Microleakage Assessment of Single Cone Gutta Percha Obturation Technique Using Different Types of Sealers

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This Thesis Submitted for Partial Fulfillment of The Requirements for The Degree of Master Science in Dental Materials Department.

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University of Benghazi **Faculty of Dentistry**

Department of Dental Materials

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This Thesis was Successfully Defended and Approved on **30 .3.2021**

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بسم الله الرحمن الرحيم

قَالُواسُبحَانَك لاَعِلمَ لنَا إلا مَاعَلمتَنَا

إنكَ أَنتَ العَلِيمُ الحَكِيمُ

صدق الله العظيم

(سورة البقرة – الآية ٣٢)

Declaration

I declare that this study is an individual work in which there was no unethical behavior during all the stages from planning the thesis until its writing and all the information in this thesis was obtained according to academic and ethical rules. I declare that I have referenced all the interpretations not obtained in this study and that these sources are listed in the list of sources, there is no violation samples or working during this study and the writing of thesis.

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Anas Samir Elatrash

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LIST OF ABBREVIATIONS

Abb	Full Term
CRCS	Calcibiotic root canal sealer
HCSCs	Hydraulic calcium silicate cements
MTA	Mineral trioxide aggregate
NaOCl	Sodium hypochlorite
NiTi	Nickel-titanium
ZnOE	Zinc oxide eugenol
ZOE	Zinc oxide-eugenol
PTN	Protaper next
PTU	Protaper universal
PTG	Protaper gold
RCFMs	Root canal filling materials
GP	Gutta percha
SC	Single cone
CW	Continuous wave
WL	Working length
ISO	International Standards organization
SD	Standard deviation
ANOVA	Analysis of variance
P	Probability

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Abstract

Introduction: Endodontic sealers play a critical role in providing an impervious seal and creating a fluid-tight apical and coronal seal to prevent microleakage which can potentially lead to treatment failure. Voids in the sealer mass have the potential to allow leakage through obturation. They are more serious in single cone (SC) obturation as the volume of sealer used in this obturation is large.

Aim: To compare the coronal and apical seal of canals obturated with different root canal sealers and to evaluate gaps or voids occurring in roots filled with different root canal sealers.

Materials and Methods: One hundred extracted human upper molars with fully formed and sound palatal roots were used in the study. Sixty teeth were used for microleakage test and the other forty teeth were subjected to voids detection test. The crown of each tooth was decoronated at cement-enamel junction and the palatal root canal was prepared using ProTaper gold rotary instruments. **For microleakage testing:** Sixty specimens were used and divided into 3 equal groups(*n=20)* for SC obturation using two different types of epoxy resin sealers AH26 and vioseal sealers respectively and one control group without sealer. All the specimens were exposed dye penetration test using 2% methylene blue dye. Samples were then evaluated under a stereomicroscope to detect the linear measurement of the dye penetration from the apical constriction. **For voids detection test:** The remaining forty samples were divided into two groups each group (n=20) for SC obturation using AH26 and vioseal sealers respectively. The obturated teeth were sectioned at apical, middle, and coronal third, and area of voids in the sealer was assessed using a stereomicroscope. The collected data was statistically analysis by using Graph Pad Instat software for windows. One-way ANOVA was done for compared time followed by Tukey's pair-wise if showed significant for leakage results. Two-way analysis of variance was performed for gap results. Student t-test was done between groups at different regions for gap. Correlation between leakage and gap/voids area was performed by Pearson correlation test.

Results showed that ***for microleakage assessment,*** the difference in dye penetration microleakage means between groups was statistically significant as revealed by one-way ANOVA test ($p < 0.05$). Pair-wise Tukey's post-hoc test showed non-significant ($p>0.05$) difference between (***AH26*** and ***Vioseal*** *sealers*) groups. ***For gap/voids area*** area (μm^2) for both sealer groups regardless to radicular regions, it was found that vioseal sealer recorded statistically significant higher mean value of gap area than AH26 sealer. Totally irrespective of sealer type it was found that coronal region recorded the highest mean value of gap area followed by apical region mean value. There was a statistically significant direct correlation between leakage and gap/voids area as proved by Pearson correlation test.

Conclusion none of the tested root canal sealers could eliminate the dye infiltration or microleakage formation. Single cone gutta-percha combined with AH26 sealer exhibited less microleakage than vioseal sealer.

Key words: AH26, Vioseal, root canal sealer, single cone obturation, microleakage, voids

1. Introduction

The complete obturation of the thoroughly cleaned and shaped root canal system and the creation of a fluid-tight hermetic seal is the ultimate clinical objective of the endodontic therapy, since its quality can affect the outcome of the root canal treatment [1, 2]. The three-dimensional obturation of the root canal system is essential to isolate residual bacteria and preventing any bacterial recontamination that would lead to relapse of the apical periodontitis [3]. Obturation of the root canal system with a good hermetical seal, both apically and coronally, prevents leakage and contamination of the root canal space [4].

The phenomena of microleakage which is identified as a clinical undetectable passage of bacteria, fluids, molecules or ions between tooth and filling material has been known for more than 100 years [5]. It was reported that presence of such leakage has a great influence on the long-term success of endodontic therapy as it may cause many severe biological effects leading to recurrence of the pathology and failure of the root canal treatment [6]. It has been reported that approximately 60% of endodontic failures are due to inadequate obturation of the root canal system [7]. Such failures have been contributed to the penetration of substances from the apical tissues into the canal [8]. Additionally, failure could be caused by irritants left in the canal that may seep out through an inadequate seal into the periapical tissues [8].

Various obturation techniques based on different strategies have been introduced for the filling of root canals such as the lateral condensation, vertical compression, and thermoplasticized gutta-percha techniques [9]. It was reported that lateral condensation and warm vertical compaction show some disadvantages, such as: lack of gutta-percha homogeneity, high percentage of endodontic cement at the apical portion of the root, poor adaptation to the root canal walls, and apical extrusion of the gutta-percha [10]. To overcome these disadvantages, the single cone technique has been recently used with the advancement of the rotary instrumentation systems [11]. This technique uses larger master cones that best match the geometry of the nickel-titanium rotary [11]. The single-cone technique is one that uses a single principal or master cone with different tapers [11]. This technique has become popular among endodontists over the years due to its greater adaptability to the characteristics of nickel-titanium (NiTi) rotary systems [12]. It was reported that the use of these cones with endodontic cement when the root canal is enlarged with rotary instruments, may promote the sealing of the root canal without the need for accessory cones or lateral condensation which on turn reduces the working time, allows easier and faster filling, and hence, causing less fatigue for both the patient and the operator [13].

It was reported that the combination of single cone and endodontic cement results in minimum applied pressure to the root canal walls and with a uniform mass that prevents failures observed among multiple cones [14]. Another study reported that in terms of quality of the obturation, apical microleakage, and bacterial penetration, this technique provides similar results to those achieved using other techniques [15].

More recently, gutta-percha points of the Pro-Taper system were introduced into the market through which the manufacturer claimed that they are simple to use and result in more rapidly obturation [16]. In this system, root canals are shaped with Pro Taper instruments and filled with perfectly fit gutta-percha point size matching the size of the last instrument used [16].

Since, the single-cone technique is thought simpler than the lateral condensation technique and the operator is less subjected to fatigue during treatment hence, such considerations should be subordinated to the main objective of providing the best treatment for the patient.

Endodontic sealers play a critical role in providing an impervious seal to reduce leakage as they fill the irregularities and minor discrepancies between the root canal walls and core filling material (17). However, inappropriate sealer coating may result in voids and permit bacterial microleakage that can potentially lead to treatment failure (18). The occurrences of these voids are very critical in single cone technique (SC) because the volume of sealer used in this technique is larger than with other techniques (19). A variety of sealers based in different compositions have been used for this purpose including zinc oxide eugenol (ZOE)-based cements, glass ionomer cements, polymer-based sealers, calcium hydroxide-based sealers and silicon-based sealers (20). At present, sealers based on epoxy resins provide very good physical properties and ensure adequate biological performance (21). Leakage along root fillings may increase or decrease during the course of a long period after filling (22).

Dissolution of sealer and the smear-layer may result in a rise in leakage (22), whereas gutta-percha swelling may result in diminished leakage (23). Most sealers shrink during setting, leaving unwanted voids, and gradually dissolve (24). Their sealing ability is also influenced by such physical properties as viscosity, flow, setting time, and film thickness (25). Therefore, Leakage studies on the sealing properties of endodontic materials constitute an important area of research.

Various test methods have been described to evaluate the quality of the seal, such as dye penetration, clearing of the teeth, radioactive isotope testing, bacterial penetration, electrochemical test, and fluid filtration [25,26]. The methodology that uses tooth immersion in various types of dyes is easy to perform [27, 28].

Many studies had used methylene blue as a dye because it is inexpensive, easy to handle, has a high degree of staining and has a molecular weight lower than that of bacterial toxins [29 ,30].

Therefore, the purpose of this in vitro study was to compare the coronal and apical seal of canals obturated with single cone technique using different types of sealers and to assess of the areas of sealer voids.

2. Review of literature

2.1. Overview of root canal treatment

Successful root canal treatment is based on diagnosis, treatment planning, knowledge of tooth anatomy and the traditional concepts of debridement, sterilization, and obturation [31]. Adequate access and a straight-line path to the canal system allow complete irrigation, shaping, cleaning, and quality obturation [32].

Root canal treatment is predictably successful with careful cleaning, and shaping of the canal system, three dimensional obturation and well-fitting coronal restoration [33].

2.1.1. Root canal preparation using Pro-Taper Rotary System

Canal preparation is the most significant step for a successful root canal treatment because this determines the extent of the sterility of the root canal system and the possibility of achieving a satisfactory three-dimensional root filling [34].

Traditional canal preparation techniques using stainless steel (SS) hand files are often complex and their success largely dependent on the clinician's skill, due to the inherent stiffness of these files, which plays a major role in the creation of canal aberrations [35].

These preparation techniques have evolved over time leading to the development of Nickel-Titanium (NiTi) rotary instrumentation [36].

These new techniques are more productive for the clinician as they help in performing root canal treatment in a single visit made the patients more receptive to having endodontic treatment [37].

Rotary nickel-titanium (NiTi) instruments have become popular because of their elasticity, resistance to torsional fracture and superiority over stainless steel hand files [38].

Moreover, rotary NiTi instruments improve working safety, shorten working time and prepare well-shaped root canals with less canal procedural errors compared to hand SS files [39].

It was reported that the type of the alloy, thermomechanical processing and file designs exhibited a great positive effect on the flexibility and fracture resistance properties of the NiTi alloy [40].

Also, Von Fraunhofer et al, 2000 reported that canals preparation with rotary instruments exhibited less microleakage than that one which prepared with hand instruments [41].

ProTaper Universal (PTU) rotary file made of conventional NiTi Wire (Dentsply Maillefer, Ballaigues, Switzerland) characterized by a variable taper through the file's length, passive tips and a convex triangular cross-section to provide superior flexibility and efficiency has been widely used and studied [42].

Recently, ProTaper Next (PTN) files made out of M-Wire alloy having also a changeable taper design and a rectangular cross-section, presenting improved cyclic fatigue resistance in comparison with those made of conventional super elastic were introduced as second generation of ProTaper system [43].

A more recent approach, the same manufacturer introduced ProTaper Gold (PTG) rotary files. This system has identical geometric characteristics as PTU with more flexibility and fatigue resistance, as it is claimed by the manufacturer [44]. In this system, each instrument falls into shaping files (SX, S1, S2) which demonstrate a progressively tapered design or finishing files (F1, F2, F3, F4, F5) which have fixed tapers between D1 and D3, and their tapers decrease progressively from D4 to D14 [45].

Netoand Ginjeira, 2016 reported in their study that protaper gold (PTG) was the rotary system which best respected the initial anatomy of the root canal by presenting a more centered preparation in both coronal and apical curvatures [46].

However, PTG properties have not been widely studied, as this system was introduced in the market in the end of 2014 [47]. For that reason, it was used in this study.

Stavileci et al., 2013 reported in their study that the manual technique for preparation of root canals with stainless steel files produces more canal transportation, whereas rotary files remain more centered in the canal [44].

Guezlow et al., 2005 compared different parameters of root canal preparation using a manual technique and six different rotary nickel-titanium instruments. They found that all NiTi system maintained the original curvature of the root canals well, with minor degree of straightening and the pro-taper instrument created more regular canal diameters with few instrument fractures [48].

`2.2. Root canal Obturation

After the root canal system has been appropriately prepared, it must be obturated with a material capable of completely preventing communication between the oral cavity and the periapical tissue. Nearly 60 % of the failures in endodontic treatment are apparently caused by incomplete obliteration of the radicular space [49].

2.2.1. Purpose of obturation

The purpose of obturation is to seal the cleaned, shaped and disinfected root canal system and to prevent re-infection, since poorly obturated are often poorly prepared [50]. When assessing obturated roots, it has been reported that obturation without voids and to within 2.0 mm of the apex has a significant positive influence on the outcome of treatment [51]. It has been emphasized that good obturation should create a good seal which includes apical and coronal seal as well as lateral seal [51].

2.2.2. Root canal filling materials (RCFMs)

The RCFMs are divided into three types [52]:

- Cones or cores, which are prefabricated root canal filling materials of a given size and shape (taper).

- Sealers, which are pastes and cements that are mixed and hardened by a chemical setting reaction after a given amount of time.
- Combination of the two.

✓ Core materials

A variety of core materials exist which can be used in conjunction with a sealer or cement.

Grossman et al., 1988 have described the properties of an ideal obturation material which include [53]:

1. Easily manipulated and provides sufficient working time.

2. Dimensionally stable with no shrinkage once inserted.

3. Good sealing ability, bacteriostatic and good biocompatibility.

5. Impervious to moisture, and nonporous.

6. Unaffected by tissue fluids with no corrosion or oxidization.

7. It should be or at least not encourage bacterial growth.

9. Radiopaque and easily discernible on radiographs.

10. Does not discolor tooth structure.

11. Sterile or easily and quickly sterilized immediately before insertion.

12. Easily removed from the canal if necessary.

- **Gutta-percha**

Gutta-percha is the most used root canal filling material. Modern gutta-percha cones that are used for root canal fillings contain only about 20 % gutta-percha while the major component is zinc oxide (60 % to 75 %) and the remaining 5 % to 10 % consists of various resins, waxes, and metal sulfates [54]. Chemically pure gutta-percha (or balata) exists in two distinctly different crystalline forms (alpha and beta) that can be converted into each other and the alpha form comes directly from the tree [27]. Most commercial gutta-percha, however, is the beta crystalline form [11].

There are few differences in physical properties between the two forms, merely a difference in the crystalline lattice depending on the annealing and/or drawing process used when manufacturing the final product [11].

Traditionally, the beta form of gutta-percha was used to manufacture endodontic gutta-percha points to achieve an improved stability and hardness and reduce stickiness [44]. However, through special processing and/or modifications to the formulation of the gutta-percha compound, more alpha-like forms of gutta-percha have been introduced, resulting in changes in the melting point, viscosity, and tackiness of the gutta-percha point Gutta-percha with low viscosity will flow with less pressure or stress, while an increase in tackiness will help create a more homogeneous filling [55]. and hence, several manufacturers have introduced products to take advantage of these properties such as Thermal, Densfil, Microseal) [56].

According to Vishwanath and Rao, 2019 the main advantages of gutta-percha as a filling material are [57].

1. It is an inert material with high compatibility and adaptability to the irregularities and contour of the canal by the lateral and vertical condensation method.
2. It can be softened and made plastic by heat or by organic solvents and easily removed from the canal.

3. It is dimensionally stable, tissue tolerant, radiopaque and does not cause tooth discoloration.

On other hands, the same authors reported main disadvantage of gutta-perch is lack of rigidity where the smallest, standardized gutta-percha cones are relatively more difficult to use unless canals are enlarged above size 25. Because of their greater taper, no- standardized cones of smaller sizes are more rigid than small, standardized cones and they are often used to better advantage as primary cones in small canals (55).

Also, Banasode et al., 2018 reported that gutta-percha is suffered from lack of adhesive quality since gutta-percha does not adhere to the canal walls consequently, sealer or a cementing agent is required which may bring the risk of using tissue-irritating sealers (58). So, it can be easily displaced by pressure or vertical distorted by stretching which permits its overextension beyond the apical foramen during the condensation process unless it meets an obstruction or is packed against a definite apical constriction (58).

- **Gutta-percha points or cones are supplied in two shapes, which are:**

The traditional form (solid form) is a cone shaped to conform to the perceived shape of the root canal (fig. 1) (59).

Figure 1. Cone shaped gutta-percha points.

Today, these cones are preferred by dentists who use the warm vertical compaction technique of filling [60]. This is because the original spreaders used in the lateral compaction technique were shaped to match these cone shapes and sizes [60]. The traditional cones have long been used as the accessory cones in the lateral compaction technique.

The other shape of gutta-percha points is standardized to the same size and shape as the standardized (ISO) endodontic instruments (fig. 2) [59].

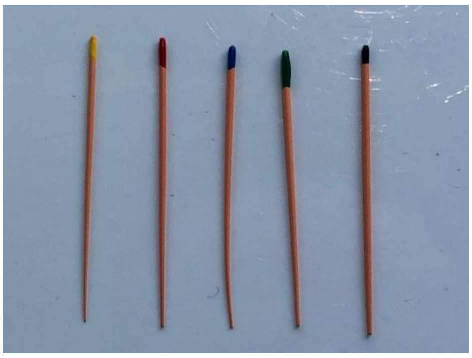


Figure2. Standard gutta-percha cone.

These points are available in the standardized .02 taper as well as in increased taper sizes (.04, .06, etc.) to correspond to the newer tapered instrument sizes (55).

Color coding the numbered points to match ISO instrument color has become routine and it is now rare to find the standardized points without these convenient markings (55).

Gutta-percha cones are available in non- standardized form (fig. 3) (55). The non-standardized cones have relatively small diameter tips compared to their larger bodies. Their nomenclature which refers to these two dimensions a «fine-medium» cone has a fine tip and a medium body (11).

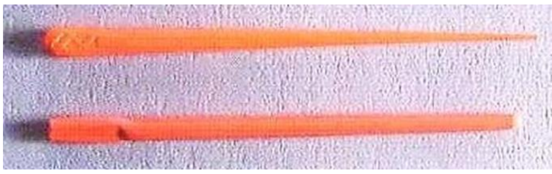


Figure 3. Non-standardized (top) and standardized (bottom) cones.

The accessory gutta-percha points have a pointed shape. They are available in assorted sizes and are used to supplement the standardized master point to fill the coronal flared part of the root canal (11).

More recently, gutta-percha points for ProTaper (Dentsply Maillefer) have been introduced for simple and time-efficient obturation. In this system, root canals are prepared with the ProTaper instruments and filled with the point that fits the size of the finisher file. The manufacturer claims that ProTaper gutta-percha points perfectly fit canals that have been prepared with ProTaper files (16).

Table (1): Dimensions of gutta-percha cones [61].

Type of cone	Size
Standardized cones	Corresponds in diameter and taper (2 %) to root canal shaping instruments according to ISO 6877. The sizes of the gutta-percha cones range from ISO 10 to ISO 140
Accessory cones	Larger taper, descriptive size, may be used for lateral compaction
Greater taper cones	Cones with a 4 % or 6 % (and up to 12 %) taper or cones with varying taper used together with special engine-driven root canal shaping instruments
Compaction cones	Taper corresponds to the taper of finger-spreaders

Because gutta-percha cannot be heat sterilized, other decontamination methods must be used. The most practical method to disinfect gutta-percha by submerging them in 5% NaOCl for 1 minute before its use [62].

However, after this disinfection and before its use for obturation, it is imperative that the gutta-percha be rinsed in ethyl alcohol to remove crystallized NaOCl, such crystals may impair the obturation seal [63].

Gutta-percha cones should be stored in cool and dark conditions in order to prevent hardening and brittleness due to further crystallization and/or oxidation [52].

Gutta-percha cannot be used as the sole filling material; it lacks the adherent properties necessary to seal the root canal space. Therefore, a sealer or cement is always needed for the final seal [52].

2.3. Types of modified gutta- percha (GP)

2.3.1. Coated gutta-percha

This surface modification is performed to improve and enhance adaptability of GP such as:

- Resin coated GP is now available that may achieve bonding between the solid core and a resin sealer. This uniform methacrylate-based resin coat is placed on the gutta-percha cone by the manufacturer, so, when the material meets the resin sealer, a resin bond is formed (64).
- Bioceramic coated GP in which bioceramic particles in the form of nano particles of calcium phosphate silicates are incorporated and coated onto GP points to enhance the quality of obturation along with specific hydrophilic bioceramic sealers. These kinds of obturation bring about slight expansion rather than the usual shrinkage, which is advantageous to seal the canals (65).

2.3.2. Medicated gutta-percha

The melding of an antibacterial substance to a gutta-percha cone or other solid core obturation materials may have utility in preventing root canal therapy failures due to coronal or apical microleakage for that reason Medicated gutta-percha cones are not used on a regular basis (11).

2.3.3. Calcium hydroxide containing gutta-percha

Calcium hydroxide containing gutta-percha is made by combing 58 % of calcium hydroxide in matrix of 42 % gutta-percha and they are available in

ISO size of 15-140. Action of Ca (OH)2 is activated by moisture in canal [66].

It was reported that this type of gutta-percha cones has many advantages such as easy to insert and remove, minimal or no residue and firm for easy insertion left but on other hand, they are suffered from radiolucency and short-lived action [58].

2.3.4. Iodoform containing gutta-percha

Iodoform containing gutta-percha remains inert till it comes in contact with the tissue fluids. On coming in contact with tissue fluids, free iodine is released which is antibacterial in nature [67].

2.3.5. Chlorhexidine diacetate containing gutta-percha

In this gutta-percha matrix embedded in 5 % chlorhexidine diacetate. This material is used as an intracanal medicament [68].

2.3.6. Active gutta-percha

Active GP (Brasseler, USA) consists of gutta-percha cones impregnated on the external surface with glass ionomer. Single cones are used with a glass ionomer sealer. They are available in .04 and .06 tapered cones; the sizes are laser verified to ensure a more precise fit. The single cone technique is designed to provide a bond between the dentinal canal wall and the master cone [69].

2.4. The resin-based obturation systems

The resin-based obturation systems Epiphany (Pentron Clinical Technologies), RealSeal (Sybronendo), and Resinate (Obtura Spartan, earth City, Mo) have been introduced as alternatives to gutta-percha (70).

Resilon is high performance industrial polyurethane that has been adapted for dental use. The resin sealer bonds to a resilon core, and attaches to the etched root surface forming a monoblock system, a matter that remains controversial (71).

The system resembles gutta-percha and can be placed by lateral compaction, warm lateral or vertical compaction, or thermoplastic injection. It consists of a resin core material (resilon) composed of polyester, difunctional methacrylate resin, bioactive glass, radiopaque fillers, and a resin sealer (72). Resilon is non-toxic, non-mutagenic and biocompatible (72).

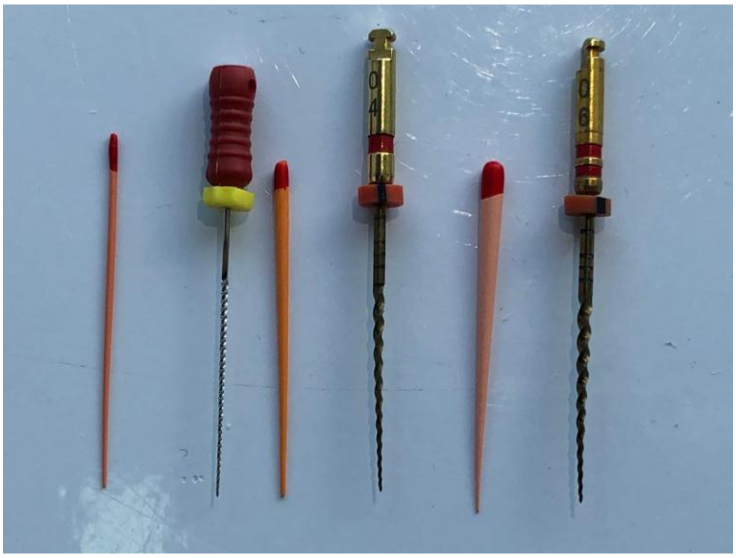


Figure 4.#.02, #.04, and #.06 tapered single cone gutta-percha.

2.5. Silver cones

Silver points were the most widely used solid-core metallic filling material, although points of gold, iridium-platinum, and tantalum are also available. Silver points cannot conform with the shape of root canal because they lack plasticity; the use of silver points is not indicated in filling of large, triangular canals as in maxillary teeth [73]. Silver cones do not possess adhering qualities, so a sealer is required to adequately seal the canal [74].

The rigidity provided by the silver cones makes them easy to place and permits more predictable length control; however, their inability to fill the irregularly shaped root canal system permits leakage [75]. When silver points contact tissue fluids or saliva, they corrode. It has been seen that silver corrosion products are toxic in nature and thus may cause tissue injury and hence, their uses today are below the standard of care in contemporary endodontic practice [74,188].

2.6. Sealers

Root canal sealers are necessary to seal the space between the dentinal wall and the obturating core interface and to fill voids and irregularities in the root canal, lateral and accessory canals, and spaces between gutta-percha points used in lateral condensation [73]. Sealers also serve as lubricants during the obturation process [76]. However, inappropriate sealer coating may result in voids and permit bacterial microleakage which can potentially lead to treatment failure [77].

2.6.1. Functions of root canal sealers

According to Rathi et al., 2020 root canal sealers are used in conjunction with filling materials for the following purposes [78]:

1. Antimicrobial agent: All the commonly used sealers contain some antibacterial agent. So, a germicidal quality is excreted immediately after its placement.

2. Sealers are needed to fill in the discrepancies between the filling material and the dentin walls.

3. Binding agent: Sealers act as binding agent between the filling material and the dentin walls.

4. Lubricant: With the use of semisolid materials, the most important function for the sealer to perform its action of lubrication.

5. Radiopacity: All sealers display some degree of radiopacity; thus, they can be detected on a radiograph. This property can disclose the presence of auxiliary canals, resorptive areas, root fractures, and the shape of apical foramen.

2.6.2. Acceptable methods of placing the sealer into the canal include the following [79, 80]:

1. Placing the sealer on the master cone and pumping the cone up and down in the canal.

2. Placing the sealer on a file and spinning it counterclockwise.

3. Placing the sealer with a lentulo spiral.

4. Using a syringe.

2.6.3. Properties of an ideal sealer [81]

1. Exhibit tackiness when mixed to provide good adhesion between it and the canal wall when set.

2. Establishes a hermetic seal.

3. Radiopaque, so that it can be seen on a radiograph.

4. Very fine powder, so that it can mix easily with liquid.

5. No shrinkage on setting.

6. No staining of tooth structure.

7. Bacteriostatic, or at least does not encourage bacterial growth.

8. Exhibits a slow set.

9. Insoluble in tissue fluids.

10. Tissue tolerant; that is, nonirritating to peri radicular tissue.

11. Soluble in a common solvent if it is necessary to remove the root canal filling.

12. The sealer also must have cohesive strength to hold the obturation material together.

13. It should not provoke an immune response in peri radicular tissue.

14. It should be neither mutagenic nor carcinogenic.

On other hand, according to the American National Standards Institute/American Dental Association's (ANSI/ADA) the ideal requirements for sealer include radiopacity of at least 3 mm aluminum thickness, less than 3% solubility, more than 20 mm flowability, not more than 50 µm film thickness and setting time that does not exceed 10% of the time specified by manufacturer's statement [82].

2.6.4. Classification of root canal sealers

Sealers may be broadly classified according to their composition [83]:

1. Eugenol.

2. Non-eugenol.

3. Medicated.

I. Eugenol group may be divided into subgroups, namely:

- Silver containing cements:

a) Kerr sealer.

b) Procosol radiopaque silver cements.

- Silver free cements:

a) Procosolnonstaining cements.

b) Grossman's sealer.

c) Tubliseal.

d) Wach's paste.

II. Non-eugenol: These sealers do not contain eugenol and consist of a wide variety of chemicals.

III. Medicated group which have therapeutic properties.

- **Classification of sealer according to Grossman [84]**

1. Zinc oxide resin cements.

2. Calcium hydroxide cements.

3. Paraformaldehyde cements.

4. Pastes.

- **According to the intended use [84]**

Type I: Material is intended to be used with core material:

- Class I: Includes materials in the form of powder and liquid that set through a non-polymerizing process.
- Class II: Includes materials in the form of two pastes that set through a nonpolymerizing process.
- Class III: Includes polymers and resin systems that set through polymerization.

Type II: Intended for use with or without core material or sealer:

- Class I: Powder and liquid- non-polymerizing.
- Class II: Paste and paste- non-polymerizing.
- Class III: Metal amalgams.

- Class IV: Polymer and resin systems polymerization.

- **Classification of sealer according to Clark [85]**

1. Absorbable.

2. Non-absorbable.

- **Classification of sealer according to Ingle [85]**

1. Cements.

2. Pastes.

3. Plastic.

4. Experimental sealers.

2.7. Brief details on some root canal sealers used today

2.7.1. Zinc oxide eugenol cements

Many endodontic sealers are simply zinc oxide eugenol (ZnOE) cements that have been modified for endodontic use [86]. ZnOE-based sealers are easy to handle, radiopaque material [87], and having antimicrobial properties on a variety of microorganisms [88]. They exhibit a slow setting time, low solubiity, and less shrinkage on setting [89]. Formaldehyde-releasing ZnOE root canal sealers should not be used anymore because of their inherent toxic potential [90.

2.7.2. Calcibiotic root canal sealer (CRCS)

CRCS is a zinc oxide, eugenol-eucalyptol sealer to which calcium hydroxide has been added for its osteogenic effect [91, 92].

CRCS takes three days to set fully in either dry or humid environment and because of little water resorption property, it is quite stable [91].

Though sealing is improved, but since calcium hydroxide is not released from the cement, its main role (osteogenic effect) becomes questionable [91].

2.7.3. Chloropercha

Chloropercha was another type of sealer used for many years. It is made by mixing white gutta-percha (i. e., Alba) with chloroform to allow gutta-percha to fit better in the canal [93]. However, chloropercha has no adhesive properties and is no longer used as an obturation material in root canal therapy. The use of chloroform has been sharply curtailed for many years because of its demonstrated toxicity [94].

- ✓ **Modified chloropercha methods.** There are two modifications [93]:
  - Johnston–Callahan.
  - Nygaard–Ostby.
- ✓ **Johnston–Callahan method.** In this method, the canal is repeatedly flooded with 95 percent alcohol then dried and after that, it is flooded with Callahan resin chloroform solution for 2–3 minutes [95]. A gutta-percha cone is inserted and compressed laterally and apically with a plugger until the gutta-percha is dissolved completely in the

chloroform solution in the root canal. Additional points are added and dissolved in the same way [60].

- ✓ **Nygaard–Ostby method.** It consists of Canada balsam, colophonium and zinc oxide powder mixed with chloroform. In this technique, the canal walls are coated with Kloroperka. The primary cone dipped in sealer is inserted apically pushing partially the dissolved tip of the cone to its apical seal [96]. Additional cones dipped in sealer are packed into the canal to obtain a good apical seal [84].

2.7.4. Calcium hydroxide sealers

These sealers are promoted as having therapeutic effects because of their Ca (OH)2 content [97]. It was thought that these sealers would exhibit antimicrobial activity and have osteogenic cementogenic potential, which is thought to occur because of its ability to release hydroxyl ions and by having a high pH [97].

These materials have been shown to have similar sealing ability to zinc oxide and eugenol preparations; however, long-term exposure to tissue fluid may possibly lead to dissolution of the material as calcium hydroxide is leached out [98].

Handling properties of calcium hydroxide sealers are adequate; the radiopacityis regarded as sufficient and the material can be removed from the root canal with common rotary instruments [99].

2.7.5. Hydraulic calcium silicate cements

Hydraulic calcium silicate cements (HCSCs), which well known as MTA (mineral trioxide aggregate) were developed more than 20 years ago. Their composition is largely based on Portland cement components (di- and tri-calcium silicate, Al- and Fe-silicate) sealers [(100)]. Some hydraulic calcium silicate-based materials contain additional components (setting modulators, radiopacifying agents, drugs, etc.) [(101)].

They have important properties such as the ability to set and to seal in moist and blood-contaminated environments, biocompatibility, adequate mechanical properties, but their principal limitations are long setting time, low radiopacity and difficult handling [(102)]. Hydraulic calcium silicate cements regulate the differentiation of osteoblast, fibroblasts, cementoblasts, odontoblasts, pulp cells and many stem cells because they can induce the chemical formation of a calcium phosphate/apatite coating when immersed in biological fluids [(101,103)].

These properties have led to a growing series of innovative clinical applications such as root-end filling, pulp capping and scaffolds for pulp regeneration, root canal sealer, etc. [(101)]. The material is rather difficult to place, and the working time may be short [(87)].

2.7.6. Glass ionomer sealer:

Glass ionomer cements were first introduced into dentistry in 1975 and since then they have been used in a wide range of clinical applications and they advocated for use in obturation because of their dentin bonding properties [(104)].

Conventional glass ionomers are dispensed in a powder form supplied with its own liquid. The powder is formed of Conventional glass ionomers are dispensed in a powder formed of fluoroaluminosilicate glass and liquid which is an aqueous solution of a polyalkenoic acid, such as polyacrylic acid, although in later formulations, the acid may be added to the powder in a dried polymer form (105).

These cements have optimal physical qualities, good bonding to dentin, show a minimum number of voids, low surface tension and optimal flow property (106). But on other hand, they cannot be removed from the root canal in the event of retreatment as there is no known solvent for glass ionomer cements (107).

2.7.7. Resin sealer

Resin sealers have a long history of use, provide adhesion, and do not contain eugenol. The use of dentin bonding agents in root canal filling was introduced to enhance the endodontic resin-based sealers adhesion to the root dentin (83). The newer endodontic methacrylate resin-based sealers (RealSeal, Epiphany) use a separate self-etching primer before application of flowable composites to the primed dentin (108). or else consist of a single product of the self- adhesive methacrylate sealer, incorporating a self-etching primer and a moderately filled flowable composite (MetaSEAL; RealSeal SE, Epiphany SE) (108,109).

Epoxy-based sealers were introduced to endodontics by Schroeder (110) and they have been used for more than 40 years worldwide and their handling properties are usually considered to be good in addition to their sufficient radiopacity [111]. However, the materials set to a hard mass that, in a clinically relevant time, is virtually insoluble even for organic solvents and hence, they must be used together with gutta-percha cones [112].

Among of these epoxy resin sealers is AH-26 sealer which composed of low molecular weight epoxy resins and methenamine and bismuth oxide and set by addition reaction between epoxide groups attached to epoxy resins and amines to form polymer [113,114].

It was reported that AH26 sealer is considered as one of the most consuming sealers in dentistry nowadays due to owning desirable properties such as positive handling characteristics, good flow, adherence to dentin walls, appropriate flow, proper dentinal sealing ability and sufficient functioning time [6,115]. For these reasons it has been utilized in the present study.

Zemner et al., 1997 reported that AH26 shows least leakage when compared with the AH Plus on which the microleakage was assessed using dye penetration after 2, 4 and 10 days [116].

Ehsani et al., 2014 evaluated the microleakage of different endodontic sealers and they concluded that leakage in AH26 provided the least apical micro-leakage when compared with zinc oxide eugenol and MTA [117].

The findings obtained by Tabrizizadeh et al., 2008 for the assessment of the apical sealing ability of MTA alone and laterally condensed gutta-percha with AH26 a showed that the canal obturation with gutta-percha and AH26 sealer may provide a better apical seal compared with MTA alone [118].

Shourgashti et al., 2018 performed a study to evaluate the physical properties, cytotoxicity and sealing ability of HealApex (a new premixed calcium-silicate-phosphate-based biosealer) in comparison with AH-26. The specimens were obturated with gutta-percha and experimental sealers employing lateral condensation technique. Sealing ability of sealers was investigated for up to one month using fluid filtration method. The obtained results showed that short term, the sealing ability of HealApex was comparable with AH-26 whilst in long term, HealApex's sealing ability was better than the epoxy resin-based sealer [(119)].

Other epoxy resin–based sealer used in the present study was Vioseal sealer. The manufacturer claims that Vioseal has good sealing ability, biocompatibility, and insoluble in tissue fluids and it has an excellent antibacterial effect and lubricant during inserting of GP point [(82)].

Al-Anaz et al., 2020 evaluated the interfacial adaptation of EndoSequence BC sealer, MTA Fillapex and Vioseal sealers to root canal dentin with and without a main gutta-percha cone. A total of 60 single-rooted human teeth with single canal were used after removal of their crowns at the CEJ level to standardize the root length (16 mm). Samples were instrumented using Protaper next NiTi rotary system and after irrigation and smear layer removal, samples were randomly divided according to the sealers used into three groups of 20 samples each, and each group was further subdivided based on obturation technique into six subgroup three group with cone and three group without cone of 10 sample each. The samples were sectioned to examine sealer adaptation using scanning electron microscope. The authors reported that Vioseal sealer showed high interfacial adaptation when compared with other sealers. The superior adaptation of this sealer could be due to its ability to bond to root dentin chemically by reacting with any exposed amino groups in collagen to form covalent bonds between the epoxy resin and collagen [120].

2.7.8. Epiphany sealers

Epiphany is a dual curable dental resin composite sealer composed of Bis-GMA, ethoxylatedBisGMA, UDMA, and hydrophilic difunctional methacrylates with fillers of Ca (OH)2, barium sulfate, barium glass, and silica with total filler content 70 % by weight [121].

Epiphany was designed for use with resilon instead of gutta-percha, although it can also be used with either core material [122]. Unlike other resin sealers, this system's sealer requires a self-etch primer before placement of the resin sealer. Uniform application of a primer or an adhesive in root canals and removal of solvent are considered to be difficult, especially in the apical third [122]. Massive air blowing into the canal should generally be avoided. The use of paper point is not very effective and special delivery systems (e.g. Microbrushes) are recommended for application of primers and sealers [87,123].

It was reported that epiphany sealer is biocompatible, non-toxic, provides good coronal seal, and Forms monoblock, but it does not retain its softness after heating [87].

2.7.9. Silicone sealers

The first of those materials was based on C-silicones (condensation crosslinking silicones); newer materials are based on A-silicones (addition crosslinking). Silicone sealers are supplied in capsules and after mixing can easily be injected into the canal followed by the insertion of gutta-percha [124]. They arenon-resorbable sealers with rubbery consistency and show a great difficultly to remove from the canals [87].

2.7.10. Bioceramic sealers

Bioceramic sealer is composed of zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, and various filling and thickening agents [125]. It is biocompatible and exhibits antimicrobial properties during the setting reaction. The manufacturer advocates expressing the sealer into the coronal one third to one half of the canal and then seating the master gutta-percha cone [125].

2.8 Obturation Techniques

Today, most root canals are being filled with gutta-percha and sealers [32]. Several obturation techniques are used for the filling of root canals: the lateral condensation, vertical compression, and thermoplasticized gutta-percha techniques, Carrier-based systems, Plastic- injection techniques, and Apical barrier techniques. More recently, with the advancement of the rotary instrumentation systems, the single-cone obturation technique has been used. The choice of using these techniques depends on the canal anatomy and the unique objectives of treatment in each case [32].

2.8.1. Lateral Cold Condensation

This technique has been the gold standard to which other techniques have been compared [126]. Lateral cold condensation has the advantage of excellent length control thus overfilling is avoided and can be accomplished with any of the acceptable sealers [127]. In this technique, a master cone corresponding to the final instrumentation size and length of the canal is coated with sealer, inserted into the canal, laterally compacted with spreaders and filled with additional accessory cones [59]. However, this technique may not fill canal irregularities, it does not produce homogenous mass and thus spaces may be present in between the cones [127].

It has been found that using of vibration, heat and ultrasonic with lateral condensation can produce adequate obturation where the heat can soften the cone for better condensation and homogeneity of gutta-percha and hence the clinical success rate will increase [128].

2.8.2. Vertical Compaction

Vertical condensation of gutta-percha forms the basis for many techniques, such as the master cone sectional, warm gutta-percha, and thermoplasticized techniques. A master cone corresponding to the final instrumentation size and length of the canal is fitted, coated with sealer, heated and compacted vertically with pluggers until the apical 3-4mm segment of the canal is filled. Then the remaining root canal is back filled using warm pieces of core material [74].

Advantage of warm vertical compaction technique includes movement of the plasticized gutta-percha and filling of canal irregularities and accessory canals, while the main disadvantage includes risk of vertical root fracture, extrusion of material in to the peri radicular tissues and time consuming [128].

2.8.3. System B/Continuous Wave

It was developed by Buchanan as a variation of warm vertical compaction. Continuous wave is essentially a vertical compaction (down-packing) of core material and sealer in the apical portion of the root canal using commercially available heating devices such as System B (SybronEndo, Orange, Calif.) and Elements Obturation Unit™ (SybronEndo, Orange, Calif.), and then back filling the remaining portion of the root canal with thermoplasticized core material using injection devices [59,129].This technique provides excellent apical control, thorough condensation of the main and the lateral canals and it creates single wave of heating and compacting thereby compaction of filling material can be done at the same time when it is heat softened [84].

2.8.4. Thermomechanical Compaction

The idea of this technique involved master cone coated with sealer is fitted to working length and is compacted by hand spreader and then with a rotary instrument running between 5000 and10000 rpm [130]. The rotary instrument is precoated with pre-warmed gutta-percha, which owing to its more fluid state, and due to friction of the compactor and the canal wall, the GP and sealer are compacted apically and laterally as the device is slowly withdrawn from the canal. This technique provides a good 3-

dimensional obturation but on other hand, the risks of apical extrusion and instrument separation are very high [128].

2.8.5. Carrier-based thermoplasticized technique

This technique depends on uses Warm GP or 'Resilon'-coated plastic core carried and inserted into the canal to the working length following coating the canal with sealer. This technique is fast and obturates the canal well, but true length control is lacking and there is a risk of extrusion of both sealer and GP risk of voids and difficulties in removal in retreatment cases [131].

2.8.6. Plasticized GP injection techniques

This plastic technique based on the benefit of improving obturation as the material can flow within the canal space. It was reported that using of Injection technique alone without a cold cone or plug of GP at the apical constriction promoted difficulties in length control cannot prevent extrusions, especially into the sinus or inferior dental canal [132].

2.8.7. Apical barrier

An apical barrier technique plays an important role when obturating teeth with open apices [133]. Mineral trioxide aggregate (MTA) is the material of choice in which MTA is compacted by hand to fill the apical 3−5 mm of the canal first then, a total of 3−5 mm of MTA should be placed in increments with either hand instruments or micro pluggers [133]. The remainder of the canal system can then be filled with an injection technique is hydrophilic and sets in moist atmosphere having several advantages include excellent biocompatibility, reduced toxicity, radiopacity, bacteriostatic nature, and resistance to marginal leakage [134].

2.8.8. Silver cone obturation technique

It is indicated in teeth with fine, tortuous, curved canals and in mature teeth with calcified canals [59]. This technique is easy to handle and it is useful in case of negotiation of extremely curved canals, but the silver cone is prone to corrosion and difficult to retrieve [59].

2.8.9. Single Cone Technique

The single-cone technique was developed in the 1960s, with the standardization of the endodontic instruments and filling points [135].

It was advocated that, after the preparation of the apical stop, filling points such as a gutta-percha, silver or titanium point would promote the root canal sealing after application of a thin and uniform cement layer [136].

Historically, the idea of using a single gutta-percha point to obturate canals was rejected because this method would depend too heavily on sealers that were subject to dissolution and shrinkage to fill the voids that surround the master point, especially in ovoid canals [137].

On other hand, Hommez et al.,2003 reported that this single-cone obturation was still the method of choice for 16% of the Flemish dentists [138] and other data from UK showed that 13% of qualified dentists using the same technique [139].

However, other study demonstrated that the use of conventional sealer between the point and the root canal walls allowed fluids infiltration from both the peri radicular areas and oral environment and consequently, the cement degradation occurred, and microorganisms will be installed, leading to endodontic treatment failure [140].

Now a day, the popularity of single-cone obturation technique is increasing because of widespread using of rotary nickel-titanium (NiTi) instruments and matched-taper gutta-percha cones which provide a satisfied gutta-percha/root canal sealer balance [141].

This technique is considered simple, improves practice and causes less stress for both patient and to clinician [142,143].

Although SC technique can overcome certain drawbacks associated with other obturation techniques, it has few disadvantages such as limited penetration of spreader or plugger for any further lateral compaction and poor adaptation of Gutta-percha in a canal with oval, irregular, or complex anatomy. Therefore, sealer and its application in sufficient volume play an important role in providing a predictable seal in SC technique [144].

2.9. Microleakage in endodontic

Microleakage is defined as undetectable passage of bacteria, fluids, molecules or ions between tooth and the restorative or filling material and considered a major factor influencing the long-term success of endodontic as it causes many severe biological effects leading to recurrence of the pathology and failure of the root canal treatment [6].

2.9.1. Causes of microleakage

The apical leakage is considered the common cause for endodontic failure and is influenced by many variables such as different filling techniques, chemical and physical properties of root canal filling materials and presence and absence of smear layer [25]. While, the coronal leakage occurs as a result of recontamination due to loss of temporary filling material or inadequate endodontic permanent restoration or crown sealing which allows contact between the oral bacterial flora and root canal [25]. So, several factors appear to influence the extent of both apical and coronal leakage [25].

2.9.2. Influence of the smear layer on microleakage

According to Torabinejad et al., 2003 the smear layer is one of the factors that can adversely affect the apical and coronal microleakage compromising the long-term success of the treatment. These unwanted layers of organic and inorganic materials should be removed before obturation of the root canal system [145].

Haapasalo et al., 2000 advocated that on removal of the smear layer, intracanal medicaments could penetrate the dentinal tubules in infected root canals more easily and consequently cause a better disinfection procedure [146].

Other authors have demonstrated that removal of the smear layer permits penetration of filling materials into patent dentinal tubules, increasing the contact surface, improving mechanical retention and reducing the possibility of microleakage through the filled canal independently of the obturation technique [(147)].

According to Kennedy et al., 1986 and Taylor et al., 1997 one of the main factors is the influence of the smear layer on leakage which has been evaluated and its removal has been advocated as it is believed that bacteriatrapped within the smear layer can multiply and cause recontamination of the root canal system through microleakage [(148)].

Dhanyakumar et al., 2009 pointed out that the removal of this layer depends not only on the irrigation method, but also on the endodontic instrument (149). Also, the same authors reported that smear layer formation were highest for ProTaper instrumentation in coronal, middle and apical third of the root canals [(149)].

2.9.3. Influences of the irrigation on microleakage

The irrigating solutions have an important role in chemo-mechanical preparation [(150)]. The primary goal of the irrigation is to remove the smear layer from instrumented canal walls. It was reported that using an irrigant such as ethylene diamine tetra acetic acid (EDTA) alone can only remove the inorganic portion of smear layer and hence to eliminate smear layer completely, it should be combined with NaOCl which acts by dissolving the organic content of the pulp [(151)].

Irrigation with 1% NaOCl combined with 17% EDTA had the least mean coronal microleakage after obturation [(151)].

Sharifian et al., 2008 concluded that characteristics of CHX treated dentin might also explain the greater resistance to microbial leakage. The presence of surface surfactant in CHX increases the surface energy and wetting ability of dentin, which in turn increases the bonding of some hydrophilic bonded materials such as Epiphany (152).

Torabinejad et al., 2003 found in their study that samples with intact smear layer showed less microleakage than samples that had the smear layer removed with EDTA or mixture of tetracycline, an acid and a detergent (MTAD). They concluded that increased coronal leakage in samples treated with EDTA compared with those treated with MTAD might be caused by the erosive property of EDTA and the length of dentin exposure to this solution (145).

Other studies have shown that EDTA is destructive in the coronal and middle thirds of root canals if left for more than 1 min in contact with the root dentin (145,153).

Singh et al., 2016 evaluated the effect of two different root canal irrigation solutions (5.25% NaOCl followed by 17% EDTA and QMix) on the apical sealing ability of two different root canal sealers (MTA Fillapex and Adseal). They concluded that using of5.25% sodium hypochlorite followed by 17% EDTA and Adseal resulted in the best apical seal (154). This irrigation protocol was used in our study.

2.9.4. Effect of Sealers on Microleakage

The sealing ability of the sealers used plays an important role in achieving hermetic obturation of the root canal system (155). The root canal sealer is required to adhere to dentin and fill the discrepancies between the core-filling material and the dentinal walls (155).

Zemner et al., 1997 reported that AH26 shows least leakage when compared with the AH Plus on which the microleakage was assessed using dye penetration after 2, 4 and 10 days (116).

De moor and Hommez 2002 evaluated and compared the sealability of root fillings in extracted teeth by using AH 26 and AH Plus in conjunction with three different obturation techniques. It was reported that leakage occurred whatever filling technique was combined with AH26. The degree of coronal leakage and the number of leaking teeth were significantly high than the other gutta-percha obturation techniques (156).

Maryameand and Atena 2014 evaluated the microleakage of different endodontic sealers and they concluded that leakage in AH26 provided the least apical micro-leakage when compared with zinc oxide eugenol and MTA (117).

The findings obtained by Tabrizizadeh., et al., 2008 for the assessment of the apical sealing ability of MTA alone and laterally condensed gutta-percha with AH26 a showed that the canal obturation with gutta-percha and AH26 sealer may provide a better apical seal compared with MTA alone (118).

Shourgashti et al., 2018 performed a study to evaluate the physical properties, cytotoxicity and sealing ability of HealApex (a new premixed calcium-silicate-phosphate-based biosealer) in comparison with AH-26. The specimens were obturated with gutta-percha and experimental sealers employing lateral condensation technique. Sealing ability of sealers was investigated for up to one month using fluid filtration method. The obtained results showed that short term, the sealing ability of HealApex was comparable with AH-26 whilst in long term, HealApex's sealing ability was better than the epoxy resin-based sealer (119).

Juhász et al., 2006 studied the influence of root canal shape (curved or straight) on the sealing ability of sealers in fluid transport models and concluded that a complete seal was more frequently observed in straight canals compared with curved canals. They reported that Seal apex allowed more leakage than Pulp Canal sealer (157).

Oliver and Abbott 1998 performed a study to compare both apical and coronal dye penetration when Ketac- Endo and AH- 26 sealers were used in root canals of 28 teeth with lateral condensation gutta percha technique. The study demonstrated that the apical and coronal seals obtained with Ketac- Endo and AH- 26 were not significantly different between them. Also, they reported that the apical seal obtained with AH- 26 was significantly better than the corresponding coronal seal which was attributed to the suggests that the sealer appeared to bond more effectively to gutta-percha than to dentine (158).

2.9.5. Influence of the single-cone technique on microleakage

Several authors have evaluated the apical microleakage of the single-cone technique [159,160].

Heran et al., 2019 stated that in the single cone technique, the root canal is generally obturated with a fitted cone that best matches the shape (taper and apical gauge) of the last rotary instrument used in combination with large quantity of sealer [161].

Ozawa et al., 2009 and Schäfer et al., 2012 concluded in their studies that the single-cone technique was faster than lateral condensation [162].

Hörsted-Bindslev et al., 2007 reported that the lateral condensation does not differ from single cone technique regarding to the quality of the radiographic obturation [163].

Tasdemir et al., 2009 reported in their study that the single-cone technique might produce a better sealing than lateral condensation at 2 mm short of the apex, which was related to the reality that the single gutta-percha point had the same diameter and taper of the last instrument used during the preparation of the canal [164].

On the other hand Damasceno et al., 2008 demonstrated that the ProTaper single cone and thermoplasticized TC system technique showed apical microleakage, and the highest infiltration was recorded for the single-cone technique which was attributed to the fact that the gutta-percha point is not compacted, but only inserted within the working length to the nature of the beta type gutta-percha, which is more consistent and less adhesive, and to the poor condensation of the apical third due to the diameter of the compactors which, often, do not reach this third [159].

Ellakany et al., 2016 illustrated in their study that the type of instrument and its taper had an effect on the quality of obturation where the Protaper Next group exhibited better results than Wave One group specially at coronal and middle thirds. This could be attributed to Protaper Next file design and its swaggering action which might increase the volume of filling material inside the canal enhancing the quality of obturation. Also, the authors postulated that the single-cone obturation technique was able to fill the apical part effectively when compared to traditional lateral compaction technique [165].

Monticelli et al., 2007 compared the apical sealing of two systems of single-cone obturation Active GP/glass ionomer sealer (Brasseler USA, Savannah, GA) and GuttaFlow (Coltène/WhaledentInc, Cuyahoga Falls, OH, USA) with the vertical condensation technique and AH-Plus cement by using a model of bacterial infiltration in single-rooted teeth. The authors reported that none of the two single-cone systems assured a durable apical sealing against the bacteria, while the vertical compaction technique reached this type of sealing [144].

Gordon et al., 2005 evaluated the quality of the obturation in root canals filled with single-cone techniques, compared the area occupied by the gutta-percha/ cement or the empty spaces in curved canals of the mesial-buccal roots of extracted maxillary first molars. The specimen preparation was performed by using the Profile .06 system and the obturation techniques were: size .06 single-cone and size .02 gutta-percha points through lateral condensation. In both techniques, the AH 26 cement was used and the time elapsed for each technique was measured. The authors concluded that the size .06 single-cone technique was comparable with the lateral condensation regarding to the amount of gutta-percha occupying the curved canals [(143)].

Holland et al., 2004 evaluated the effect of sealer type and filling technique on the apical marginal microleakage, using the single-cone and lateral condensation methods. The authors reported that the single-cone technique showed less marginal leakage than lateral condensation, but it was characterized by overfilling in all cases, which did not occur with the lateral condensation technique [(166)].

Wu et al., 2006 estimated the long-term apical leakage of the single-cone technique in teeth filled with Roeko Seal cement. The authors concluded that in long and straight canals, the single-cone technique prevented the fluid infiltration after one year [(160)].

Sadr et al., 2015 compared the coronal and apical seal of canals obturated with different sealers including AH-26, glass ionomer cement (GIC) and zinc oxide eugenol (ZOE) in single gutta-percha obturating. Seventy extracted anterior single-rooted teeth were selected for this study. The root canals were prepared using ProTaper rotary instruments. The samples were exposed to dye penetration using 5% methylene blue for microleakage test using stereomicroscope. The authors found AH-26 group had the least amount of microleakage compared to the other groups ($P<0.05$) which was correlated to the considerable bond strength of AH-26 to dentin as well as gutta-percha [(161)].

Hegde and Arora 2015 compared the corono-apical sealing ability of three single-cone obturation systems using a glucose leakage model in which 90 maxillary single-rooted teeth was selected. The authors found a significant different glucose leakage values at all test periods ($P < 0.05$) and the epoxy resin AH plus groups showed high leakage due to the fast setting and subsequent polymerization shrinkage of AH plus sealer which was attributed to the lack of bonding between this sealer and gutta-percha, the low penetration ability of this sealer within the dentinal tubules and its hydrophobic property that prevents good adaptation to the incompletely dried canal [(167)].

2.9.6. Influence of voids in the sealers on endodontic microleakage

The occurrence of voids in the sealer is believed to be due to the inherent factors associated with either sealer manipulation and handling or its properties or both. The entrapments of voids in the sealers usually occur due to air inclusion during mixing or carrying and coating the sealer to the canal walls in addition to other factors such as the density and flow properties of the sealer [(168)].

It is postulated that any existence of voids in the obturation have the potential to permit the passage of toxins to the periapical area and decreases the quality of obturation [(14, 19)]. The occurrence of voids can be expected to occur within the sealer mass or at the interface in the obturation because gutta-percha is a solid core obturation material [(169)].

It was reported that the occurrence of voids is more critical and more predictable in the SC technique as single master cone needs a greater interaction with the sealer to promote the sealing and sealer is required in larger volume than with other obturation techniques. Hence, the sealers should be devoid of or display minimal voids when used with SC technique (170).

Various studies showed that the evaluation of gaps and voids within the sealer could be achieved through the using of either stereomicroscope (143), digital images or computer program (19), or using micro-CT (171).

However, root sectioning followed by stereomicroscopic examination and digital image analysis with software was employed in our study to assess the voids. Though, this methodology leads to structural loss or destruction of samples during sectioning, it has many advantages such as easy to use, provides a three-dimensional view of the surface to be examined, requires no pretreatment of the specimen unlike in scanning electron microscopic examination and is associated with image analysis software to aid in eliminating human errors during the interpretation of the parameters (172,173).

Different ways are employed for voids measurement. Iglecias et al.,2017 divided the root into three areas including apical, middle, and cervical sections (174).

Somma et al., 2011 measured void distributions in root canal obturation in three different techniques in a straight canal in single-rooted permanent teeth using micro-CT, but found no significant difference between the

Thermafil group, the SC group, and the System B group [175]. In a similar study, Alshehri et al.,2016 measured the volume of voids in the apical one-third of a curved canal in the mesial root of human mandibular first molars using micro-CT and found similarities between the SC and CW groups [176]. In addition, Iglecias et al., 2017 measured the volume of voids in the mesial root of the human mandibular molar in the apical one-third and found no significant difference between the SC and CW groups in the apical area [174].

Kumar et al., 2016 compared the area of voids in MTA Fillapex, AH26, and Pulpdent sealers when employed with SC obturation technique. The obturated teeth were sectioned at apical, middle, and coronal third, and area of voids in the sealer was assessed using a stereomicroscope. The results indicated that the three tested sealers showed voids in all the sections except MTA Fillapex, which was void free in apical and middle sections followed by the one with AH26 sealer, whereas SC obturation with Pulpdent sealer had significantly most area of voids. The occurrence of voids in a sealer was attributed to apart from its manipulative and handling properties and the rheological properties of AH26 sealer [177].

Nabavizadeh et al., 2013 compared the percentage of voids following root canal obturation with gutta-percha combined with AH26 sealer using four different sealer placement techniques in the root canals of 50mandibular second premolars. After obturation, the canals were horizontally cut into 3 mm slices and evaluated under a digital microscope for void detection in apical, middle and coronal thirds. Results of the study showed no significant difference in void percentage in one-thirds or total sections between the four methods of sealer placement (p=0.276) and sealers application with Lentulospiral were more effective than other techniques in the apical and coronal sections [178].

Iglecias et al., 2017 assessed the presence of voids in mesial root canals of mandibular molar teeth obturated by using the single-cone (SC) and continuous wave of condensation obturation techniques, and results were analyzed by using micro-computed tomography. The authors reported that the percentage volume of voids was similar in the 2 groups and was influenced by the obturation technique only in the cervical third [174].

Akman et al., 2010 reported in their study, which was performed, on thirty extracted human single-rooted teeth to evaluate the gaps or voids occurring in root filled with three different resin-based sealers that no significant differences were found among the sealers in the scores for the gaps or voids areas among the tested sealers [168].

Therefore, it is very important to quantify the area of voids in the sealer mass to assess the quality of obturation and potential for any leakage through obturation [173].

3. Aim of the study

The aim of this in vitro study is to assess microleakage of single cone gutta percha obturation technique using different types of sealers.

- **The objectives of the study:**

1. Compare the apico-coronal seal of canals obturated with AH26 and vioseal root canal sealers.

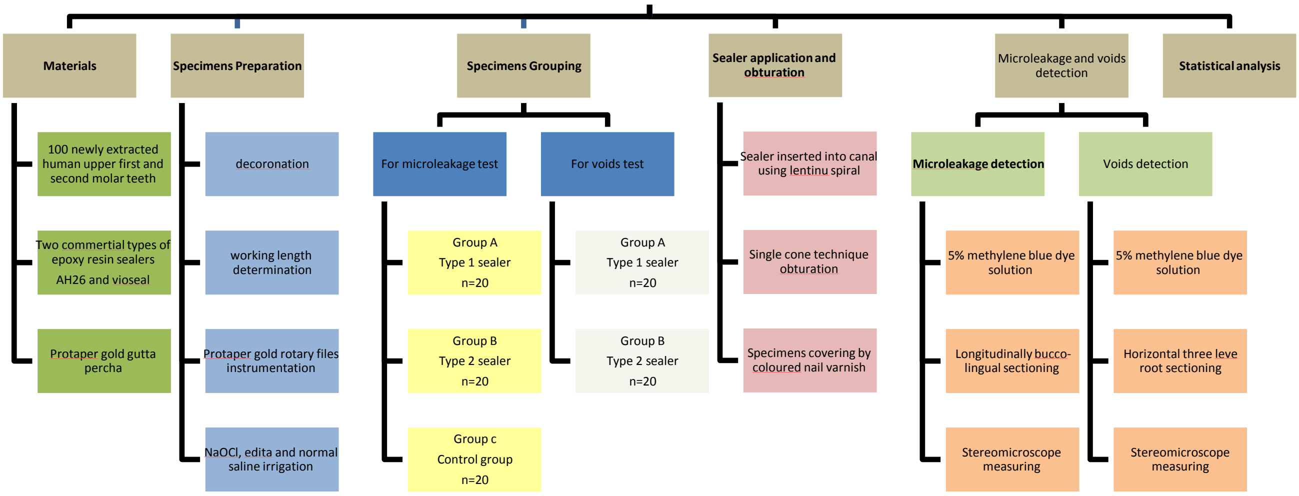
2. Evaluate gaps or voids occurring in roots filled with AH26 and vioseal root canal sealers.

4. Materials and Methods

Providing a filling in the root canal space capable of sealing the coronal, apical, and lateral openings is one of the main treatment objectives in endodontic [179]. Sealing the root canal system relies on the adequate adaptation of a filling material to obliterate the canal space and its fins details of the root canal system [180]. Obturation of the root canal system hermetically in three dimensions after cleaning and shaping is paramount in preventing re-infection of the root canal space, prevents microleakage leakage and contamination of the root canal space [4].

On other hands, inappropriate sealer coating may result in voids and permit bacterial microleakage, which can potentially lead to treatment failure [18]. A variety of sealers have been used for this purpose among them epoxy resin sealers [181].

Study design



4.1. Materials

The materials used in the study are listed in the following tables:

Table 2: Materials used in the study**:**

The product	Composition	Manufacture	Uses
Vioseal selear (Epoxy resin sealer)	-Base: epoxy oligomer resin Ethylene glycol salicylate other -catalyst:poly(1.4 butanedol) bis (4 aminobenzoate) Calcium phosphate	Spident co.Ltd Korea	Root canal sealer.
AH26 (Epoxy resin sealer)	Powder: bismuth oxide Hexamethyleneteramine Silver powder Titanium oxide Liquid: bisphenol diglycidyl ether	DENSPLY DeTrey GmbH Germany	Root canal sealer.
F2 gutta-percha and paper points PG		Densply switzerland	Obturating core material
2.5% Sodium hypochlorite			For canal irrigation.
17% Edita solution			Canal irrigation Smear layer removal.
Normal saline			Canal irrigation.
2% Methylene blue		Supreme organization for drugs Germany.	Dye penetration for microleakage detection.
Nail varnish			Painting on root surface, for color coded & microleakage testing

Table 3: Different armamentarium used in the study:

Device	Origin	Uses
High speed handpeice	Coxo cx 207 China	To rotate high speed burs.
TC-11C diamond bur	Mani	Decoronation of teeth at CEJ

	Japan	
K-files #10,15	Densply Switzerland	#10 for canal negotiation and patency #15 for working length determination.
Protaper gold rotary files	Densply Switzerland	For canal preparation
27-gauge plastic syringe	China	For canal irrigation
Endodontic ultrasonic activation tip #15	China	For sodium hypochlorite activation inside canals
Ultrasonic scaler P7	China	Cleaning of selected teeth used in the study Intracanal activation of sodium hypochlprite
Plastic spatula	China	For mixing of sealers.
Lentulo spiral file #25	Densply switzerland	Carrying sealer inside canals.
Sand paper 400 grit	Spain	To remove superficially adhering dye.
Chisel and mallet	Germany	complete the sectioning of roots till separation
Gutta-cut	china	Cutting of excess gutta-percha after obturation
E-connect S	Eightieths China	Rotary engine device used with rotary files for canal preparation
Low speed diamond saw	Korea	For preparation of void specimens.
Dental microscope 20x	China	Exclusion of immature, cracked and root resorbed teeth

4.2. Methods

4.2.1. Samples selection

A total of 100 freshly extracted human upper first and second molar teeth with fully formed and sound palatal roots was selected to be used in the study based on clinical examination by visual inspection under dental microscope (magnified lenses 20x) to exclude those with immature apex, cracks, previous RCTs, root caries or root resorption from the study (fig.7).

Sixty teeth were used for microleakage test and the other forty teeth were subjected to voids detection test.

The teeth immersed in 5.25% NaOCl solution for 5 min. for disinfection. Subsequently, the samples cleaned of tissue remnants and calculus by ultrasonic scaler (fig.5) followed by rinsing under tap water and then stored in normal saline solution until the time of use (fig.6).

Figure 5. Scaling and cleaning of saline collected teeth using ultrasonic scaler**.**

Figure 6. Collected teeth saved in normal saline.

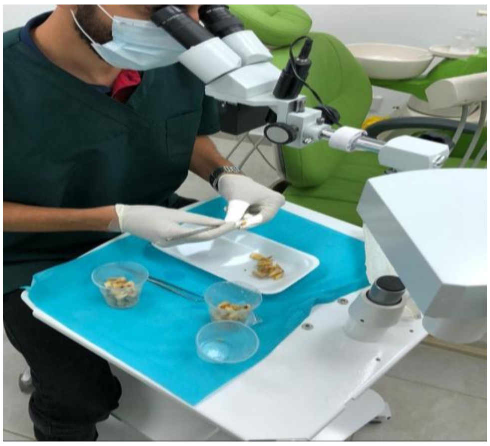


Figure 7. Teeth examination under dental microscope (osaka dent co.20x magnification).

4.2.2. Microleakage test

a. Specimens Grouping

Sixty teeth were used and divided into 3 groups, consisting of two experimental groups (*n*=20) according to the types of epoxy resin sealers used in the study and one control group (*n=20)* without sealer.

- Group 1: In this group (sealer A) AH26 sealer was used in combination with single gutta-percha cone for canal obturation with (*n*=20).
- Group 2: In this group (sealer B) Vioseal sealer was used in combination with single gutta-percha cone for canal obturation with (*n*=20).
- Group 3: Control group (*n*=20), in this group the single gutta-percha cone was placed in the canal without sealer.

b. Group identification

The palatal roots of each of the experimental groups (except the control group) were painted with one layer of nail varnish with specific color excluding the coronal and apical 1 mm of the roots for easy identification (fig.8).

- For group A, the color coded was red.
- For group B, the color coded was blue.

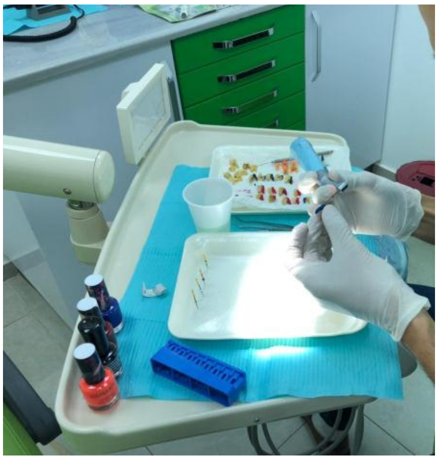


Figure 8. Marking of the teeth with nail varnish according to each group

c. Specimens Preparation

The crown of each tooth was decoronated using a high-speed handpiece with TC-11C diamond bur under continuous water spray at the cemento-enamel junction in order to ensure that all the specimens were relatively at the same length 11± 4mm.

K-file #10 was used for canal patency and negotiation then working length (WL) determined by inserting a K-file# 15 into the canal until it was just visible at the apical foramen, and then the actual length of the canal was determined by subtraction of 1 mm from the first measurement.

The working length (W.L) of each root was registered in a table drew in a plain paper. fig.9 (A&B).

(A) **(B)**

Figure 9 (A&B). Working length determination of palatal roots of collected teeth.

The root canals prepared using ProTaper gold rotary instruments installed on an electrical endodontic handpiece (eight teeth e-connect S) at speed and torque as recommended by manufacturer, respectively (fig.10). Preparation carried out according to the manufacturer's recommendations using the crown-down technique starting by Sx file then S1, S2, F1 and finally by F2 file. A five new set of instruments was used for each group of teeth (each set prepare four canals). No instrument separation occurred during preparation of the specimens.

The canal irrigation was performed between each step of instrumentation with 5 ml. of freshly prepared solution 5% NaOCl carried up to the apical 3 mm with 27-gauge disposable plastic syringes then intra canal ultrasonic activation for 30 second and k-File #10 used for canal patency after each irrigation. Needle tip of the plastic syringe was placed passively into the canal. Following instrumentation, root canals irrigated with 1 ml EDTA 17% for 1min. followed by 5 ml 2.5% NaOCl.

Figure 10. Root canal preparation using protaper gold rotary files and irrigation of canals by sodium hypochlorite.

Finally, the root canals flushed with 3 ml of saline solution [182] and dried with F2 protaper gold paper points (fig.11).

Figure 11. Root canal dryness using protaper gold paper points.

d. Sealers application and obturation for the experimental groups [186].

Both sealers were mixed according to manufacture recommendation and carried out into the prepared canals according to each group using #25 Lentulo spiral rotated 3 mm away from the apex [142] (fig.12).

Samples in Group 1 were filled with single cone ProTaper gutta-percha size F2 which sealed with AH26 sealer (sealer A).

Samples in Group 2 were filled with single cone ProTaper gutta-percha size F2which sealed with Vioseal sealer (sealer B).

Figure 12. Application of sealer inside root canals using lentulo spiral file.

In both groups, the tip of each prefitted master cone was slightly coated with its respective sealer and inserted into the prepared canal using up-and-down pumping motion until reaching the full working length (183) (fig.13).

Figure 13. Obturation of instrumented root canals using single cone protaper gold gutta percha points.

The excess gutta-percha removed with a gutta-percha cutter device and the remaining gutta-percha vertically compacted at the canal orifice.

All specimens were lift four weeks in room temperature to allow complete setting of the sealers [114].

e. Obturation of the control group

For control group (n=20), all the samples were obturated with single gutta-percha cone size F2 without sealer to have maximum dye penetration.

The excess gutta-percha for all groups was removed with a gutta-cut and the remaining gutta-percha vertically compacted at the canal orifice.

f. Microleakage testing procedure

- Dye penetration test:

The roots were then placed in 2% methylene blue dye (Supreme organization for drugs, Germany) for 24 hr. in incubator (37^{o} C) (fig.14).

Figure 14. Specimens placed in incubator.

The teeth were then removed from the dye and excess of dye was washed off under running tap water to remove dye on external root surface. The teeth were dried, and the apical surface gently ground on a fine (400 grit) sandpaper to remove superficially adhering dye.

j. Root preparation and sectioning

The roots were then sectioned vertically along the long axis to ensure that the sectioning process did not damage the inside of the canal, the sectioning was initially done with diamond bur (KG Sorensen, SP industrial, Brazil) operated on low-speed drill (ARATHON, SAE YANG CO., Korea) (fig.15 A&B) to make a guide for the chisel and mallet to complete the sectioning till separation (fig.16 A&B) (fig.17).

(A) **(B)**

Figure 15 (A&B). Root canal sectioning using kg Sorensen diamond bur.

(A) **(B)**

Figure 16(A&B). Using of a chisel and mallet to complete root sectioning till separation.

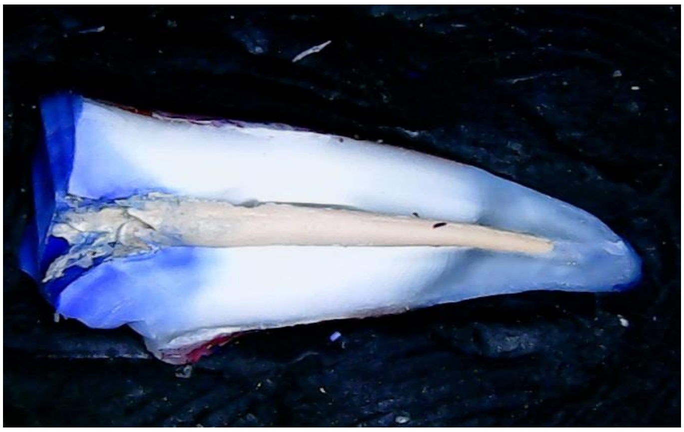


Figure 17. Showing complete root section ready for microleakage evaluation.

h. Microscopic evaluation

Samples were then evaluated under a stereomicroscope (Nikon Eclips E600, Tokyo, Japan) at ×25 magnification to detect the extent of dye penetration from the apical constriction, and the higher value among them was taken (fig.18).

With the help of the microscopic images obtained, the linear measurement of the dye penetration was noted from apical to coronal direction. The image transferred to a computer equipped with the image analysis software program (Image J 1.43U, National Institute of Health, USA), where the dye penetration along the filling dentine interface was evaluated (fig.19).

i. Software calibration

Within the software, all limits, sizes, frames, and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real-world units. Calibration was made by comparing an object of known size (a ruler in this study) with a scale generated by the software. Image J software was used to measure dye penetration expressed in mm.

Figure18. Specimen under stereomicroscope for microleakage evaluation.

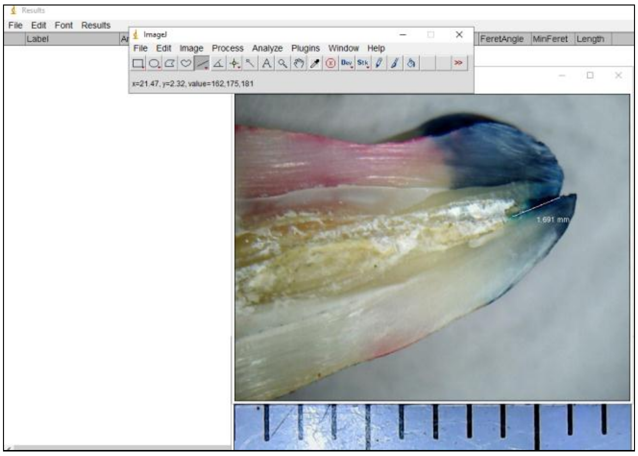


Figure 19. Image analysis software for microleakage detection

4.2.3. Voids detection test

a. Sample grouping:

The remaining twenty teeth divided into two groups (*n*=20) for each type of sealer.

- Group A: sealer A (AH26) (*n*=20)
- Group B: sealer B (vioseal)(*n*=20)

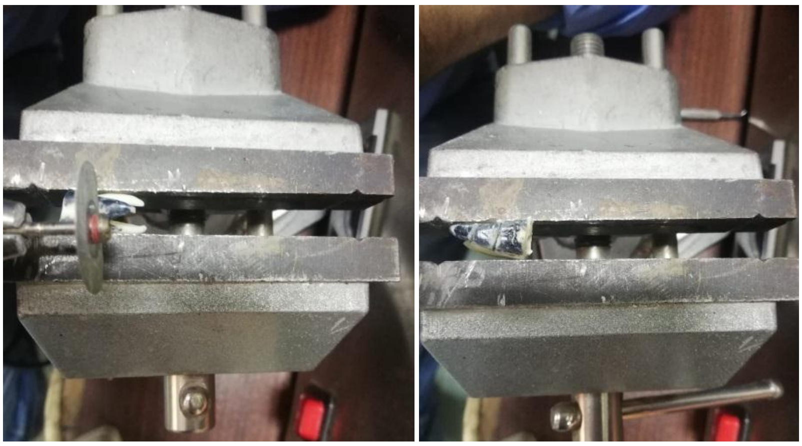
The external root surfaces of all the specimens in each group were painted by one layer of one color of nail varnish differed from the color of the other group.

Orange color for group A, and black color for group B

b. Sample preparation:

The same procedure as previously described for root canal preparation and obturation for microleakage detection was performed for voids detection.

The apical 2 mm of the remaining roots for each group (n=20) were removed using a slow-speed, water-cooled diamond saw (Isomet, Buehler, Lake Bluff, IL) (fig.20 A%B). Each root was then sectioned at three levels (coronal, median and apical). The thickness of sections was approximately 3±0.5 mm (calibrated using digital calibration tool (fig.22). A total of 120 section surfaces were obtained (fig.21).



(A) (B)

Figure 20 (A&B). Root sectioning using a slow-speed diamond saw.

Figure 21. Showing coronal, median and apical level of the root sections.

Figure 22. Using digital calibration tool to calibrate the thickness of each root section.

Digital images were taken from the apical side of each section using a stereo-microscope (Nikon Eclips E600, Tokyo, Japan) at X30 magnification. The images were then transferred to a computer with image analysis software and evaluated for the surface area of all the gaps or voids. A total of three measurements were done for each root (coronal, middle and apical) and the surface area of the gaps or voids were calculated in μm2 (fig.23).

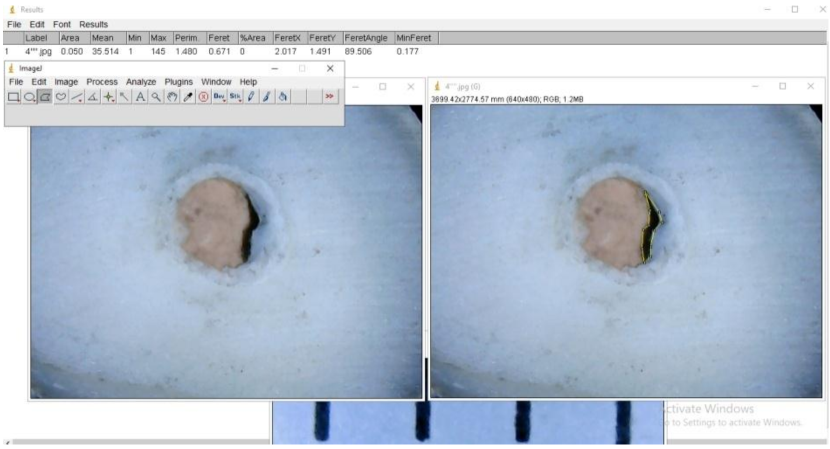


Figure 23. Image analysis software for voids evaluation.

4.3 Statistical analysis

The collected data was statistically analysis by using Graph Pad Instat (Graph Pad, Inc., USA) software for windows. A value of $P < 0.05$ was considered statistically significant. One-way ANOVA was done for compared time followed by Tukey's pairwise if showed significant for leakage results. Two-way analysis of variance was performed for gap results. Student t-test was done between groups at different regions for gap. Correlation between leakage and gap/voids area was performed by Pearson correlation test.

5. Results

The success of a root canal therapy strongly depends on creating a fluid-tight apical and coronal seal. Various materials and methods have been introduced for obturating an instrumented root canal. Endodontic sealers play a critical role in providing an impervious seal as they fill the irregularities and minor discrepancies between the root canal walls and core filling material [(184)].

However, inappropriate sealer coating may result in voids and permits bacterial micro-leakage which can potentially lead to treatment failure [(184)]. A variety of sealers have been used for this purpose including zinc oxide-eugenol (ZOE)-based cements, glass ionomer cements, polymer-based sealers, calcium hydroxide-based sealers and silicon-based sealers [(185)].

The popularity of single-cone obturation technique is increasing because of widespread using of rotary nickel-titanium (NiTi) instruments and matched-taper gutta-percha cones. Moreover, this technique is considered simple, improves practice and causes less stress for both patient and clinician [(142)].

Therefore, this in vitro study was aimed to compare the coronal and apical seal of canals obturated with two different types of epoxy resin root canal sealers.

5.1. Data collection

The results were analyzed using Graph Pad Instat (Graph Pad, Inc., USA) software for windows. A value of $P < 0.05$ was considered statistically significant. Continuous variables were expressed as the mean and standard deviation. After homogeneity of variance and normal distribution of errors had been confirmed, one-way ANOVA was done for compared time followed by Tukey’s pairwise if showed significant for leakage results. Two-way analysis of variance was performed for gap results. Student t-test was done between groups at different regions for gap. Correlation between leakage and gap/voids area was performed by Pearson correlation test. Sample size (n=20/group) was large enough to detect large effect sizes for main effects and pair-wise comparisons, with the satisfactory level of power set at 80% and a 95% confidence level.

5.2. Results of microleakage testing

Microleakage results were measured by apico-coronal extension of dye in millimeter were summarized in (Table 4) and graphically drawn in (fig.24) (fig.25,26,27,28).

According to (table1) which represented descriptive statistics of dye penetration leakage results for all the groups, the overall data showed that the experimental groups exhibited different degrees of dye leakage.

Our finding showed that the highest dye penetration leakage mean value was recorded for Control group (1.302636±0.713421 mm) followed by Sealer B group (0.540188±0.231313 mm) while the lowest dye penetration leakage mean value recorded for Sealer A group (0.502±0.290462). The difference in dye penetration microleakage means between groups was statistically significant as revealed by one-way ANOVA test ($p < 0.05$). Pair-wise Tukey’s post-hoc test showed non-significant ($p>0.05$) difference between (Sealer A and Sealer B) groups.

Table 4. Descriptive statistics of dye penetration leakage results (Mean ± SD) for all sealer groups (mm).

Variable		***Descriptive statistics***		***Range***		***95% confidence intervals***	
		Mean	***SD***	***Minimum***	***Maximum***	***Low***	***High***
Sealer type	***Sealer A***	0.502[B]	0.290462	0.039	1.642	0.374702	0.629298
	Sealer B	0.540188[B]	0.231313	0.183	1.334	0.438812	0.641563
	Control	1.302636[A]	0.713421	0.255	2.972	0.989971	1.615301
ANOVA	***F***	18.9					
	P value	<0.0001*					

Different superscript capital letters indicating significant (p<0.05)
ns; non-significant (p>0.05)
*; significant (p<0.05)

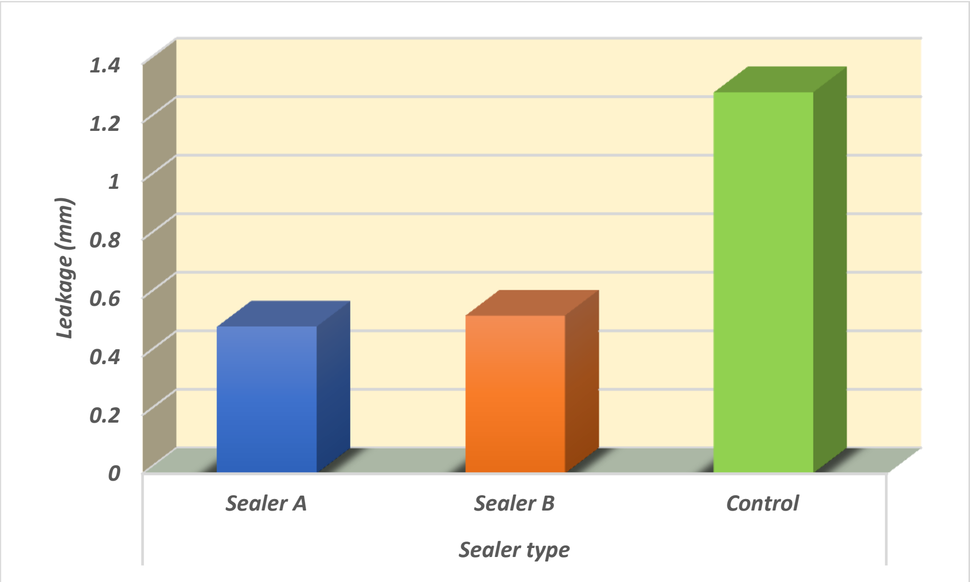


Figure 24. Column chart of dye penetration leakage means values for all sealer groups.

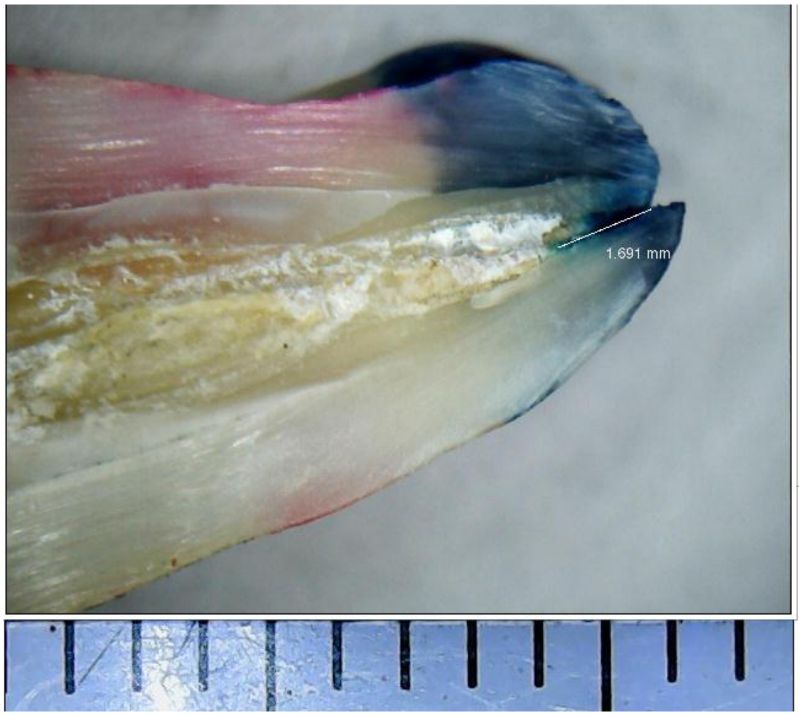


Figure 25. Showing dye penetration leakage evaluation by image analysis software.

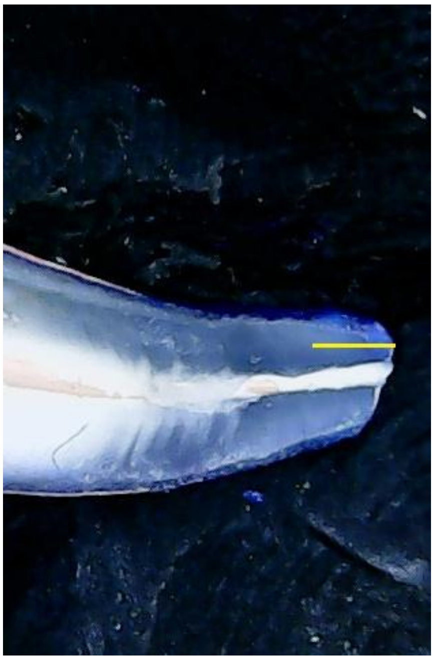


Figure 26. Stereomicroscopic image showing dye penetration leakage evaluation for sealer A group.

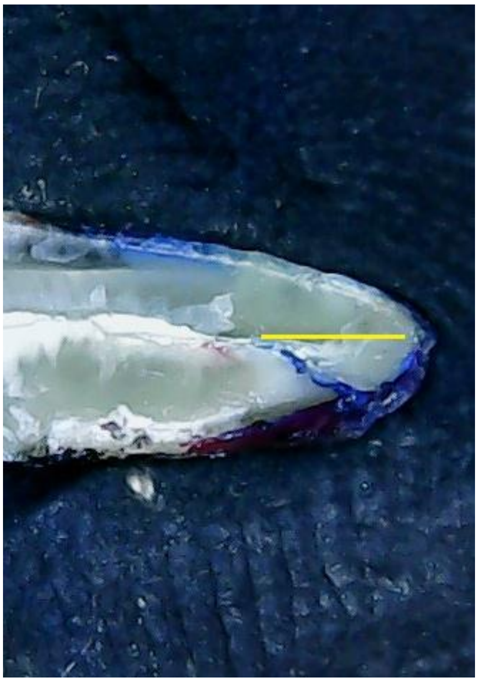


Figure 27. Stereomicroscopic image showing dye penetration leakage evaluation for sealer B group.

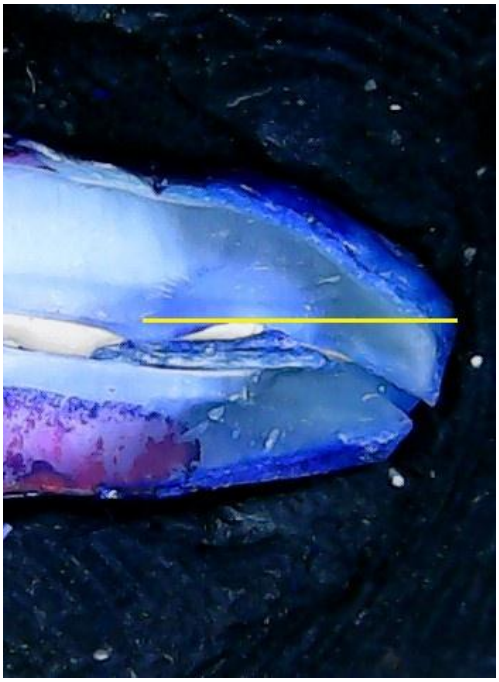


Figure 28. Stereomicroscopic image showing dye penetration leakage evaluation for Control group.

5.3. Results of gap/voids area testing

The mean values and standard deviation of adaptation test results measured by gap/voids area (μm^2) for both sealer groups as function of radicular region are summarized in (table 5).

5.3.1 Comparison between both sealer groups as function of radicular region

At cervical region**,** it was found that the ***sealer B*** group recorded higher mean ± SD value of gap area (50.38±2.47μm^2) than ***sealer A*** group mean ± SD value (49.13±1.99μm^2*)*. The difference between both sealer groups was statistically ***non-significant*** as indicated by t-test (t=1.77, P=0.08 > 0.05).

At middle region**,** it was found that the ***sealer B*** group recorded higher mean ± SD value of gap area (34.44±5.65 μm^2) than ***sealer A*** group mean ± SD value (29.69±3.26μm^2*)*. The difference between both sealer groups was statistically ***significant*** as indicated by t-test (t=3.26, P=0.002 < 0.05).

At apical region**,** it was found that the ***sealer B*** group recorded higher mean ± SD value of gap area (40.98±4.76 μm^2) than ***sealer A*** group mean ± SD value (33.19±8.28 μm^2*)*. The difference between both sealer groups was statistically ***significant*** as indicated by t-test (t=3.6, P=0.0008 < 0.05).

5.3.2. Comparison between radicular regions within each sealer group

In sealer A group; it was found that th***e cervical region*** recorded the highest mean ± SD value of gap area (49.13±1.99μm^2*)* followed by ***apical region*** mean ± SD value of (33.19±8.28 μm^2*)* meanwhile the lowest mean ± SD value was recorded with ***middle region*** (29.69±3.26μm^2*)*. The difference between radicular regions subgroups was statistically ***significant*** as indicated by one-way ANOVA (F=17.12, P=<.0001<0.05). Tukey's post-hoc showed non-significant (p>0.05) difference between middle and apical regions.

In sealer B group; it was found that the ***cervical region*** recorded the highest mean ± SD value of gap area (50.38±2.47µm^2) followed by ***apical region*** mean ± SD value of (40.98±4.76 µm^2) meanwhile the lowest mean ± SD value was recorded with ***middle region*** (34.44±5.65µm^2). The difference between radicular regions subgroups was statistically ***significant*** as indicated by one-way ANOVA (F=17.12, P=<.0001<0.05).

Table 5. Comparison of gap/voids area (µm^2) results (Mean values± SDs) between both sealer groups as function of radicular region.

Variable		***Radicular region***			***ANOVA***
		Cervical	***Middle***	***Apical***	***P value***
Sealer	***Sealer A***	49.13_a±1.99	29.69_b±3.26	33.19_b±8.28	<0.0001*
	Sealer B	50.38_a±2.47	34.44_c±5.65	40.98_b±4.76	<0.0001*
t-test	***P value***	0.08 ns	0.002*	0.0008*	

Different subscript small letters in the same row indicating statistically significant difference between regions (*p*< 0.05)

*; significant (*p*< 0.05)

ns; non-significant (p>0.05)

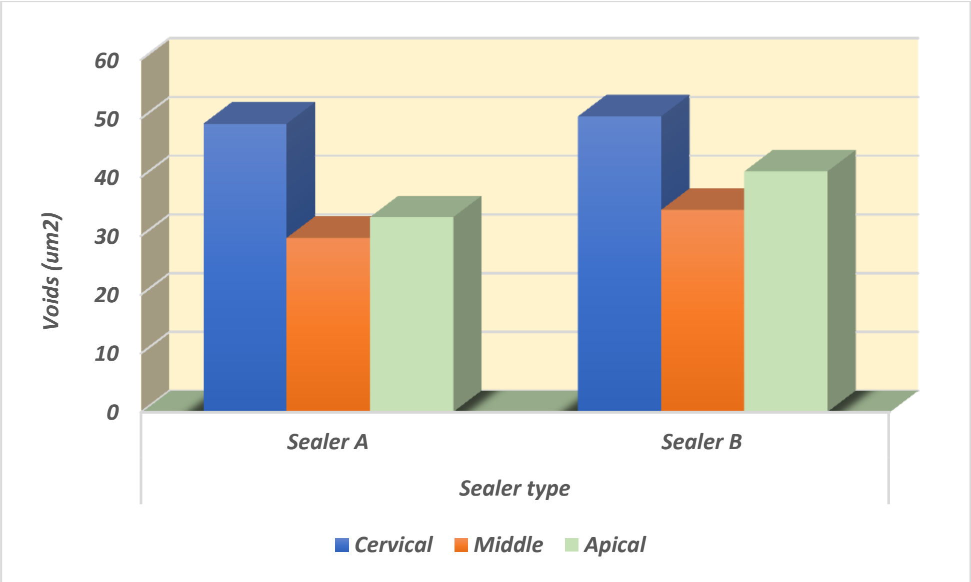


Figure 29. Showed column chart showing the mean values of gap area for both sealer groups as function of radicular region.

Totally, regardless to radicular region, it was found that sealer B group recorded statistically significant higher mean value of gap area than sealer A group mean value as indicated by two-way ANOVA test ($p = 0.002 < 0.05$).

Totally, irrespective of sealer type it was found that cervical region recorded the highest mean value of gap area followed by apical region mean value meanwhile the lowest mean ± SD value was recorded with middle region as indicated by two-way ANOVA ($P = < .0001 < 0.05$) (fig.30).

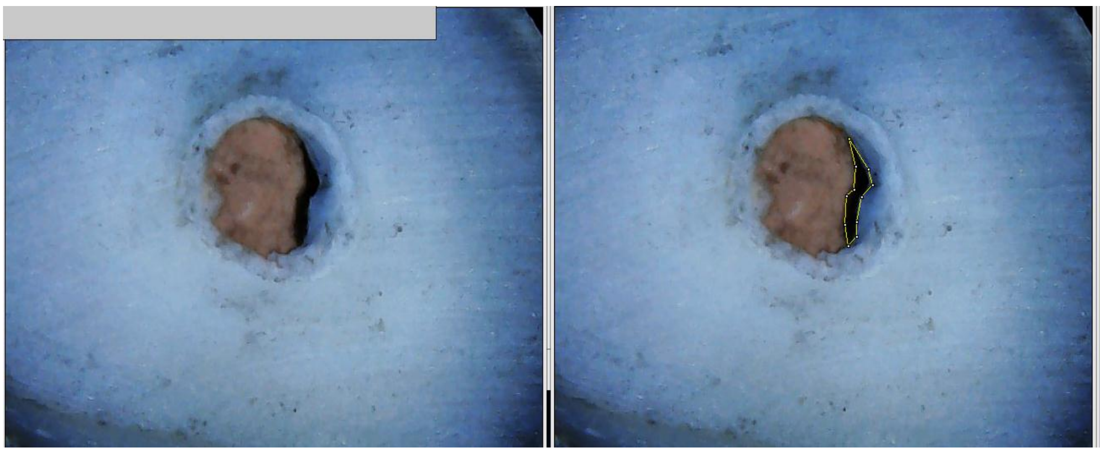


Figure 30. Image showing gap/voids area evaluation by image analysis software.

5.4. Correlation between leakage and gap/voids area

There was a statistically significant direct correlation between leakage and gap/voids area as proved by Pearson correlation test (correlation coefficient (r)= 0.8556, coefficient of determination r squared r^2=0.7321, p value =0.02 <0.05) (fig.31).

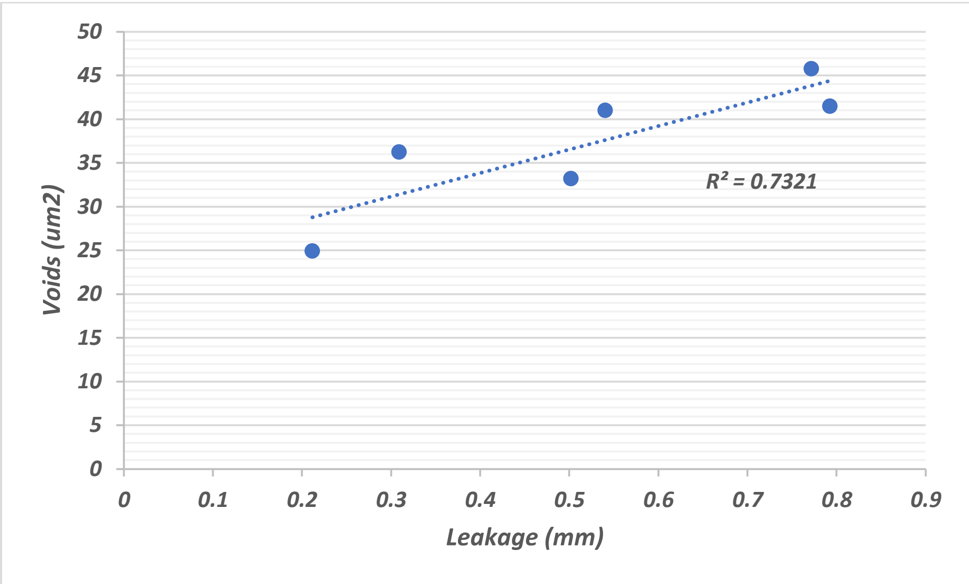


Figure 31. Linear chart showing correlation between leakage and gap/voids area.

6. Discussion

The success of a root canal therapy strongly depends on the thorough debridement of the root canal system, the elimination of pathogenic organisms and finally the complete sealing of the canal space to prevent ingress of bacteria from the oral environment and spread to the periapical tissue [184].

A three-dimensional obturation and creating a fluid-tight seal along all the communication pathways between the coronal and apical portions of a root canal system play a role in preventing percolation and microleakage of periapical exudate into the root canal space and create a favorable environment for healing to take place [185].

Various materials and techniques have been employed to achieve this goal. Combination of core material and sealer is the standard protocol used in root canal filling due to the lack of adhesion property in gutta-percha.

Single-cone obturation technique has recently been revived with the introduction of master cones with greater taper that match the geometry of nickel–titanium instrumentation systems [143].

It was reported that employing of this obturation technique leads to a less time-consuming with better or comparable treatment outcomes in comparison to conventional techniques [14].

Bonding of the sealer to dentin by either mechanical retention or chemical adhesion or both is important to maintain tight seal and to achieve a three-dimensional filling by filling the irregularities and minor discrepancies between the root canal walls and core filling material and reducing apical and coronal micro-leakage [185]. So, inappropriate sealer coating may result in voids and permit bacterial microleakage which can potentially lead to treatment failure. Leakage along root fillings may increase or decrease during a long period after filling. Dissolution of sealer and the smear-layer may result in a rise in leakage, whereas gutta-percha swelling may result in diminished leakage [186].

Different types of sealers based on various formulas are available. Root canal sealers based on epoxy resins were introduced in endodontic by Schroeder [5], and current modifications of the original formula are widely used for root canal filling procedures [110]. It was reported that these sealers provide good physical properties and adequate biological performance [82].

One of these sealers is (AH26) which has been extensively evaluated for its sealing ability and gap formation is characterized by a reactive epoxide ring and is polymerized by the breaking of this ring [187]. It was reported that AH26 showed good sealing ability, high tissue compatibility, it can harden in the presence of moisture, and it showed less than 0.5% restriction when entering the accessory canals [156]. AH26 has also been shown to have larger initial expansion compared to other types of epoxy –resin sealer [188]. However, the release of formaldehyde and its long setting time (4 weeks) are unfortunate the main disadvantages [114].

Another epoxy resin–based sealer is Vioseal which is a paste / paste type of dual syringe with very few reports in literature about its interfacial adaptation, leakage and void formations although the manufacturer claims that Vioseal has good sealing ability, superior biocompatibility, radiopacity, tight sealing, and insoluble in tissue fluids, excellent antibacterial effect and acts as a lubricant during inserting of GP point components [82].

So, the current study was performed to evaluate and compare the apical microleakage in apical coronal direction of canals obturated with two different types of epoxy- resin root canal sealers and to assess gaps or voids occurring in roots filled within these sealers.

This study was conducted on 100 recently extracted human first and second molars with fully formed palatal roots, where sixty teeth were used for microleakage test and the other forty teeth were subjected to voids/ gaps detection test.

6.1. Discussion of microleakage test

Sixty teeth were used and divided into 3 groups, consisting of two experimental groups (n=20) for each type of sealer and one control group (n=20) without sealer; Group 1: sealer A (n=20), Group 2 sealer B (n=20), and Group 3: control group (n=20). In all the groups, the root canal preparations were performed by ProTaper gold rotary instruments and the root canal obturation was carried out using the single cone obturation technique. In this technique the single cone gutta-percha in combination with corresponding sealer (AH26 sealer in group 1 and Vioseal sealer in group2was placed within the canal up to the working length except for the control group 3 which obturated by single cone gutta-percha without sealer. 2% methylene blue dye penetration method was selected as a leakage marker for the current study because it is inexpensive, easy to manipulate, having a high degree of staining capability, a lower molecular weight and penetrates more deeply along the root canal filling [27,29,30].

All the samples were subjected to sectioning then to a dye penetration testing before microleakage evaluation using a stereomicroscope at ×25 magnification.

Analysis of our findings revealed that the highest dye penetration leakage mean value was recorded for control group which was (1.302636±0.713421 mm) followed by (Vioseal sealer) group B (0.540188±0.231313 mm) while the lowest dye penetration leakage mean value recorded for (AH26 sealer) group A (0.502±0.290462). The difference in dye penetration microleakage means between groups was statistically significant ($p < 0.05$), while there was non-statistically significant ($p>0.05$) difference between group A sealer and group B sealer.

By going through the results of this study, it was observed that all the samples in the study group experienced apical microleakage.

Apical microleakage is one of the initial causes of a root canal treatment failure, occurred due to inadequate obturation of root canal. Apical- coronal microleakage occurs on the surface of the sealer with dentin or with gutta-percha [189].

In the present study, the apical- coronal microleakage is characterized by the penetration of methylene blue as shown in table 4 and figure 29. The dye penetration was linearly measured from the apical end of root canal filling material toward its maximum coronal extent and not from the anatomical root end to assess the actual dye leakage alongside the obturation materials. The highest apical- coronal microleakage linear measurement was observed in the group 3 (control group) which had average value of 1.3 mm. followed by group 2 (sealer B) which had average value of 0.58 mm. and finally group 1 (sealer A) which had average value of 0.5 mm. The explanation of this finding could be attributed to several reasons.

For the control group which showed the highest level of dye penetration, indicated that sealing ability of single-cone gutta-percha is deteriorated when used without a root canal sealer since the beta type gutta-percha lacks adhesive quality as it was reported by Samiei et al., 2014 in their study [(190)].

Other explanation postulated that the gutta-percha serves as the core-filling material, whereas the root canal sealer forms a fluid tightly seal and barrier apically, laterally and coronally between the dentin and gutta-percha and that the sealer fills the space between gutta-percha cones depending on its adhesive properties [(181)].

For the epoxy resin-based sealer of the two study groups the apical microleakage occurs due to the natural properties of the sealer made from epoxy- resin, which is mainly due to the occurrence of shrinkage during polymerization which may cause bonding failure between the sealer and the root canal wall at first meeting as it was postulated by Wong and Cputo 2013 [(191)].

The result showed that although there were not statistically significance differences between the apical microleakage of the two sealer groups, AH-26 sealer (group A) demonstrated the least amount of microleakage. The results could be related to the considerable bond strength of AH-26 to dentin as well as gutta-percha because AH-26 mainly contains Bismuth oxide and hexamethylenetetramine as powder and Bis Phenol di-glycidyl ether as resin [(187)].

Also, the result could be attributed to the positive effect of EDTA on bonding of AH-26 sealer as it was postulated by Sheena et al., 2017 where smear layer removal by EDTA leads to expose dentinal tubules, creating rougher surface and producing greater adherence of AH-26 to the dentin through a micromechanical interlocking. Furthermore, the authors reported that the epoxy resin-based AH-26 sealer is thought to be able to react with any exposed amino groups in collagen to form chemical bonds between the resin and collagen when the epoxide ring opens. The potential of this chemical bonding due to ring opening explains the higher adaptation of AH-26 which is consistent in many studies [181].

Kokkas 2004 assessed the penetration depth of different sealers into the dentinal tubules and he found the penetration to be 10 to 80 μm after removal of the smear layer, whereas no penetration was observed with the smear layer intact [192].

Also, our results agreed with De Moore and De Bruyne 2004 study who assessed coronal and apical leakage via dye penetration of AH26 to other types of epoxy - resin sealers in 940 teeth obturated with different techniques. The authors reported that AH26 sealer produced the least microleakage among the sealer groups. Also, they reported that AH26 and other sealers resulted in comparable sealing ability at all evaluation times when used with identical obturation techniques [193].

Also, our results coincided with the results of Oliver and Abbott 1998 who found that AH- 26 produced better the apical seal than the other tested groups of sealers which appeared to be due to bonding efficiently to gutta-percha than to dentine [158].

Our finding was coincided with the result of Sadr et al., 2015 in which, the positive control teeth showed maximum dye penetration and leaked at least 5 mm into the canals and AH-26 group had the least amount of micro-leakage compared to the other groups [161].

On the contrary of our result, Al-Anazi et al., 2020 reported in their study that vioseal sealer had a significant interfacial adaptation and least gap than other sealer groups due to its superior mechanical retention properties [120].

The discrepancy between the apical microleakage between the two sealer groups in our study could be also credited to the difference in density and diameter of dentinal tubules found at the apical level, resulting in lower sealer penetration [194]. Moreover, the smear layer removal is difficult at the apical third that might act as a physical barrier which interfered with sealer adaptation to root canal dentin [76].

6.2. Discussion of voids detection test

In the present study, the remaining forty teeth were used for voids detection test. After samples preparations, the teeth were divided into two groups (n=20) according to the types of sealer used in combination with single gutta-perch cone for canal obturation. Group A (n=20): sealer A (AH26) and Group B(n=20): sealer B (Vioseal). Each root was sectioned at three levels (coronal, median and apical).

Digital images were taken from the apical side of each section using a stereo-microscope at X30 magnification. The images were then transferred to a computer with image analysis software and evaluated for the surface area of all the gaps or voids.

6.2.1. Comparison between both sealer groups as function of radicular region

The analysis of the results as shown in table (5) and figure (29) at the coronal region revealed that sealer B group recorded higher mean ± SD value of gap area (50.38±2.47 µm2) than sealer A group mean ± SD value (49.13±1.99 µm2). The difference between both sealer groups was statistically non-significant as indicated by t-test (t=1.77, P=0.08 > 0.05), at middle region, it was found that sealer B group recorded higher mean ± SD value of gap area (34.44±5.65 µm2) than sealer A group mean ± SD value (29.69±3.26 µm2). The difference between both sealer groups was statistically significant as indicated by t-test (t=3.26, P=0.002 < 0.05), while at apical region, it was found that sealer B group recorded higher mean ± SD value of gap area (40.98±4.76 µm2) than sealer A group mean ± SD value (33.19±8.28 µm2). The difference between both sealer groups was statistically significant as indicated by t-test (t=3.6, P=0.0008 < 0.05).

Based on the previously mentioned results, the presence of voids within both sealers was clear and could not be avoided. Our results were in agreement with the finding of Kumar and Vivekananda, 2016 who reported in their study that the occurrence of voids in the sealer could not be avoided and their existences were attributed to inherent factors associated with either sealer manipulation and handling or its properties or both. They also added that the occurrence of voids in the sealers could be rendered to air entrapment during mixing or carrying and coating the sealer to the canal walls [(177)].

Another study declared that the occurrence of voids within the sealers also depends on the density, flow properties of the sealer and the thickness of the sealer layer [(195)].

Other stated that the induced polymerization stresses during setting of these epoxy resin sealers may lead to debonding of the resin from the canal wall or may cause void formation along the periphery of the root filling [64].

In addition, Wu et al., 2009 and Gomes-Filho et al., 2012 postulated that the occurrence of voids in the SC technique is very significant because the single master cone needs a greater interaction with the sealer to promote the sealing and the volume of sealer used in this technique is larger than with other techniques [14,196]. Therefore, it can be anticipated that SC obturation may be more prone to have voids in the sealer than other obturation techniques and for this reason, sealers should be devoid of or display minimal voids when used with SC technique.

The result of the present study showed that AH26 sealer group exhibited less gap/ voids areas in the three root sections than vioseal sealer group. This finding could be attributed to the chemical composition of AH26 which composed of methenamine and bismuth oxide and to the recommended low powder/ liquid ratio along with the presence of resin in AH26 which led to favorable flow, working time, low solubility and good adhesion to dentinal wall compared to the vioseal which is a paste/paste sealer [197].

It has been reported that there are only a few studies available on the presence of voids within the sealer mass [174].

6.2.2. Comparison between radicular regions within each sealer group

The finding in the current study according to table (5) and figure (29) showed:

In AH26 sealer group: the difference between radicular regions subgroups was statistically significant according to one-way ANOVA with the highest mean ± SD value of gap area (49.13±1.99 μm2) was recorded in the coronal region, followed by apical region mean ± SD value of (33.19±8.28 μm2) meanwhile, the lowest mean ± SD value was recorded within middle region (29.69±3.26 μm2). On other hands, Turkey's post-hoc showed non-significant (p>0.05) difference between middle and apical regions.

In Vioseal sealer group: one-way ANOVA test showed that there was statistically significant difference between radicular regions subgroups as indicated in table (5) and figure (29). The coronal region recorded the highest mean ± SD value of gap area (50.38±2.47µm2) followed by apical region mean ± SD value of (40.98±4.76 μm2) meanwhile the lowest mean ± SD value was recorded with middle region (34.44±5.65µm2).

Ongoing through the results, it was noticeable that both sealers exhibited high value of area of voids/gaps in the coronal radicular region compared to those middle and apical regions. Our result was in agreement with a study performed by Obeidat and Abdallah 2014 who found that matched cone (SC) showed inferior density and more voids in the coronal-third of the root canal than apical and middle thirds in which they recommended the use accessory cones gutta-percha in wide canal to improve the density and quality of obturation [(198)].

Other study, performed by Mckissock et al., 2011 who studied the sealing ability of single cone technique, concluded that single-cone filling technique showed statistically significant higher leakage than other obturation techniques due to the presence of more coronal voids in this technique [(199)].

Other study reported that when the SC is pushed into the canal some of the excess sealers are displaced and backflows coronally which may lead to increase the tendency for air entrapment and probably may explain the occurrence of more voids in the coronal and middle thirds [120].

The results of the study of Gad et al., 2016 confirmed the finding of previous authors who proved that the highest percentage of voids within the root canal filling materials were associated with coronal and middle levels compared to the apical level. From a technical point of view, it is possible to hypothesize that the greater pressure produced in the apical third during the filling procedure may reduce the number of voids and may result in improved adaptation [200].

Regarding the values of voids per area in the middle and apical radicular regions, the finding of the present study revealed that the middle sections of both sealer subgroups recorded lesser values of voids/area when compared to apical sections with best result was recorded for SC obturation with AH26 sealer which showed no significant different between the two subgroups while, for voiceal sealer subgroups recorded a significant different between them.

On the contrary, Al-Anazi et al., 2020 reported in their study that vioseal sealer showed no statistically significant difference on comparing the percentages of voids in the middle section to those of apical sections. A result which was attributed to the superior adaptation of vioseal which could be due to its ability to bond to root dentin chemically by reacting with any exposed amino groups in collagen to form covalent bonds between the epoxy resin and collagen [120].

On other hand, Ferrari et al., 2000 postulated that the discrepancy between apical, middle, and coronal levels might be accounted for the degree of adhesion of the sealer to the dentin wall which is influenced by surface energy and degree of dentin cleanliness, as well as to the surface tension and wetting ability of the sealant. Accordingly, dentin at the coronal, middle, and apical sections have different surface energies and cleanliness which could be difficult to achieve in the apical region due to difficulties in removing the smear layer at this area which prevents sealer infiltration into the dentin tubules. So, they believed that differences between the apical, middle, and coronal regions could be attributed to the lower density and diameter of dentin tubules in the apical regions which resulting in lower sealer penetration [(194)].

Also, the results could be contributed to the presence of the sealer in a thinner film thickness at the apical portion which increases its liability to incorporate more voids at this section compared to the middle one [(201)].

6.3. Correlation between leakage and gap/voids area

Furthermore, as regard Correlation between leakage and gap/voids area aa shown in figure (8) there was a statistically significant direct correlation between leakage and gap/voids area as proved by Pearson correlation test (correlation coefficient (r) = 0.8556, coefficient of determination r squared r2=0.7321, p value =0.02 <0.05).

Our results agree with Moradi et al., 2013 who used fluid filtration test for leakage rate study. There was non-significant correlation between obturation limits and apical leakage. The fluid filtration test shows leakage only when there is at least one void extending from the apical to the coronal thirds. On the other hand, very small 'through and through' type voids are invisible on radiographs but may be detected by the fluid filtration test as having considerable leakage rates [172].

Also, our finding agreed with Cecchin et al., 2012 who compared the correspondence between voids formation and apical micro-leakage in root canals filled with epoxy-resin-based (AH Plus) combined or not with resinous primer or with a methacrylate-based root canal sealer (Epiphany). The voids at apical third were observed by scanning electron microscopy. Apical micro-leakage was detected in the specimens by scanning electron microscopy/energy dispersive spectroscopy. There was correspondence between the presences of voids and microleakage [171].

In the study of Gad et al., 2016, there was non-significant correlation between apical micro-leakage and voids collectively regardless root section and at apical, middle, and coronal root sections [200].

The differences in the results among various studies could be due to different methodologies in detection of voids and leakage rate.

6.4. Limitation of the study

- The present study includes lack of post obturation radiographs to assess quality of obturation before sectioning of specimen for assessment.
- Void testing was carried out in one section at each level of the root (apical, middle and coronal).
- Only two different types of sealer were used in this study of same group (epoxy resin type).
- Preparing the samples was done in a laboratory outside the country (Egypt) and it was relatively expensive.

Conclusion

- Within the limitations of this study, the following results can be drawn:
- None of the tested root canal sealer materials could eliminate the dye infiltration or microleakage formation.
- None of the tested root canal sealer materials provided a gap-free or void-free root canal filling.
- Single cone gutta-percha combined with AH26 sealer exhibited less microleakage than vioseal sealer although there were no statically significant differences between them.
- Regardless to radicular regions, it was found that vioseal sealer (group B) recorded statistically significant higher mean value of gap area than AH26 sealer (group A) mean value as indicated by two-way ANOVA test.
- Concerning the radicular regions, it was found that both sealer groups exhibited higher mean values of gap/voids at the coronal radicular region of the root canal compared to the apical and middle regions with a highest value was recorded for vioseal root canal sealer but with no statically significant differences between the values of the two sealer groups.
- Apical radicular regions of both sealers exhibited higher areas of voids/gap than the middle regions with a highest void area values were recorded for vioseal root canal sealer within both regions and there were statistically significant differences between them.

Recommendation

- Further studies should be employed using a larger sample and calculating the percentage of voids in relation to the total area of each canal section or the whole canal would assist to further validate the results of this study.
- Further studies are needed using other effective methods for the evaluation of voids and gap formation.
- It is important that future studies should be conducted using single cone obturation technique in conjunction with large number of different types of epoxy resin sealers for microleakage evaluation and voids/ gaps detection.
- Further long-term studies are necessary to establish the clinical performance of single gutta-percha obturating system in conjunction with different sealers.
- Further studies should be conducted to assess the leakage in multi rooted teeth when obturated with different obturation techniques.

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Microleakage Assessment of Single Cone Gutta Percha Obturation Technique Using Different Types of Sealers

تقييم معدل الارتشاح لمادة حشوة قناة الجذر الفردية باستخدام عدة أنواع من مواد مانعات التسرب لحشو العصب

By

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1.Introduction

The goal of root canal filling is to create a three-dimensional sealing in order to prevent the recurrence of bacterial infection [1]. By preventing the leakage between the root canal and the periapical tissues, the procedure should also prevent that any microorganism and toxic bacterial products penetrate into the periapical tissues [1]. Several obturation techniques are used for the filling of root canals: the lateral condensation, Tag ger's hybrid, vertical compression, and thermoplasticized gutta-percha techniques. More recently, with the advancement of the rotary instrumentation systems, the single-cone obturation technique has been used. This technique uses larger master cones that best match the geometry of the nickel-titanium rotary systems (NiTi) [2]. The use of these gutta-percha points does not require either accessory points or the lateral condensation when the root canal is enlarged with rotary instruments. The technique speeds the root canal filling while minimizes the pressure applied to the root canal walls. The combination of single cone and endodontic cement results in a uniform mass that prevents failures observed among multiple cones [3]. More recently, gutta-percha points of the ProTaper system were launched into the market emphasizing that they are simpler and result in faster obturation. In this system, root canals are shaped with ProTaper instruments and filled with the gutta-percha point size matching the size of the last instrument used. Their manufacturer claims that the ProTaper gutta-percha points perfectly fit within the root canals shaped with the instruments of this system [4]. Lateral condensation and warm vertical compaction show some disadvantages, such as: lack of gutta-percha homogeneity, high percentage of endodontic cement at the apical portion of the root, poor adaptation to the root canal walls, and apical extrusion of the gutta-percha [5]. To overcome these disadvantages, the single cone technique was developed. The use of these cones with endodontic cement may promote the sealing of the root canal without the need for accessory cones, it takes less time than the lateral condensation when the root canal is enlarged with rotary instruments [5]. Because the single-cone technique is simpler than the lateral condensation, the operator is less subjected to fatigue; however, such considerations should be subordinated to the main objective of providing the best treatment for the patient [6].

The root canal sealer plays an important role in reducing leakage. Many types and brands of sealers are commercially available. At present, sealers based on epoxy resins provide very good physical properties and ensure adequate biological performance [7]. Leakage along root fillings may increase or decrease during the course of a long period after filling. Dissolution of sealer and the smear-layer may result in a rise in leakage [8],whereas gutta-percha swelling may result in diminished leakage [9].Most sealers shrink during setting, leaving unwanted voids, and gradually dissolve [10].Their sealing ability is also influenced by such physical properties as viscosity, flow, setting time, and film thickness [11].Leakage studies on the sealing properties of endodontic materials constitute an important area of research.

Various test methods have been described to evaluate the quality of the seal, such as dye penetration, clearing of the teeth, radioactive isotope testing, bacterial penetration, electrochemical test, and fluid filtration. The methodology that uses tooth immersion in various types of dyes is easy to perform [12,13].A large number of studies have used methylene blue as a dye [14,15] because it is inexpensive, easy to handle, has a high degree of staining [16] and has a molecular weight lower than that of bacterial toxins [17]. The purpose of this *in vitro* study is to compare the coronal and apical seal of canals obturated with different types of sealers.

2. Aim of the study

The aim of this *in vitro* study is to compare the coronal and apical seal of canals obturated with different types of sealers.

3. Materials and Methods

3.1. Sample selection:

100 newly extracted human upper first and second molar teeth with fully formed palatal roots will be selected for this study. Visual inspection under dental microscope will be done to verify any open apices, cracks, resorptive defects and canal calcifications. The teeth will be immersed in 5 % NaOCl solution for 5 min. Subsequently, the samples will be cleaned of tissue remnants and calculus and then will be rinsed and stored in normal saline.

3.2. Specimens Preparation

The crowns of the teeth will be decoronated using a high-speed handpiece under continuous water spray then working length (WL) will be determined by inserting a K-file# 15 into the canal until it will just visible at the apical foramen, then 1 mm will be subtracted from this measurement. The root canals will be prepared using ProTaper gold rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) installed on an electrical endodontic handpiece (e-connect s by eighteeth company, china). Preparation will be carried out according to the manufacturer's recommendations using the crown-down technique.

The canals will be irrigated between instruments with 5 mL of freshly prepared solution of 5% NaOCl carried up to the apical 3 mm with 27-gauge disposable plastic syringes needle tips placed passively into the canal. Following instrumentation, root canals will be irrigated with 1 mL EDTA 17% followed by 5 mL 5% NaOCl to remove the smear layer. Finally, the root canals will be flushed with 3 mL of saline solution and dried with paper points.

3.3. Specimens Grouping

3.3.1 for microleakage test:

Sixty teeth were used and divided into 3 groups, consisting of two experimental groups (*n*=20) according to the types of epoxy resin sealers used in the study and one control group (*n=20)* without sealer.

- Group 1: In this group (sealer A) AH26 sealer was used in combination with single gutta-percha cone for canal obturation with (*n*=20).
- Group 2: In this group (sealer B) Vioseal sealer was used in combination with single gutta-percha cone for canal obturation with (*n*=20).
- Group 3: Control group (*n*=20), in this group the single gutta-percha cone was placed in the canal without sealer.

3.3.2 for voids test:

The remaining twenty teeth divided into two groups (*n*=20) for each type of sealer.

- Group A: sealer A (AH26) (*n*=20)
- Group B: sealer B (vioseal)(*n*=20)

The external root surfaces of all the specimens in each group were painted by one layer of one color of nail varnish differed from the color of the other group.

3.4. Sealer application and obturation

The sealers will be carried into the canals using a lentulo spiral except for the control group that will be obturated by single cone gutta percha without sealer. In all of the groups, root canal obturation will be carried out using the single-cone obturation technique up to the full working length.

The excess gutta-percha will be removed with a gutta percha cutter device and the remaining gutta-percha will be vertically compacted at the canal orifice

All specimens will be leaved four weeks in room temperature to allow complete setting of the sealers.

3.5. Microleakage detection

- Dye penetration test:

The roots will then be placed in 2% methylene blue dye (for 24 hr. in incubator (37^o C).

The teeth will then be removed from the dye and excess of dye will washed off under running tap water to remove dye on external root surface.

The roots will then be sectioned vertically along the long axis to ensure that the sectioning process did not damage the inside of the canal, the sectioning.

Samples will then be evaluated under a stereomicroscope to detect the extent of dye penetration from the apical constriction, and the higher value among them will be taken.

With the help of the microscopic images obtained, the linear measurement of the dye penetration will be noted from apical to coronal direction. The image transferred to a computer equipped with the image analysis software program where the dye penetration along the filling dentine interface will be evaluated.

3.6. Voids detection:

Each root will be sectioned at three levels (coronal, median and apical). A total of 120 section surfaces will obtained.

Digital images will be taken from the apical side of each section using a stereo-microscope magnification. The images will then be transferred to a computer with image analysis software and evaluated for the surface area of all the gaps or voids. A total of three measurements will done for each root (coronal, middle and apical) and the surface area of the gaps or voids

3.7. Statistical analysis

The collected data will be statistically analysis by using Graph Pad Instat (Graph Pad, Inc., USA) software for windows. A value of $P < 0.05$ was considered statistically significant. One-way ANOVA will be done for compared time followed by Tukey's pairwise if showed significant for leakage results. Two-way analysis of variance will be performed for gap results. Student t-test was done between groups at different regions for gap. Correlation between leakage and gap/voids area was performed by Pearson correlation test.

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تقييم معدل الارتشاح لمادة حشوة قناة الجذر الفردية باستخدام عدة أنواع من مواد مانعات التسرب لحشو العصب

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الملخص العربي

تلعب مواد منع التسرب اللبية دورًا مهمًا في توفير ختم غير منفّذ وإنشاء ختم قمي وإكليل محكم للسوائل لمنع التسرب الدقيق الذي يمكن أن يؤدي إلى فشل العلاج. الفراغات الموجودة في كتلة المادة المانعة للتسرب لديها القدرة على السماح بالتسرب من خلال السد. إنها أكثر خطورة في سد المخروط الفردي حيث أن حجم السداد المستخدم في هذا السد كبير.

الهدف: مقارنة الختم الإكليلي والقمي للقنوات المسدودة بمواد سد مختلفة لقناة الجذر ولتقييم الفجوات أو الفراغات التي تحدث في الجذور المملوءة بمواد مختلفة من مانعة التسرب لقناة الجذر.

المواد والطرق: تم استخدام مائة من الأضراس العلوية البشرية مع جذور حنكية مكتملة التكوين وسليمة في الدراسة. تم استخدام ستين سنًا لاختبار التسرب المجهري بينما تم إخضاع الأربعين سنًا الأخرى لاختبار كشف الفراغات. تمت إزالة تاج كل سن عند تقاطع المينا الأسمنتي وتم تحضير قناة الجذر الحنكي باستخدام أدوات بروتيير جولد الدوارة.

لاختبار التسرب المجهري: تم استخدام ستين عينة وقسمت إلى 3 مجموعات متساوية (ن = 20) لسد المخروط الفردي باستخدام نوعين مختلفين من السدادات راتنجات الإيبوكسي أي إتش 26 والسدادات فايوسيل على التوالي ومجموعة تحكم واحدة بدون مادة مانعة للتسرب.

تم تعريض جميع العينات بالورنيش متبوعًا بصبغة زرقاء ميثيلين بنسبة 2 ٪ ثم تقطيع الجذر. ثم تم تقييم العينات تحت المجهر الضوئي لاكتشاف القياس الخطي.

تم نقل الصورة إلى جهاز كمبيوتر مزود ببرنامج تحليل الصور.

بالنسبة لاختبار كشف الفراغات: تم تقسيم العينات الأربعين المتبقية إلى مجموعتين (ن = 20) لسد المخروط المفرد باستخدام السدادة المخروطية أي إتش 26 والسدادة فايوسيل على التوالي. تم تقسيم الأسنان المسدودة إلى الثلث القمي والمتوسط والإكليلي، وتم تقييم مساحة الفراغات في السداد باستخدام مجهر ضوئي رقمي وصور رقمية وبرامج صور.

تم تحليل البيانات التي تم جمعها إحصائيًا باستخدام برنامج جراف باد إنستانت لنظام التشغيل ويندوز.

تم إجراء أنوفا أحادي الاتجاه لوقت المقارنة متبوعًا بزوج توكي إذا أظهر نتائج تسريب كبيرة. تم إجراء تحليل التباين ثنائي الاتجاه لنتائج الفجوة.

تم إجراء اختبار تي استيودينت بين المجموعات في مناطق مختلفة للفجوة. تم إجراء الارتباط بين منطقة التسرب والفجوة / الفراغات بواسطة اختبار ارتباط بيرسون.

أظهرت النتائج أنه بالنسبة لتقييم التسرب المجهري، كان الاختلاف في اختراق الصبغة يعني التسرب الدقيق بين المجموعات ذات دلالة إحصائية كما يتضح من اختبار أنوفا أحادي الاتجاه (p $0.05>$).

أظهر اختبار زوج توكي فرقا غير مهم ($p> 0.05$) بين مجموعات (أي إتش 26 وفايوسيل). بالنسبة لمساحة الفجوة / الفراغات (ميكرون) لكلتا مجموعتي السدادات بغض النظر عن المناطق الجذرية، فقد وجد أن السداد فايوسيل سجل قيمة متوسطة أعلى ذات دلالة إحصائية لمساحة الفجوة مقارنة بمواد السداد أي إتش 26.

بغض النظر عن نوع السدادة وجد أن المنطقة الإكليلية سجلت أعلى متوسط قيمة لمساحة الفجوة تليها القيمة المتوسطة للمنطقة القمية.

توجد علاقة ارتباطية مباشرة ذات دلالة إحصائية بين منطقة التسرب ومنطقة الفجوة / الفراغات كما أثبت اختبار ارتباط بيرسون.

الخلاصة: لا يمكن لأي من سدادات قناة الجذر المختبرة القضاء على تسلل الصبغة أو تكوين التسرب المجهري. أظهر جوتا بيركا المخروطي المفرد جنبًا إلى جنب مع مانع التسرب أي إتش 26 تسريبًا ميكروليًا أقل من السداد الفيوسيل على الرغم من عدم وجود فروق ذات دلالة إحصائية بينهما. وقد وجد أن جهاز السدادة الفيوسيل سجل قيمة متوسطة أعلى ذات دلالة إحصائية لمساحة الفجوة من جهاز ختم أي إتش 26.

تقييم معدل الارتشاح لمادة حشوة قناة الجذر الفردية باستخدام عدة أنواع من مواد مانعات التسرب لحشو العصب

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قدمت هذه الدراسة استكمالا لمتطلبات الحصول على درجة الماجستير في خواص مواد الأسنان

جامعة بنغازي

كلية طب وجراحة الفم والاسنان

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