Colgate "refers to the need to have several millimeters of sound tooth structure left above the bone (alveolar bone) to decrease the risk of a tooth fracturing after certain procedures that require a crown, such as a root canal."
5- Metal posts seem to work slightly better than resin but Composite post failures tend to be repairable vs metal post failures that tend to be terminal for tooth.
6- Biomechanical Criteria for Evaluation of Core Materials

Bonding (Maximum to Least)
Resin composites > Glass ionomers > Amalgam

Strength
Amalgam > Resin composite > Glass ionomers

Ease of Use
Resin composites > Amalgam > Glass ionomers

Setting Time

Resin composite > Glass ionomers > Amalgam

Dimensional Stability

Amalgam > Glass ionomers > Composite resins

References

A

Adanir, N., Belli, S., Eraslan, O., & Eskitascioglu, G. (2003). Effect of post length on stress distribution under functional forces in a glass fiber-post-restored maxillary central incisor model. Journal of Dental Research, 82(Abstract), 253.

Akkayan, B., & Gülmez, T. (2002). Resistance to fracture of endodontically treated teeth restored with different post systems. Journal of Prosthetic Dentistry, 87(4), 431-437.

Andersson, L., Andreasen, J.O., Day, P., Heithersay, G., Trope, M., Diangelis, A.J., ... Tsukiboshi, M. (2012). International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 2. Avulsion of permanent teeth. Dental Traumatology, 28(2), 88-96.

Anusavice, K. J. (2003). Phillips' science of dental materials (11th ed.). Saunders: St. Louis.

B

Barkhodar, R. A., Radke, R., & Abbasi, J. (1989). Effect of metal collars on resistance of endodontically treated teeth to root fracture. Journal of Prosthetic Dentistry, 61(6), 676-678.

Belli, S., & Özer, F. (2000). A simple method for single anterior tooth replacement. Journal of Adhesive Dentistry, 2(1), 67-70.

Bower, R. C. (1979). Furcation morphology relative to periodontal treatment. Journal of Periodontology, 50(7), 366-372.

Bower, R. C. (1983). Furcation development of human mandibular first molar teeth: a histologic graphic reconstructional study. Journal of periodontal research, 18(4), 412-419.

C

Calt, S., & Serper, A. (2002). Time-dependent effects of EDTA on dentin structures. Journal of endodontics, 28(1), 17-19.

Caputo, A. A., & Standlee, J. P. (1976). Pins and posts-why, when and how. Dental clinics of North America, 20(2), 299-311.

Carrotte, P.V. (2006). Vital guide to Endodontics. Vital, 3(1), 21-25.

Chan, F. W., Harcourt, J. K., & Brockhurst, P. J. (1993). The effect of post adaptation in the root canal on retention of posts cemented with various cements. Australian Dental Journal, 38(1), 39-45.

Cohen, S., & Burns, R. C. (2002). Pathways of the pulp. Mosby.

Colley, T. T., Hampson, E. L., & Lehman, M. N. (1968). Retention of post crown. British Dental Journal, 124(2), 63-69.

Cooney, J. P., Caputo, A. A., & Trabert, K. C. (1986). Retention and stress distribution of tapered-end endodontic posts. Journal of Prosthetic Dentistry, 55(5), 540-546.

Cruz, E. V., Shigetani, Y., Ishikawa, K., Kota, K., Iwaku, M., & Goodis, H. E. (2002). A laboratory study of coronal microleakage using four temporary restorative materials. International endodontic journal, 35(8), 657-662.

D

Dahl JE, Pallesen U. (2003). Tooth bleaching—a critical review of the biological aspects. Critical Reviews in Oral Biology & Medicine, 14, 292.

Davidson CL, & Feilzer AJ. (1997). Polymerization shrinkage and polymerization shrinkage stress in polymer-based restoratives. Journal of Dentistry, 25, 435.

DeCleen, M. J. (1993). The relationship between the root canal filling and post space preparation. International endodontic journal, 26(2), 53-58.

Deliperi, S., & Bardwell, D. N. (2009). Reconstruction of nonvital teeth using direct fiber-reinforced composite resins: a pilot clinical study. Journal of Adhesive Dentistry, 11, 71.

Denry, I. L. (1996). Recent advances in ceramics for dentistry. Critical Reviews in Oral Biology and Medicine, 7, 134.

Dental Trauma Guide. (n.d.). Avulsion.

Dickey, D. J., Harris, G. Z., Lemon, R. R., & Luebke, R. G. (1982). Effect of post space preparation on apical seal using solvent techniques and peeso reamers. Journal of endodontics, 8(8), 351-354.

Dickey, D. J., Harris, G. Z., Lemon, R. R., & Luebke, R. G. (1982). Effect of post space preparation on apical seal using solvent techniques and Peeso reamers. Journal of Endodontics, 8(3), 351-354.

Drummond, J. L., King, T. J., Bapna, M. S., et al. (2000). Mechanical property evaluation of pressable restorative ceramics. Dental Materials, 16, 226.

E

Eskitascioglu, G., & Belli, S. (2002). Use of bondable reinforcement fibre for post and core build up in an endodontically treated tooth: A case report. Quintessence International, 33(7), 549-551.

Eskitascioglu, G., Eskitascioglu, A., & Belli, S. (2004). Use of polyethylene ribbon to create a provisional fixed partial denture after immediate implant placement: A clinical report. Journal of Prosthetic Dentistry, 91(1), 11-14.

F

Fernandes, A. S., Rodrigues, S. V., Sar Dessai, G. M., & Mehta, A. R. (2001). Retention of endodontic posts: a review. Endodontology, 13(1), 11-18.

Freedman, G. A. (2001). Esthetic post and core treatment. Dental Clinics of North America, 45(1), 103-116.

G

Garg, N., & Garg, A. (2013). Textbook of Endodontics (3rd ed.). New Delhi: Jaypee Brothers Medical Publishers.

Gelb MN, Barouch E, & Simonsen RJ. (1986). Resistance to cusp fracture in class II prepared and restored premolars. Journal of Prosthetic Dentistry, 55, 184.

Gelfand, M., Goldman, M., & Sunderman, E. J. (1984). Effect of complete veneer crowns on the compressive strength of endodontically treated posterior teeth. Journal of Prosthetic Dentistry, 52(1), 635-638.

Göhring, T. N., & Peters, O. A. (2003). Restoration of endodontically treated teeth without posts. American Journal of Dentistry, 16, 313.

Goldberg, A. J., & Burstone, C. J. (1992). The use of continuous fibre reinforcement in dentistry. Dental Materials, 8(4), 197.

Grandini, S., Goracci, C., Monticelli, F., & Ferrari, M. (2005). SEM evaluation of the cement layer thickness after luting two different posts. Journal of Adhesive Dentistry, 7(3), 235-240.

Gutmann, J. L. (1992). The dentin-root complex: anatomic and biologic considerations in restoring endodontically treated teeth. Journal of Prosthetic Dentistry, 67(4), 458-467.

H

Hamza, T. A., Rosenstiel, S. F., Elhosary, M. M., & Ibraheem, R. M. (2004). The effect of fibre reinforcement on the fracture toughness and flexural strength of provisional restorative resins. Journal of Prosthetic Dentistry, 91(3), 258-264.

Hargreaves, K.M., Berman, L.H., & Rotstein, I. (2015). Cohen's Pathways of the Pulp (11th ed.). St. Louis, MO: Mosby Elsevier.

Hattab FN, Qudeimat MA, & al-Rimawi HS. (1999). Dental discoloration: an overview. Journal of Esthetic Dentistry, 11, 291.

Holand, W., Rheinberger, V., Apel, E., et al. (2006). Clinical applications of glass-ceramics in dentistry. Journal of Materials Science: Materials in Medicine, 17, 1037.

I

Ingle, J. I., & Bakland, L. K. (1994). Endodontics. Williams and Wilkins.

Joseph, M. L. (1998). Essentials of textiles. New York, NY: Holt, Reinhardt and Winston.

K

Kama, J. C. (2000). Conservative treatment of cracked tooth syndrome using Ribbond fibre-reinforced composite resin. Dental Products Report, 48-49.

Karaman, A. I., Kir, N., & Belli, S. (2002). Four applications of reinforced polyethylene fibre material in orthodontic practice. American Journal of Orthodontics and Dentofacial Orthopedics, 121(6), 650-654.

Kern, S. B., Von Fraunhofer, J. A., & Mueninghoff, L. A. (1984). An in vitro comparison of two dowel and core techniques for endodontically treated molars. Journal of Prosthetic Dentistry, 51(4), 509-514.

King, P. A., & Setchell, D. J. (1990). An in vitro evaluation of a prototype CFRC prefabricated post developed for the restoration of pulpless teeth. Journal of Oral Rehabilitation, 17(6), 599-609.

Koutayas, S. O., & Kern, M. (1999). All-ceramic posts and cores: the state of the art. Quintessence International, 30(6), 383-392

Krejci, I., Lutz, F., & Füllemann, J. (1992). Tooth-colored inlays/overlays, tooth-colored adhesive inlays and overlays: Materials, principles and classification. Schweizer Monatsschrift fur Zahnmedizin, 102, 72.

Kuttler, S., McLean, A., Dorn, S., & Fadavi, S. (2004). The impact of post space preparation with Gates-Glidden drills on residual dentin thickness in distal roots of mandibular molars. Journal of the American Dental Association, 135(6), 903-909.

Kvist, T., Rydin, E., & Reit, C. (1989). The relative frequency of periapical lesions in teeth with root canal retained posts. Journal of Endodontics, 15(6), 578-580.

Kwan, E. H., & Harrington, G. W. (1981). The effect of immediate post preparation on apical seal. Journal of Endodontics, 7(8), 325-329.

L

Lertchirakarn, V., Palamara, J. E., & Messer, H. H. (2001). Anisotropy of tensile strength of root dentin. Journal of Dental Research, 80(2), 453-456.

Libman, W. J., & Nicholls, J. I. (1995). Load fatigue of teeth restored with cast posts and cores and complete crowns. International Journal of Prosthodontics, 8(2), 155-161.

M

Martinez-Insua, A., da Silva, L., Rilo, B., Santana-Penín, U. & Díaz-Afonso, A. (1998). Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon fiber post with a composite core. Journal of Prosthetic Dentistry, 80(5), 527-532.

McLean, A. (1998). Criteria for the predictably restorable endodontically treated tooth. Journal of the Canadian Dental Association, 64(9), 652-656.

Morgano, S. M., & Brackett, S. E. (1999). Foundation restorations in fixed prosthodontics: Current knowledge and future needs. Journal of Prosthetic Dentistry, 82, 643.

O

Ottl, P., Hahn, L., Lauer, H. C. H., & Watzek, G. (2002). Fracture characteristics of carbon fiber, ceramic, and non-palladium endodontic post systems at monotonically increasing loads. Journal of Oral Rehabilitation, 29(3), 175-183.

P

Pierrisnard, L., Leforestier, E., Barthel, C. R., & Bonte, E. (2002). Coronoradicular reconstruction of pulpless teeth: A mechanical study using finite element analysis. Journal of Prosthetic Dentistry, 88(4), 442-448.

Pitel, M. L., & Hicks, N. L. (2003). Evolving technology in endodontic posts. Compendium of Continuing Education in Dentistry, 24(3), 13-29.

Plotino G, Grande NM, Pameijer CH, et al. (2008). Nonvital tooth bleaching: a review of the literature and clinical procedures. Journal of Endodontics, 34, 394.

Powers JM, & Sakaguchi RL. (2006). Craig's Restorative Dental Materials (12th ed.). Mosby, St. Louis.

Purton, D. G., & Payne, J. A. (1996). Comparison of carbon fibre and stainless steel root canal posts. Quintessence International, 27(2), 93-97.

Reeh, E. S., Douglas, W. H., & Messer, H. H. (1989). Stiffness of endodontically treated teeth related to restoration technique. Journal of Dental Research, 68, 540.

R

Reeh, E. S., Messer, H. H., & Douglas, W. H. (1989). Reduction in tooth stiffness as a result of endodontic and restorative procedures. Journal of Endodontics, 15, 512.

Ricketts, D., & Bartlett, D.W. (2011). Advanced Operative Dentistry: A Practical Approach. Edinburgh: Elsevier.

Rocca, G. T., & Bouillaguet, S. (2008). Alternative treatments for the restoration of non-vital teeth. Revue d'Odonto-Stomatologie, 37, 259.

Rosentritt, M., Furer, C., Behr, M., & Lang, R. (2000). Comparison of in vitro fracture strength of metallic and tooth-colored posts and cores. Journal of Oral Rehabilitation, 27(7), 595-601.

S

Sauaia, T.S., Gomes, B.P., Pinheiro, E.T., Zaia, A.A., Ferraz, C.C., & Souza-Filho, F.J. (2006). Microleakage evaluation of intraorifice sealing materials in endodontically treated teeth. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology, 102(2), 242-246.

Saunders, W. P., & Saunders, E. M. (1994). Coronal leakage as a cause of failure in root-canal therapy: A review. Endodontics and Dental Traumatology, 10, 105.

Saunders, W.P., & Saunders, E.M. (1994). Coronal leakage as a cause of failure in root-canal therapy: A review. Dent Traumatol, 10, 105-108.

Soares, C. J., Soares, P. V., de Freitas Santos-Filho, P. C., et al. (2008). The influence of cavity design and glass fiber posts on biomechanical behavior of endodontically treated premolars. Journal of Endodontics, 34, 1015.

Standlee, J. P., Caputo, A. A., & Hanson, E. C. (1978). Retention of endodontic dowels: effect of cement, dowel length and design. Journal of Prosthetic Dentistry, 39(4), 400-405.

Strassler, H. E., & Serio, F. G. (1997). Stabilization of the natural dentition in periodontal cases using adhesive restorative materials. Periodontal Insights, 4, 4-10.

Suchina, J. A., & Ludington, J. R. (1985). Dowel space preparation and the apical seal. Journal of Endodontics, 11(4), 11-17.

Summit, J. B., Robbins, J. W., & Schwartz, R. S. (2006). Fundamentals of operative dentistry: A contemporary approach (3rd ed.). Quintessence: Hanover Park, IL.

T

Trabert, K. C., Caputo, A. A., & Abou-Rass, M. (1978). Tooth fracture- a comparison of endodontic and restorative treatments. Journal of Endodontics, 4(11), 341-345.

V

Verissimo, D.M., & Vale, M.S. (2006). Methodologies for assessment of apical and coronal leakage of endodontic filling materials: A critical review. Journal of Oral Science, 48(3), 93-98.

Vire, D. E. (1991). Failure of endodontically treated teeth: classification and evaluation. Journal of endodontics, 17(7), 338-342.

W

Weine, F.S. (2004). Endodontic therapy (6th ed.). St. Louis: Mosby.

Wu, M. K., Pehlivan, Y., Kontakiotis, E. G., Wesselink, P. R., & Fokkinga, W. A. (1998). Microleakage along apical root fillings and cemented posts. Journal of Prosthetic Dentistry, 79(3),

Y

Yoshikawa T, Sano H, Burrow MF, et al. (1999). Effects of dentin depth and cavity configuration on bond strength. Journal of Dental Research, 78, 898.