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Assessment of the Ability to Seal the Apex Using Gutta-Percha Combined with Bio-C Sealer, Activ GP with Bio-C Sealer, and Activ GP with Activ GP Sealer as Materials for Root Canal Filling: A Stereomicroscopic Study conducted in vitro

Mona Ismail Arto[1], Sharif Mansoor[2]

[1]General Dentist, Riyadh Kingdom of Saudi Arabia
[2]Specialist Oral and Maxillofacial surgeon, Riyadh Kingdom of Saudi Arabia

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Abstract— *Fifty freshly extracted human permanent mandibular single-rooted premolar teeth were utilized in this study. The anatomical crowns of the chosen teeth were removed with a diamond disc, and pulp tissue was eliminated using barbed broaches. The working length was established by subtracting 0.5mm from the length determined with the tip of the trial file just visible at the apical foramen of each root canal in all specimens. Biomechanical preparation was conducted in all specimens using the crown-down technique with the ProTaper Next rotary file system. The master apical file was set to X4 (Size 40 and 6% Taper). The specimens were randomly assigned to five groups, each comprising 10 specimens. Group 1 utilized Master Gutta-percha points coated with Bio-C sealer, Group 2 used Master Activ GP points coated with Bio-C sealer, and Group 3 employed Master Activ GP points coated with Activ GP sealer as obturation materials with a single-cone technique. Group 4 served as the Negative control, with root canals left unobturated, while Group 5 served as the Positive control, using Master Gutta-percha points without any root canal sealer as the obturation material. All canal orifices were sealed with restorative Glass ionomer cement. Subsequently, specimens were double-coated with nail varnish, except for the apical 3mm of roots, and immersed in petri dishes containing Indian ink dye for 48 hours. After dye removal, nail varnish was completely eliminated, and specimens were longitudinally sectioned with a diamond disk. For each specimen, the half containing the most visible part of the entire root canal was selected, and the extent of linear dye penetration was measured using a Stereomicroscope following Escobar's criteria. The measurements were recorded, tabulated, and statistically analyzed using One Way ANOVA and Tukey's Post-hoc tests. Gutta-percha coated with Bio-C sealer as a root canal obturation material exhibited the highest apical sealing ability compared to Activ GP with Bio-C sealer and Activ GP with Activ GP sealer. Activ GP with Activ GP sealer displayed the lowest or poorest apical sealing ability.*

Keywords— ***Premolar teeth, Crown-down technique, ProTaper Next, Bio-C sealer, Stereomicroscope***

I. INTRODUCTION

The primary objectives of root canal therapy are to thoroughly clean, shape, and fully fill the root canal system in three dimensions, ensuring a fluid-tight seal. This seal is crucial for preventing the ingress of microorganisms and their by-products from peri-radicular tissues into the root canal system. Approximately 60% of endodontic failures stem from incomplete obturation of the root canal space. Microleakage, often resulting from gaps within the root filling or between the filling and dentin walls, is a common

cause of treatment failure, allowing bacteria and toxins to infiltrate the canal. Thus, achieving a fluid-tight apical seal is essential for preventing reinfection.

Gutta-percha (GP) is widely regarded as the gold standard obturation material due to its biocompatibility, non-staining properties, and radiopacity. However, despite its advantages, gutta-percha alone does not provide a complete dentinal seal, leaving potential unfilled spaces that can lead to leakage. Therefore, the ability of a root canal sealer to bond effectively to both dentinal walls and obturation material is crucial for treatment success.

In recent years, there has been growing concern about the inadequate sealing properties of conventional root canal filling materials. To address this, there has been a shift towards developing obturation materials capable of bonding to dentin walls to eliminate interfacial gaps, drawing on dentin adhesive technology from restorative dentistry.

Activ GP is a novel Glass-Ionomer (GI)-based obturation system designed to address these concerns. It features a 2 µm coating of GI particles on its surface and within the cone body to enhance bonding with gutta-percha and dentinal walls. These cones are precisely sized by laser to ensure a precise fit and are used with GI sealer to improve bonding.

Bio-C (Ceramic) is a calcium silicate-based root canal sealer composed of various materials including zirconium oxide, dicalcium silicate, and calcium hydroxide. It is insoluble, radiopaque, and aluminum-free, requiring water to set and harden. Developed for single cone as well as lateral condensation techniques, Bio-C offers a working time of 4 hours at room temperature.

This in-vitro study aims to assess the apical sealing ability of Gutta-percha with Bio-C sealer, Activ GP with Bio-C sealer, and Activ GP with Activ GP sealer through stereomicroscopic analysis.

II. MATERIALS AND METHODS

Fifty freshly extracted human permanent mandibular single-rooted premolar teeth were obtained from Triveni Institute of Dental Sciences, Hospital, and Research Centre, Bilaspur, India. Inclusion criteria specified non-carious, non-fractured, unrestored matured teeth with closed root apices, single roots, single canals, and the absence of calcifications, resorptive defects, or other anatomical anomalies.

Teeth extracted solely for orthodontic reasons or those compromised by periodontal issues were considered for inclusion in this study. Criteria for exclusion encompassed teeth with caries, fractures, restorations, open root apices, multi-rootedness, or multiple canals. Initial preparation involved cleaning teeth of surface debris, calculus, and residual tissue using ultrasonic instruments, followed by immersion in a 3% sodium hypochlorite solution for disinfection, rinsing with tap water, and storage in 0.5% thymol at room temperature until use.

The anatomical crowns of selected teeth were sectioned using a diamond disc attached to a low-speed contra-angled handpiece to achieve a standard root length of up to 16 mm, perpendicular to the cemento-enamel junction. Subsequently, pulp tissue was removed with barbed broaches and K-files, ensuring patency to the apical foramen. Working length was determined by subtracting 0.5 mm from the length indicated by the trial file's tip visible at the apical foramen. Biomechanical preparation employed the ProTaper Next rotary file system in a crown-down technique as per the manufacturer's instructions, with the master apical file set to X4 (Size 40 and Taper 0.06), using 17% EDTA and 3% sodium hypochlorite solutions as irrigants. Following instrumentation, root canals were flushed with distilled water and dried with sterile paper points.

Subsequently, specimens were randomly assigned to five groups, each comprising ten specimens.

Group 1: A Master Gutta-percha point (Size 40, Taper 6%) from Dentsply Maillefer (Ballaigues, Switzerland) was uniformly coated with Bio-C sealer (Brasseler, USA). It was then slowly inserted into the root canal until the predetermined working length was reached, verified for tugback, and filled using the single-cone technique.

Group 2: A Master Activ GP point (Size 40, Taper 6%) from Brasseler (USA) was uniformly coated with Bio-C sealer. It was slowly inserted into the root canal until the predetermined working length was reached, checked for tug back, and filled using the single-cone technique.

Group 3: A Master Activ GP point (Size 40, Taper 6%) was uniformly coated with Activ GP sealer. It was slowly inserted into the root canal until the predetermined working length was reached, verified for tug back, and filled using the single-cone technique.

Group 4 (Negative control): Root canals were left unobturated; neither obturation material nor root canal sealers were used.

Group 5 (Positive control): A Master Gutta-percha point (Size 40, Taper 6%) was slowly inserted into the root canal until the predetermined working length was reached, verified for tug back, and filled using the single-cone technique, without the use of any root canal sealer.

Both Bio-C and Activ GP sealers were handled following their respective manufacturer’s instructions. Once the root

canals were filled, Gutta-percha and Activ GP cones were positioned accordingly.

The root apices were seared off 2mm below the canal orifices and sealed with Glass ionomer restorative cement (GC Corporation, Tokyo, Japan).

Following the completion of root canal filling, radiographs were taken of all specimens to evaluate the quality of obturation. The specimens were then stored at 37°C in 100% relative humidity for 10 days. Subsequently, they were double-coated with nail varnish, excluding the apical 3mm of roots. Each layer of nail varnish was allowed to dry completely before the next layer was applied. The specimens from each group were then individually placed in separate petri dishes and immersed passively in Indian ink dye (Himedia Laboratories Pvt. Ltd. Mumbai, India) for 48 hours at 37°C.

After removal from the dye, the teeth underwent a thorough rinse under running tap water for 10 minutes, and the nail varnish was completely removed using a scalpel blade. Each root was then longitudinally sectioned bucco-lingually with a diamond disk (0.3 mm in thickness) using a low-speed handpiece. The root was carefully split into two halves by wedging a fine chisel into the groove and gently twisting the chisel. For each specimen, the half containing the most visible part of the entire root canal (from root apex to the orifice) was selected, and the other half was discarded.

Root canal instrumentation and handling of all specimens among the five groups were performed by a single endodontist to minimize inter-operator variability, and the endodontist was not blind to the groups.

The extent of linear dye penetration was measured to the nearest millimeter from the root apex to the coronal extent of each sectioned specimen using a Stereomicroscope (Labline, India) at 20X magnification. Escobar's criteria were utilized to analyze the extent of apical dye penetration/leakage in this in-vitro study. All specimens were analyzed by one examiner who specialized in Endodontics, and the data were recorded.

- Score 0: Infiltration loss (dye penetration 0–<1.5 mm).
- Score 1: Simple infiltration (dye penetration 1.5–3 mm).
- Score 2: Medium infiltration (dye penetration > 3 mm).

III. RESULTS

The observed measurements of apical dye penetration/leakage for all specimens were organized into a table and subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 24, employing Analysis of Variance (One Way ANOVA) and Tukey's Post hoc test.

Analysis of Variance examines the equality of three or more means simultaneously by assessing variances. One Way ANOVA revealed a statistically significant disparity in the mean values of apical dye leakage among the groups, indicated by a P (Probability) value of < 0.05.

GROUPS	No. of Specimens	Mean ± SD*	*P value
Group 1 (Gutta-percha[GP] with Bio-C sealer)	10	0.4 ± 0.5	P < 0.05
Group 2 (Activ GP with Bio-C sealer)	10	1.0 ± 0.67	
Group 3 (Activ GP with Activ GP sealer)	10	1.5 ± 0.52	
Group 4 (Negative control)	10	2.0 ± 0.2	
Group 5 (Positive control)	10	1.8 ± 0.48	

IV. DISCUSSION

The primary goal of root canal obturation is to prevent recontamination of the root canal system by impeding the ingress of microorganisms and fluids. Various methods have been employed to assess the apical sealing ability of root canal filling materials, including dye penetration, dye extraction, and fluid infiltration. In this in-vitro study, the dye penetration method was chosen due to its simplicity, speed, and cost-effectiveness, making it a widely accepted indicator of potential leakage. A passive dye penetration method was adopted, with the positive control group specimens validating the reliability of this approach based on the extent of dye penetration observed.

It is widely acknowledged that gutta-percha alone does not establish ideal bonding with root canal dentin, leading to investigations into alternative materials capable of creating a tight and durable apical seal. When gutta-percha is used with conventional root canal sealers, gaps often exist between the gutta-percha, sealer, and root canal dentin, facilitating the passage of bacteria and fluids.

Bioceramic materials, encompassing bioinert, bioactive, or biodegradable categories based on their interaction with surrounding tissues, have emerged as promising alternatives. Bio-C sealer, a calcium silicate-based bioceramic sealer, undergoes a setting reaction resulting in calcium phosphate precipitation, promoting bioactivity and tissue growth. The setting mechanism involves a reaction

with water, either from tissue fluids or in humid conditions, leading to the formation of a hydraulic seal.

In this study, Group 1 specimens, obturated with gutta-percha coated with Bio-C sealer using a single-cone technique, exhibited superior apical sealing ability with minimal dye penetration (mean value 0.4) compared to Group 2 (Activ GP with Bio-C sealer) and Group 3 (Activ GP with Activ GP sealer). This can be attributed to the properties of Bio-C sealer, including tubular diffusion of sealer particles into dentinal tubules and formation of a mineral infiltration zone, enhancing sealing efficacy.

Efforts have been made to develop new obturation materials such as Activ GP, aiming for a "Monoblock" seal that adheres and bonds to root canal dentin. Group 2 specimens, obturated with Activ GP coated with Bio-C sealer, demonstrated optimal apical sealing ability with moderate dye penetration (mean value 1.0), although a statistically significant difference in dye leakage was noted compared to Group 1. Conversely, Group 3 specimens, obturated with Activ GP coated with Activ GP sealer, exhibited poor apical sealing ability with greater dye penetration (mean value 1.5).

In endodontics, the use of adhesive systems within the root canal remains controversial due to challenges in bonding to radicular dentin. Factors such as irregular canal anatomy, decreasing dentinal tubules in the apical area, and calcified apical canal walls pose obstacles to resin bonding. Additionally, resin bond durability may be compromised over time due to functional forces or incomplete resin infiltration into demineralized dentin, leading to fluid movement between the hybrid layer and unaffected dentin.

The increased dye leakage observed with the Activ GP system (Activ GP with Activ GP sealer) highlights the need for further research into enhancing the sealing properties of obturation materials, particularly in challenging clinical scenarios characterized by irregular canal anatomy and calcified canal walls.

Using Activ GP sealer as the obturation material in our study aligns with the findings of Horsted-Bindslev et al., who similarly linked the failure of the Activ GP system in preventing dye leakage to the polymerization shrinkage of the glass ionomer sealer (Activ GP sealer) and the inadequate bonding of the Activ GP cone with its sealer due to non-uniform coating of fillers on the cones.

The Activ GP - Sealer system employs a single-cone technique, where the master cone closely matches the geometry of NiTi rotary files used for canal instrumentation. Consequently, there may be a thicker layer of sealer at the interfacial area between root canal dentin and Activ GP. Research has demonstrated that a thicker layer of root canal sealer can compromise sealing ability, leading to voids caused by shrinkage during the setting reaction.

Data regarding the sealing ability of the Activ GP system as an obturation material have been contradictory. While Monticelli et al. found no difference in leakage between teeth obturated with Gutta-percha/AH Plus sealer and Activ GP/GI sealer (Activ GP sealer) using a fluid filtration model, bacterial leakage studies using S. mutans revealed significantly more leakage with single-cone obturation using Activ GP/GI sealer (Activ GP sealer) compared to GP/AH Plus sealer. Within the scope of our in-vitro study, none of the tested root canal obturation systems achieved a complete seal.

V. CONCLUSION

Within the limitations of our study, Gutta-percha coated with Bio-C sealer exhibited superior apical sealing ability compared to Activ GP with Bio-C sealer and Activ GP with Activ GP sealer. Activ GP with Activ GP sealer demonstrated the least effective apical sealing ability. However, further in-vivo studies are warranted to validate and correlate our in-vitro findings with clinical outcomes.

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