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Evaluation of Effectiveness of Two Different Retreatment Systems in Removal of Obturation Materials From Curved Canals: An in-Vitro Study

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Abstract

Introduction: The primary objective of endodontic retreatment is to remove the contamination of the root canals, thus facilitating the recovery of periapical tissues and allowing tissue healing.

Aim of the study: The purpose of the present study was to evaluate the effectiveness of the two retreatment rotary systems Pro-Taper retreatment system and Neo-Endo retreatment system in the removal of obturating materials from curved canals.

Materials and Methods: Forty (mesio-buccal) root canals of upper or lower molars were designated for the study and prepared using Pro-Taper Gold. Then canals were separated into two groups (A and B) based on the type of sealer. Twenty canals in group A were filled with (AH Plus sealer), whereas 20 canals in group B were filled using (Cera-Seal) bio-ceramic sealer. Each group was divided into two subgroups, subgroups (and) (n=10 for each) based on the retreatment method: Pro-Taper and Neo-Endo retreatment systems.

Results: The analysis between groups revealed statistically significant difference exists between the two evaluated sealers, bio-ceramic sealers and AH Plus sealer. Higher value of obturating materials remnants was recorded in canals filled with AH plus and retreated by Neo-endo rotary system. While the lowest mean value was measured in canals filled with bio-ceramic sealer and reshaped using the Pro-Taper rotary system.

Conclusion: Pro-Taper retreatment system is more efficient in removal of the obturating materials. AH plus remnants can be eliminated easily compared to Cera-Seal sealer.

INTRODUCTION

Successful nonsurgical endodontic retreatment depends on effective microbial reduction within the canals and the achievement of sufficient three-dimensional seal [1]. The root canal treatment failure is often associated with continued presence of microorganisms within the intricate anatomy of the canal system combined with insufficient obturation, which might lead to persistent apical pathology [2].

Endodontic retreatment necessitates the thorough elimination of current obturating materials to facilitate appropriate sterilization, reshaping, and obturation [3]. This procedure is frequently difficult, particularly in curved canals, where the existence of filling materials serves as a physical obstacle and raises risk of procedural errors and changes in canal morphology [4].

Gutta-percha utilized alongside a sealer continues to be the most prevalent filling technique. Since gutta-percha lacks the binding capacity to dentin, the sealer is essential for achieving a proper seal between the obturating materials and the walls of the canal [5]. Therefore, the type and sealer properties significantly influence both the obturation quality and the efficiency of material removal during retreatment procedures [6].

Root canal sealers are available in various formulations, including resin-based and bioceramic sealers, each exhibiting different bonding behaviors and retreatability characteristics [7]. Resin-based sealers like AH Plus commonly utilized because of their advantageous sealing capability, minimal solubility, and capacity to access canal irregularities. However, these same properties may compromise their ease of removal during retreatment [8].

Recently, bio-ceramic sealers have received growing interest due to their biological compatibility, dimensional stability, and bioactive attributes [9]. CeraSeal is a premixed bioceramic sealer that sets in the presence of moisture without shrinkage, resulting in close adaptation to dentinal walls and enhanced sealing performance [10]. The strong interaction between bioceramic sealers and dentin may influence the retreatment procedures effectiveness [11].

Various techniques have been proposed for removing obturating materials, with nickel-titanium rotary retreatment systems demonstrating superior efficiency compared with manual instrumentation [12, 13]. ProTaper and NeoEndo retreatment systems are specifically designed for extraction of the obturation materials from different levels of the canal; however, their effectiveness in curved canals may vary depending on design characteristics [14, 15].

The aim of this research was to assess and analyze the efficiency of Pro-Taper and Neo-Endo retreatment systems in the elimination of obturating materials from curved roots canals.

MATERIALS AND METHODS

1. **Study setting and ethical considerations**

The study procedures received approval from the Research Ethics Committee (REC) of the Faculty of Dentistry, Suez Canal University, under authorization number 435/2022, in accordance with the Helsinki Declaration of the World Medical Association (2008 Version).

2. **Sample size calculation**

An overall sample size of at least 40 samples was adequate to identify an effective size of 0.27, achieving a power (1-β=0.90) of 90% at a level of $p<0.05$ with a partial eta squared of 0.14. As indicated in Table (1), treatment groups (A, B) and subgroups (□, □) would each require at least 10 samples based on sample size calculations.

Table 1 Interaction of Variables.

Variables		Type of Retreatment file		Total
		Subgroup (□)	Subgroup (□)	
Type of sealer	Group A	AI (10 teeth)	A□ (10 teeth)	20
	Group B	BI (10 teeth)	BII (10 teeth)	20
Total samples				40

3. **Preparation of the Sample**

Forty newly extracted first permanent molars from the mandibular and maxillary regions were chosen for the research. The curvature of the mesio-buccal root canal varies from 25 to 35 degrees according to Schneider's technique [16]. Any calculus on the surfaces of the root was eliminated by a Gracey curette. Then, samples were soaked in normal saline at 37 ºC and 95% humidity until used. By using a high-speed fissure bur with an air water spray, all teeth were decoronated to achieve root segments measuring 15mm in length to standardize the samples. K-file size #10 will be utilized for verification of apical patency, and a working length that is 1mm shorter than the length determined with size # 15 K-file, when observed in the apical foramen of the root.

4. **Embedding of the samples in silicone blocks**

A custom-made plastic mold measuring 15 × 15 × 20 mm (length × width × height) was fabricated and coated with petroleum jelly to act as a separating medium, facilitating subsequent removal of the silicone blocks. A silicone replication substance was blended according to the producer's guidelines and placed into the plastic mold. To stop the silicone's entry into the foramina, root apices were sealed by wax before the embedding. The silicone was allowed to set completely, after which the silicone block was removed from the mold. Specimens from the different experimental groups were then numerically coded for ease of identification.

5. **Measurement of root canal curvature using periapical radiograph:**

The root canal curvature was measured by using the Image J Software, where canal curvature was obtained by drawing a straight line along the root canal longitudinal axis in the coronal third and a second straight line from the root foramen to intersect with the first line at the point where the canal begins to drift from the tooth long axis. This technique gives the deflection angle between the intersecting lines as shown in Figure 1.

6. **Root canal preparation**

All canals were shaped using Pro-Taper Gold instruments till size F3. During biomechanical preparation, irrigation was conducted by a total volume of 18 mL of 2.5% sodium hypochlorite administered through a 30-gauge needle with a side vent. A 3 mL aliquot was employed following each instrument for a period

of 1 minute. The ultimate irrigation schedule comprised of 2 mL of 17% ethylenediaminetetraacetic acid (EDTA), followed by 2 mL of saline and 2 mL of sodium hypochlorite. Then, the final rinse with 2 mL of saline was conducted, and sterile paper points were used to dry the canals. Sealing the root canals using a lateral compaction technique was employed. Sealers were utilized based on the designated experimental groups.

In Group A, an epoxy resin–based (AH Plus) sealer provided as two distinct pastes (A and B) were combined following the manufacturer's guidelines. The master cone was covered by the blended sealer and placed inside the canal.

In Group B, a bio-ceramic sealer (Cera-Seal) offered in a pre-filled syringe was directly injected inside the canal, followed by placement of master cone. A finger spreader was then positioned until 2 mm of working length of the canal to assist in lateral condensation of the gutta-percha. Accessory gutta-percha cones covered by the appropriate sealer were successively introduced until the canal was fully filled. Excessive gutta-percha eliminated by a heated tool; the canal openings were temporarily closed off using Cavit-G restorative substance.

7. **Root canal retreatment**

Subgroup I: Retreatment was performed with Pro-Taper retreatment files D1 (size 30) and (taper .09) at coronal third, D2 (size 25 and taper .08) at middle third, and D3 (size 20 and taper .07) at apical third extending to the operational length. The electric motor (E-connect pro) was used at a speed rotation of 300 rpm and a torque of 2 Ncm.

Subgroup II: Retreatment employed Neo-endo retreatment files N1 (size 30 and taper .09) at coronal third, N2 (size 25 and taper .08) at middle third, and N3 (size 20 and taper .07) at apical third extending to the operational length. Electric motor (E-connect pro) used at a speed rotation of 300 rpm and a torque of 1.5 Ncm

In the retreatment process, irrigation was carried out using 2.5 percent of sodium hypochlorite succeeding the usage of each file. Total volume of 9 mL of the solution used per canal, with 3 ml delivered after each instrument. Debris accumulated on the files was removed using sterile gauze, and the instruments were inspected for signs of deformation. No adjunctive solvents or additional instruments were employed. Retreatment was considered complete when a size # 15 K-file was observed in the apical foramen.

8. **Stereomicroscopicevaluation of retreated root canals**

Following retreatment with the respective systems, the specimens were longitudinally sectioned in a buccolingual direction using a mallet and chisel. The exposed canal surfaces were digitally imaged and divided into coronal, middle, and apical regions at 4, 8, and 12 mm from the apex, respectively. Each region was examined under a stereomicroscope, and the quantity of remaining gutta-percha and sealer was measured through image analysis software (ImageJ, NIH, United States).

9. **Statistical Analysis**

The statistical evaluation was conducted for comparison between two distinct retreatment files (Pro-Taper and Neo-endo) at different groups. The information was gathered, organized, and arranged in tables and charts utilizing Microsoft Excel 2016.

ANOVA was succeeded by Duncan multiple range tests (DMRTs) to make comparisons between intervention groups. The difference between the two retreatment files was conducted by an independent samples t-test or relevant statistical assessment for nonparametric data.

Analysis of data was performed utilizing the Statistical Package for Social Sciences software SPSS (IBM-SPSS version. 26.0 para-Mac OS)

RESULTS

Comparison between two different retreatment systems at different levels of the same group

Group (A) Resin-based Sealer

1) At the cervical third:

A statistically significant distinction was noted between the two rotary systems at the cervical third ($p < 0.05$). Root canals treated with the Neo-endo rotary system showed markedly higher amount of obturating material, in contrast to those made with Pro-Taper system exhibited the least quantity of residues.

2) At the middle third:

No notable difference was found at middle third of canals prepared by assessed rotary systems ($p>0.05$). The average amount of remains of sealing materials that were noted in canals treated by Pro-taper rotary system and Neo-endo were (8.793 and 8.187) correspondingly.

3) At the apical third:

A statistical difference found between the two rotary systems at apical third ($p < 0.05$). Root canals shaped by Neo-endo system demonstrated significantly higher remnants of obturating material, while ProTaper showed significantly lower remnants, as shown in Table 2 and Figure 2.

Table 2 Standard deviation, Mean values, and P-values of remnants of the obturating materials in root canals prepared by the two tested rotary systems.

Groups		Cervical third	Middle third	Apical third
Group A	Mean	5.181	8.793	13.073
Pro-taper	±SD	0.675	0.922	0.392
Group A	Mean	8.042	8.187	22.692
Neo-endo	±SD	0.319	0.259	3.084
	T test	7.66	1.264	6.189
	P value	0.001**	0.605	0.001**

***, **, ***, significant at p<0.05, <0.01, <0.001; ns, non-significant at p>0.05**

Group (B) Bio-Ceramic Sealer:

1) At the coronal third:

Statistical difference was noted between Pro-Taper and Neo-endo rotary systems in the cervical third ($p < 0.05$). Root canals treated using the Neo-endo system revealed the greatest quantity of residual obturating material, while those that were prepared with Pro-Taper system showed the least amount of remnants.

2) At the middle third:

There is no significant statistical difference was found between the two assessed rotary systems ($p > 0.05$). The mean remaining of the filling materials were 5.119 for Pro-Taper and 7.875 for Neo-endo.

3) At the apical third:

Likewise, in the apical third, there was no statistical difference between the two rotary systems ($p > 0.05$). The average residues of sealing material were 10.31 for Pro-Taper and 13.988 for Neo-endo, as presented in Table 3 and Figure 3.

Table 3 Standard deviation, Mean values, and P-values of remnants of the obturating materials in root canals prepared by the two tested rotary systems.

Groups		Cervical third	Middle third	Apical third
Group B	Mean	2.944	5.119	10.310
Pro-taper	±SD	0.542	0.511	2.282
Group B	Mean	8.042	7.875	13.988
Neo-endo	±SD	1.112	1.194	2.502
	T test	4.109	2.008	3.330
	P value	0.001**	0.352	0.023

***, **, ***, significant at p<0.05, <0.01, <0.001; ns, non-significant at p>0.05**

Stereomicroscopic Evaluation

Stereomicroscope showed remaining of the obturating materials on the walls of root canals following the retreatment process. The remnants of sealing material were noted at the cervical, middle, and apical thirds exhibiting differences among the tested groups Figure 4.

DISCUSSION

Effective root canal treatment mainly focuses on gaining a three-dimensional sealing of the canal system, thus creating efficient barrier against possible microbial escape and avoiding reinfection [17]. Insufficient filling of the canal space consistently recognized as a significant cause of endodontic therapy unsuccessful outcome [18].

The successful endodontic retreatment depends on the complete elimination of current filling substances, comprising gutta-percha and sealants, to enable sufficient reshaping and following refilling of the canal system of the root. Numerous retreatment methods have been outlined in the literature, including manual Instrumentation, nickel-titanium (Ni-Ti) rotary systems utilized with or without chemical solvents, ultrasonic methods, and thermoplastic removal techniques [19, 20].

Although significant advancements have been made in retreatment techniques, numerous investigations have shown that total elimination of root filling materials is seldom achieved. Nevertheless, re-establishing the working length and maintaining apical patency are considered essential prerequisites for effective retreatment [21].

Molars, both maxillary and mandibular, are the teeth most commonly requiring retreatment because of complex canal systems [22]. In comparison to anterior teeth and premolars, molars exhibit increased

anatomical variations and pronounced canal curvatures, which substantially complicate retreatment procedures. Such curved canals also serve as an appropriate model for evaluating the flexibility and shaping performance of NiTi instruments while preserving the original canal configuration. Consequently, the mesiobuccal canals of permanent molars were chosen for the present research.

In current study, gutta-percha was combined with two different sealer types: an epoxy resin sealer (AH Plus), and (Cera-Seal) bio-ceramic sealer. AH Plus has long been regarded as a benchmark material because of its favorable physicochemical properties, including low solubility and reduced polymerization shrinkage in comparison to calcium hydroxide–based sealers and zinc oxide–eugenol-based sealers [23].

CeraSeal, a recently introduced bioceramic sealer, was chosen due to its ability to establish a chemical interaction with dentin through micromechanical bonding [24]. This material relies on moisture found in dentinal tubules to finalize its setting reaction, resulting in a dimensionally stable, shrinkage-resistant interface that enhances adaptation and sealing of the canal walls [25]. However, limited data are available regarding the retreatability of CeraSeal, underscoring the need for further evaluation. Accordingly, the first aim of this research was assessment and evaluation of remnants of obturating material following retreatment of canals containing CeraSeal versus AH Plus [26].

In addition, the present research investigated the Neo-Endo Ni-Ti rotary retreatment system performance, a recently developed instrument system subjected to proprietary thermomechanical processing. This treatment enhances flexibility and minimizes shape memory, allowing the instruments to better follow canal curvatures and reduce lateral stresses on dentinal walls during retreatment [27, 28].

Evaluation of remnants of filling material was performed by longitudinally splitting the specimens using a mallet and chisel. The exposed canal surfaces were examined under a stereomicroscope, and digital images were analyzed using ImageJ software. Stereomicroscopic analysis has been widely reported as a reliable and effective method for assessing canal morphology and remaining obturation materials, making it a valuable tool in studies investigating endodontic failure [29].

The results of this research showed that Pro-Taper Universal retreatment files generated a considerably reduced proportion of canal wall coverage by obturating materials residues compared to Neo-Endo retreatment system in the cervical, middle, and apical segments, regardless the sealer type employed. These findings correspond with those shown by Patil et al., who noted enhanced removal efficiency of Pro-Taper retreatment tools compared alongside other systems, such as Neo-Endo, even though no technique has succeeded in attaining total material removal [30]. Same findings were found by Arun et al., who observed diminished remaining gutta-percha after retreatment using Pro-Taper files compared to Neo-Endo and other rotary systems [31].

The exceptional effectiveness of Pro-Taper Universal retreatment tools can be attributed to due to their unique design characteristics. The progressively tapered design and varying working lengths of the D1, D2, and D3 files facilitate effective penetration and removal of obturating materials, potentially extending

into superficial dentin layers [13]. Moreover, the rotary motion and flute design promote coronal displacement of debris. Heat generated through rotational friction may further soften gutta-percha, decreasing resistance and enhancing removal efficiency. The triangular convex cross-sectional configuration of ProTaper files increases internal surface area, thereby improving cutting effectiveness [32].

In contrast, the results of the current study are different from those presented by Muraleedhar et al., who noted fewer gutta-percha remnants with NeoEndo retreatment files compared with Pro-Taper instruments [33]. This variation may be attributed to differences in canal anatomy, as the present investigation focused on mildly curved mesiobuccal canals, which may reduce the cutting efficiency of heat-treated Neo-Endo instruments, whereas previous studies evaluated relatively straight, single-rooted canals.

In line with earlier studies, the greatest quantity of remnant materials was found in the apical third. Micro–computed tomography research carried out by Crozeta et al. and Kim et al. similarly reported greater volumes of obturation remnants in the apical region, emphasizing the inherent difficulty of achieving complete material removal in this area [34, 35].

According to the results of the present investigation, Pro-Taper Universal retreatment files could be suggested for the removal of obturating substances in mild curved root canals. However, in excessive curved canals, the Neo-Endo retreatment system may represent a suitable alternative due to its enhanced resistance to cyclic fatigue.

Consequently, null hypothesis of the study was dismissed, since a statistical difference was noted among Pro-Taper and Neo-Endo retreatment systems, with Pro-Taper showing enhanced effectiveness in eliminating root canal filling substances.

Conclusion

Within the limitations of this in vitro study, total elimination of root canal filling materials was unattainable with either retreatment systems. The Pro-Taper re-treatment system showed enhanced effectiveness in eliminating obturating materials compared to the Neo-Endo system. Additionally, remnants of AH-Plus sealer were more readily removed from canal walls than those of the Cera-Seal bio-ceramic sealer. Further clinical studies are recommended to validate these findings.

Limitations

This study has some limitations. Being conducted under in-vitro conditions, it may not fully replicate the complexity of clinical situations. Variations in root canal anatomy, operator-related factors, and intraoral conditions were not simulated. Therefore, the results should be interpreted with caution, and further in-vivo studies are recommended to confirm these findings.

Recommendations

Further investigations are warranted to evaluate endodontic retreatment in canals exhibiting different degrees of curvature using retreatment files produced with varying metallurgical characteristics. In addition, future studies should examine the ability of the Neo-Endo files to remove obturating materials using alternative obturation techniques, including warm vertical compaction.

Moreover, subsequent in vitro research should evaluate the performance of the Neo-Endo files in canals with different anatomical configurations and curvature patterns to supply a comprehensive understanding of its clinical application.

Abbreviations

EDTA: Ethylenediaminetetraacetic acid

Ni-Ti: Nickel-titanium

Declarations

Ethics approval and consent to participate

The study procedures were approved by the Research Ethics Committee (REC), Faculty of Dentistry, Suez Canal University. As the study was conducted on extracted human teeth in an in-vitro design, the requirement for informed consent to participate was waived by the ethics committee. All procedures were carried out in accordance with the principles of the Declaration of Helsinki.

Consent for publication

Not applicable.

Consent to participate declaration

Not applicable.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Clinical trial number

Not applicable.

Authors' contributions

M.A. wrote the main manuscript, Literature search, data acquisition, statistical analysis, manuscript preparation and guarantor.

S.H. designed the manuscript, definition of intellectual content and manuscript review.

D.F. manuscript editing, and manuscript review**.**

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Figures

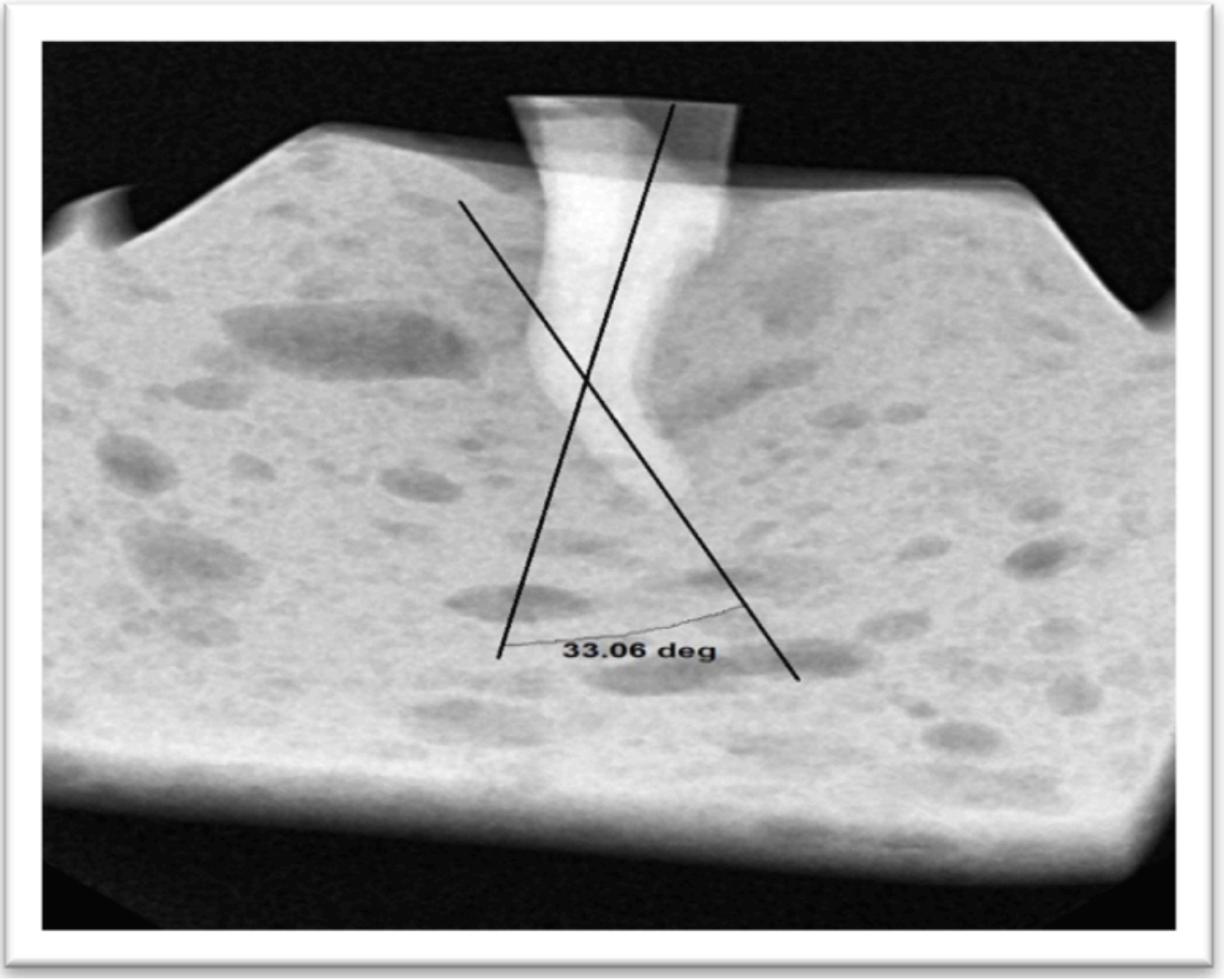


Figure 1

Pre-operative x-ray showing the angle of curvature in the root.

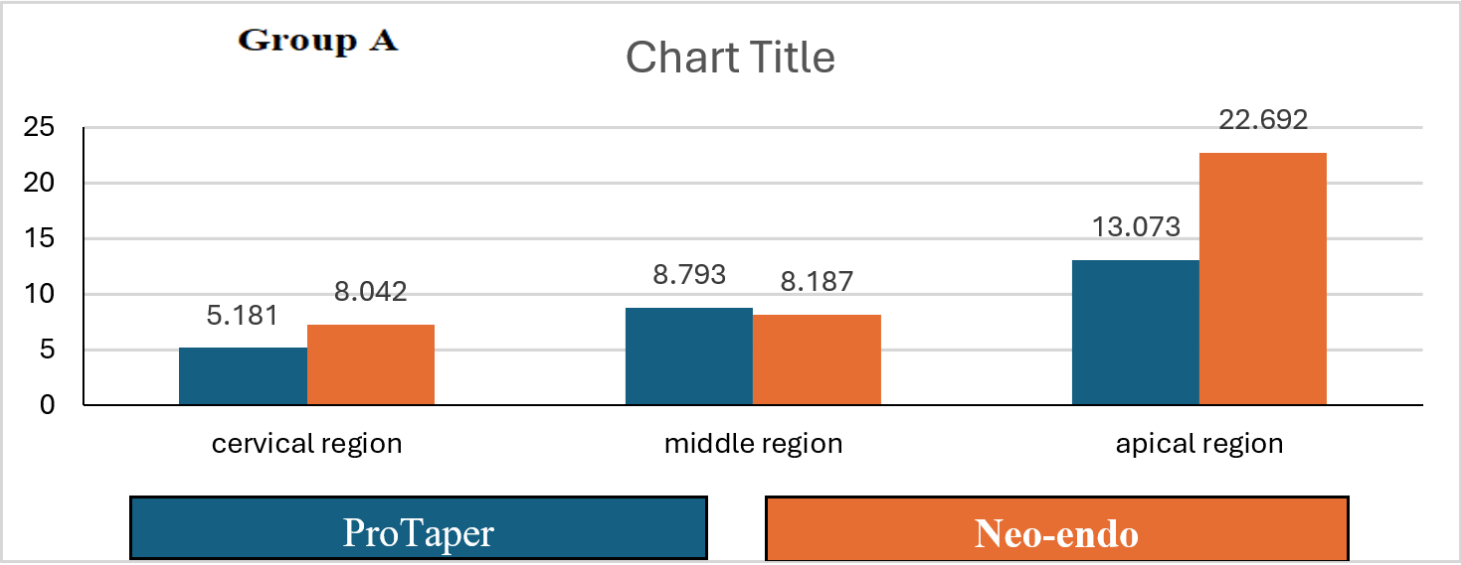


Figure 2

Bar chart representing comparison between Neo-endo and Pro-taper rotary system at different levels of the root canal in group (A) resin-based sealer.

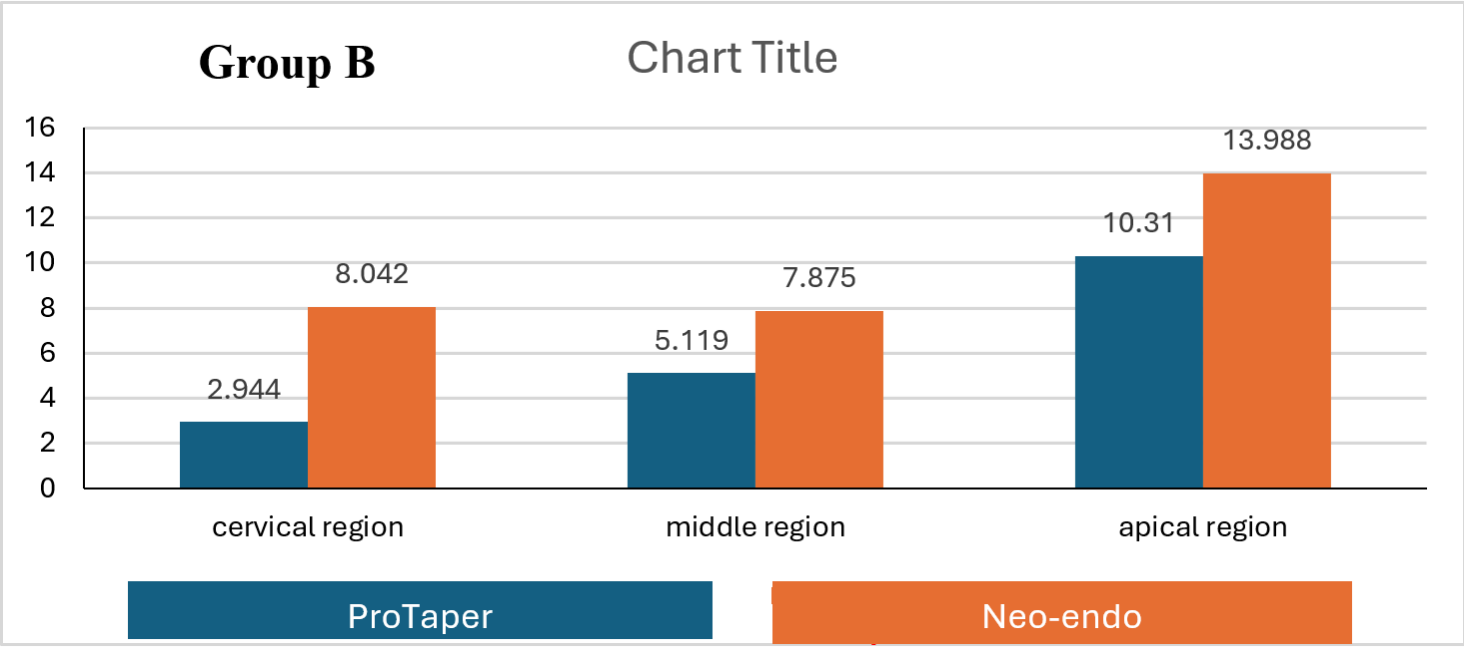


Figure 3

Bar chart representing comparison between Neo-endo and Pro-taper rotary system at different levels of the root canal in group (B) bio-ceramic sealer.

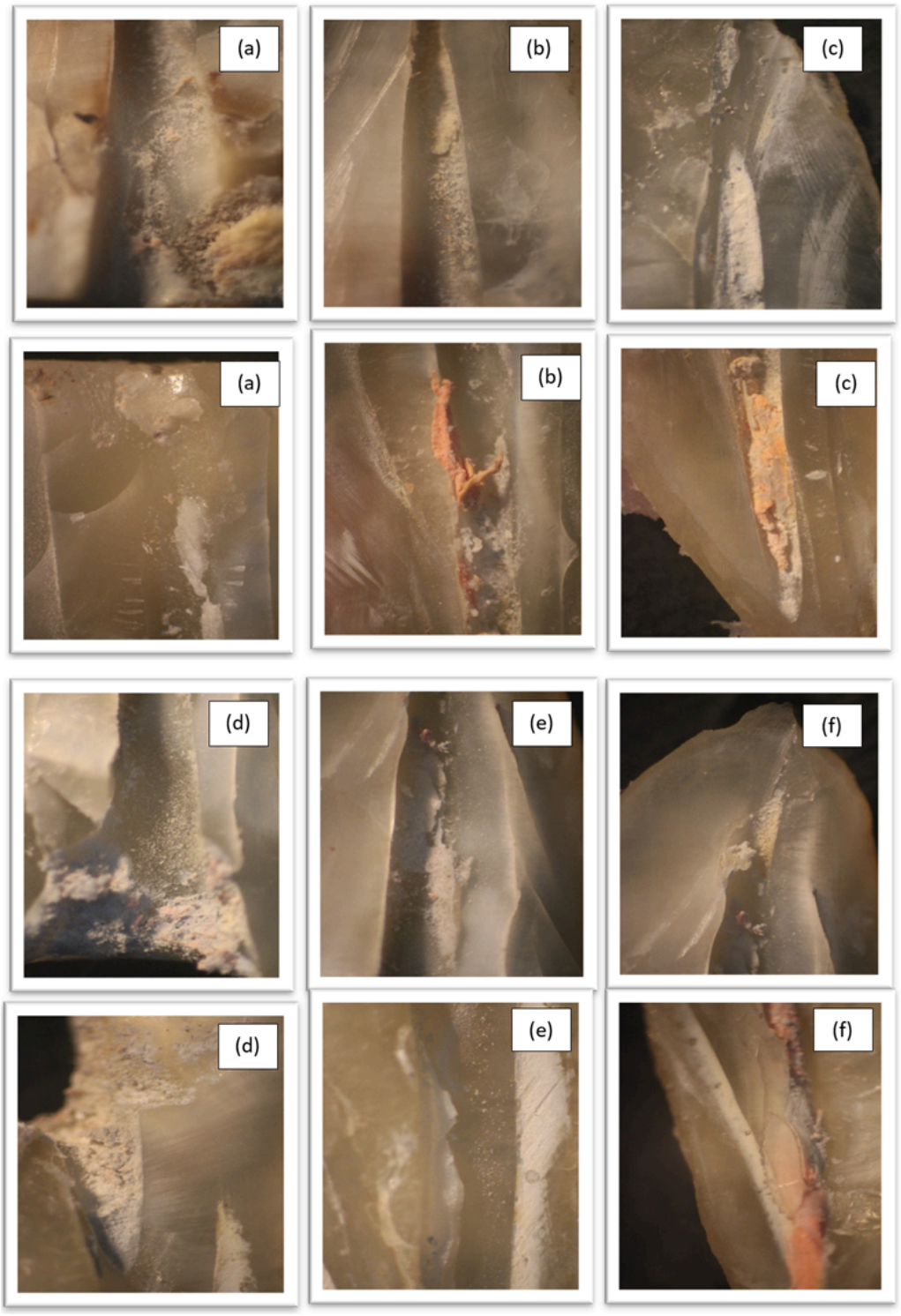


Figure 4

Stereo-microscope microphotographs showing remnants of obturating materials prepared by Pro-taper retreatment system and Neo-endo retreatment system at different levels (a) Cervical third, (b) Middle third, and (c) Apical third in group A resin-based sealer, while (d) Cervical third, (e) Middle third, and (f) Apical third in group B Bio-ceramic sealer.