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# Dentin Thickness Changes After Separated Instruments Retrieval Using Novel Ultrasonic Tip

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**ABSTRACT: Aim:** To evaluate the percentage change in mesial dentin thickness of mesiobuccal canal of mandibular molars during retrieval of separated instruments at apical,middle and coronal, using 2
ultrasonic tips of different designs
**Materials and methods:** Sixty separated segments (#25/.06) of different rotary NiTi instruments were induced in the apical , middle and coronal thirds of mesiobuccal canals of mandibular molars with moderate curvature. Samples were divided into two groups (n=30); Group A (ET25)and Group B (E6).Percentage of change in Mesial dentin thickness was evaluated using CBCT at 3 subgroups, Subgroup 1 at 3 ,Subgroup 2 at 6 and Subgroup 3 at 9mm length from the apex before and after separated instrument retrieval .
**Results:** Intragroup analysis revealed a progressive increase in reduction in dentin thickness values from the coronal to the apical third for both E6 and ET25 systems ($P < 0.001$), indicating a level-dependent variation in performance. For the E6 group, mean values increased from 0.37 ± 0.02 in the coronal third to 0.45 ± 0.06 in the middle third, and peaked at 0.57 ± 0.09 in the apical third. Similarly, ET25 showed an upward trend with mean values of 0.26 ± 0.01, 0.37 ± 0.06, and 0.48 ± 0.07 across the coronal, middle, and apical thirds, respectively, suggesting that level influences dentin thickness.
**Conclusion:** Tool design plays a critical role—sharper, more aggressive tips tend to remove more dentin, while more controlled designs offer better preservation of tooth structure
**Keywords:** Mesial dentin thickness, Retrieval technique, Ultrasonic, ET25, E6,Reduction of dentin thickness

## I. INTRODUCTION

Root canal treatment remains the cornerstone of modern endodontics, fundamentally aimed at eradicating infection and preventing reinfection by thoroughly cleaning, shaping, and obturating the complex root canal system. Among the pillars of this triad, instrumentation holds a uniquely critical role: it creates the necessary canal shape that facilitates effective irrigation and hermetic obturation. Over recent decades, the introduction of nickel– titanium (NiTi) rotary instruments has revolutionized the field, offering unparalleled flexibility, efficiency, and the ability to navigate intricate canal anatomies once considered unreachable with stainless steel hand files Despite these remarkable advancements, even the most experienced clinicians confront an enduring procedural complication: instrument separation. File fracture within the root canal— whether due to cyclic fatigue, torsional overload, manufacturing defects, or complex canal curvature—remains an unpredictable and often frustrating occurrence. Reported incidence varies, but studies frequently cite rates between 0.5% and 5%, influenced by instrument type, canal anatomy, and operator skill. The consequences of a separated file fragment can be significant: it may obstruct proper cleaning and disinfection beyond the fracture site, potentially jeopardizing treatment success, especially when the separation occurs early in the shaping phase or in the apical third.

Faced with a separated instrument, clinicians must carefully weigh their options: bypass the fragment, remove it, or leave it and obturate short of the fragment. The choice depends on multiple factors—canal curvature, fragment location, fragment length, and the remaining dentin thickness. Historically, numerous retrieval methods have been described:Bypassing techniques using small hand files to negotiate around the fragment ,Braiding techniques, where multiple Hedström or K files twist around the broken piece ,Microtubes and extractors, such as the Masserann kit or IRS systems, which mechanically engage and remove the fragment and Ultrasonic techniques, which have gained widespread popularity for their conservative nature and relatively higher success rates Among these, ultrasonics have emerged as the technique of choice in many clinical scenarios. Their success is largely attributed to several advantages: the ability to vibrate and loosen the fragment without direct mechanical engagement, the preservation of radicular dentin compared to drilling methods, and the possibility to combine

with enhanced visualization under an operating microscope .

Ultrasonic tips, by delivering focused vibration, can dislodge the fragment incrementally, often allowing removal without significant alteration of canal morphology.

However, the use of ultrasonics is not without limitations. The vibrational energy, while effective, may inadvertently cause heat generation within the root canal , risking injury to the periodontal ligament and surrounding bone if cooling is insufficient. Visibility remains a persistent challenge, particularly in posterior teeth and curved canals, where the fragment is deep apical or partially embedded in dentin. Additionally, repeated ultrasonic activation near the canal walls may[6] weaken the remaining dentin or even cause secondary fractures, perforations, or ledging . Clinicians must also navigate the learning curve associated with advanced ultrasonic retrieval—combining tactile sensitivity with microscopic visualization.

In response to these challenges, newly designed ultrasonic kits have been introduced, aiming to optimize tip geometry, vibration frequency, and cooling efficiency. Some feature thinner, more tapered designs to enhance access; others integrate irrigation channels to reduce heat buildup. These innovations promise to improve retrieval success while minimizing procedural risks. Yet, despite technological progress, the literature still calls for robust evaluation of these novel systems under standardized conditions.

Against this backdrop, the present study investigates the retrievability of broken rotary NiTi instruments using a novel ultrasonic kit. By assessing its efficiency and potential impact on dentin integrity, the study seeks to provide clinicians with evidence based insight into whether new generation ultrasonic tips can meaningfully enhance the management of one of endodontics4 most stubborn procedural complications .

**Previous** studies lack a consistent understanding regarding the retrievability of different ultrasonic tips. This study aimed to evaluate the mesial remaining dentin thickness, after removal of separated NiTi rotary instruments using 2 different ultrasonic tips E6 &ET25 from the apical,middle and coronal thirds of the root canal using ultrasonic technique and microscope.

## II. MATERIALS AND METHODS

**Sample Selection and preparation** Figure (1)

Sixty extracted human mandibular molars were collected from the Dental Teeth Bank at the Faculty of Dentistry, Ain Shams University. **Inclusion criteria**:1-Permanent lower molars with mature apices.2- Mesiobuccal roots exhibiting moderate curvature between 5° and 20°.**Exclusion criteria**:1-Teeth with prior restorations.2-Teeth that had undergone previous root canal treatment.3-Teeth with root fractures or cracks.4-Teeth affected by root caries.5-Teeth with internal or external root resorption.6-Teeth with canal curvatures <5° or >20°.

All specimens were ultrasonically cleaned, air-dried, and sterilized. Subsequently, they were immersed in a 5% sodium hypochlorite (NaOCl) solution for 15 minutes and stored in normal saline until further use. Root surfaces were examined under a dental operating microscope (Semorr DOM3000D series) at 10× magnification to ensure integrity[10].

Digital radiographs were used to assess root canal curvature, determined using **Schneider's method**.

Point A was marked at the level of the canal orifice. A line was drawn along the canal's long axis to Point B, where curvature began. A second line was drawn from Point B to Point C (apical foramen). The angle formed at the intersection of these lines was recorded as the degree of curvature [11]

**Sample Preparation**

Conventional access cavities were prepared in all specimens. Crowns were sectioned using a cylindrical diamond bur under high-speed irrigation to obtain a standardized root length of 14 mm

The mesiobuccal canal patency was verified using a size #10 K-file. Working length was determined by inserting the file until it was visible at the apical foramen and subtracting 1 mm, resulting in an average working length of 13 mm. Glide path preparation was completed using size #10 and #15 K-files.

The 60 mesiobuccal canals were randomly allocated into two groups (n = 30), based on the type of ultrasonic tip used:

- Group A: ET25
- Group B: E6

Each group was further subdivided into three subgroups according to the location of the file fracture within the root canal:

- Subgroup 1: Apical third
- Subgroup 2 : Middle third
- Subgroup 3 : Coronal third

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**E.Root canal instrumentation.**

Canals were prepared using the crown-down technique using EndoPace endo motor in all groups with sequence, torque and speed according to the manufacturer's instructions till the size needed to be fractured.

In both groups (A), W3 system, W0 file (#17/12% taper) till the coronal 2/3 of the canal, followed by W1 (#18\05% taper) till the needed length in each group , till full WL in Subgroup 1A&2A, till 7 mm in Subgroups 1B&2B , till 4 mm of WL in subgroups 1C &2C. The endo motor was utilized with pecking motion at speed 300 rpm and torque 2.5 N/cm. Throughout the instrumentation process, every canal received irrigation with 10 mL of 5.25% sodium hypochlorite.

The Size #25/6% taper was notched to a depth equal to half the instrument thickness, positioned 3mm from the file tip The notch was created using low speed diamond disk.

Then W2 (25/6% taper) was used till the previously mentioned lengths as W1 rotary files. .The endo motor was utilized with **force** in pecking motion at speed 900 rpm and torque 2.5 N/cm to allow file separation at the predetermined lengths. Subsequently, radiographs were taken to verify the location of the separated instrument at the apical third , middle and coronal third of the canal.

**Confirmation for the level of fracture in each subgroup.**

The location of the fractured segment was standardized to be 1 mm short of the radiographic apex of the root canal in **Subgroup (1A & 1B)** in the apical third of the root, and 4mm above the apex of the root canal in **Subgroup (2A & 2B)** in the middle third level of the root and 7mm above the apex of the root canal **Subgroup (3A & 3B)** in the coronal third of the canal Control of the level of file fracture within the mesiobuccal canal

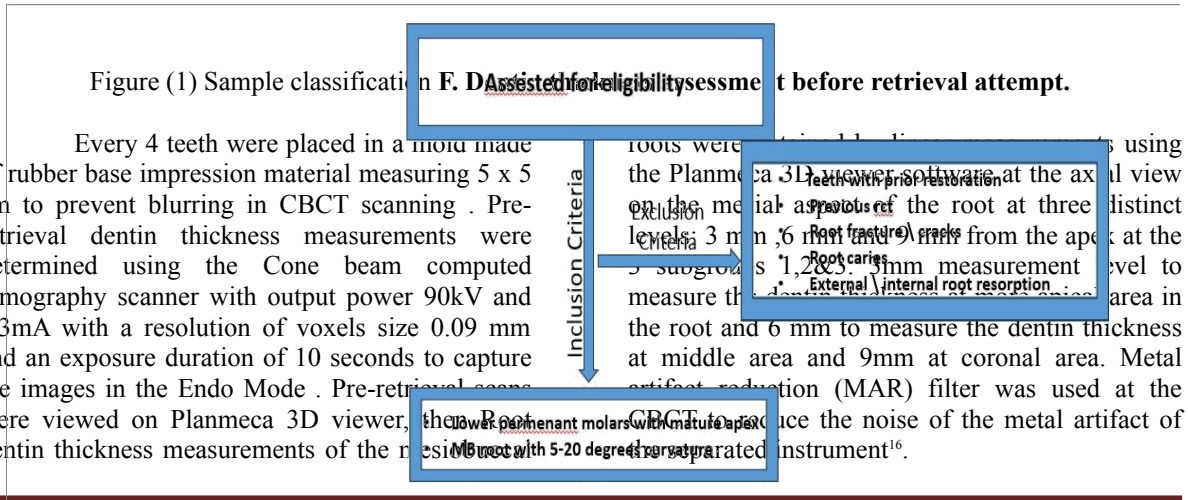


Figure (1) Sample classification **F. Data collection before retrieval attempt.**

Every 4 teeth were placed in a mold made of rubber base impression material measuring 5 x 5 cm to prevent blurring in CBCT scanning . Pre-retrieval dentin thickness measurements were determined using the Cone beam computed tomography scanner with output power 90kV and 6.3mA with a resolution of voxels size 0.09 mm and an exposure duration of 10 seconds to capture the images in the Endo Mode . Pre-retrieval scans were viewed on Planmeca 3D viewer, then Root dentin thickness measurements of the mesiobuccal roots were [illegible] using the Planmeca 3D viewer software at the axial view on the medial aspect of the root at three distinct levels: 3 mm ,6 mm and 9 mm from the apex at the 3 subgroups 1,2&3. 3mm measurement level to measure the [illegible] area in the root and 6 mm to measure the dentin thickness at middle area and 9mm at coronal area. Metal artifact reduction (MAR) filter was used at the CBCT to reduce the noise of the metal artifact of the separated instrument[16].

**Instrument retrieval:**
**Straight line access and staging platform.**

The technique for retrieving the separated files was done by the method outlined by Ruddle followed by ultrasonic technique and dental operating microscope (Semorr DOM3000D series) under adequate magnification 16X to 20X. A straight-line access and coronal enlargement within the canal, reaching the coronal end of the fractured segment, was established using Gates Glidden drills nos. 1,2 and 3 using a brushing motion[15] The Gates-Glidden drill tips of no. 2,3 were modified by making a perpendicular cut at their maximum cross-sectional diameter along their longitudinal axis by a high- speed flat fissure diamond bur then introduced into the canal at 300 rpm. A staging platform by trephining the dentin encircling the coronal portion of the separated segment which was created using Modified Gates Glidden drills no. 2 and 3. Subsequently, the coronal end of the separated fragment was observed using a dental operating microscope with a magnification of 16X.

**Ultrasonic activation**
**Group A**

• Under dental operating microscope (Semorr DOM3000D series) Magnification 16X to 20X, Fine ultrasonic tip ET25 was mounted on varios 370 iPiezo NSK ultrasonic device and activated with a lower power setting E2 which was below the manufacturer's suggested maximum power ET25 was utilized to trephine the dentin around the instrument fragment, reaching a depth of 1– 1.5 mm, to dislodge and liberate it from the canal. The ET25 ultrasonic tips were positioned between the dentinal wall and the separated fragment.

In **Group B**, a fine ultrasonic tip (E6) was mounted on a U6 Woodpecker EMS ultrasonic unit and activated under a dental operating microscope (Semorr DOM3000D series) at 16× to 20× magnification. The unit was operated at a reduced power setting (E2), below the manufacturer's recommended maximum.The E6 tip was used to trephine the dentin around the separated instrument fragment to a depth of 1–1.5 mm. It was then placed between the dentinal wall and the fragment to aid dislodgement. Activation was performed in a 360° counterclockwise direction**,** and vibration continued intermittently (10-second intervals) until the fragment was successfully retrieved Cooling was achieved via water coolant and irrigation. Following retrieval, the canal was dried using paper points, and a Stropko **irrigator** was used to remove dentinal debris size #10 K-file was reintroduced to confirm canal patency, and a radiograph was taken to ensure complete fragment removalA new ultrasonic tip was used after every 10 specimens.

**Assessment of Remaining Dentin Thickness:**
**Figure (2)** after fragment retrieval, all specimens were repositioned in their respective rubber base molds and scanned using CBCT (90 kV, 6.3 mA, Endo Mode). Using Planmeca 3D viewer software, pre- and post- retrieval scans were superimposed to ensure standardization across axial and longitudinal 13 sections Dentin thickness was measured at 3 mm, 6 mm, and 9 mm from the apex on both mesial root surface.

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Measurements were grouped based on the fracture location:

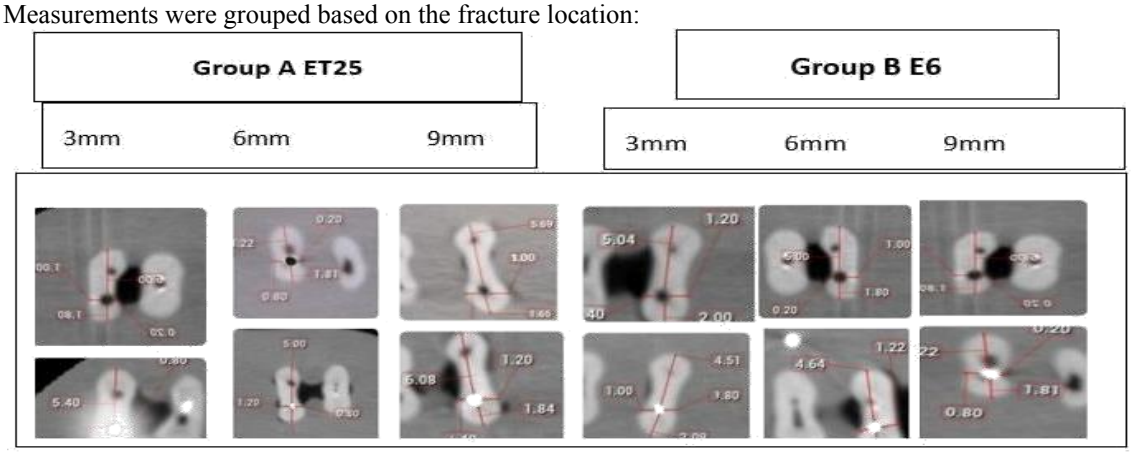


**Figure 2: CBCT axial cuts representing pre- and post-retrieval scans at 3 ,6 and 9 mm. Red lines indicate the pre- and post-retrieval dentin thickness**

- **Subgroup A Fracture Group**:

A line was drawn from the apical foramen to a point 3 mm coronally inside the mesiobuccal canal. A horizontal plane intersected this line, and axial sections at this level were used to measure dentin thickness on mesial and distal aspects.

- **Subgroup B Fracture Group**:

The same procedure was repeated, but the measurement point was at **6 mm** from the apex.

- **Subgroup C Fracture Group**: The measurement point was extended to **9 mm** from the apex.

**Dentin thickness reduction** was calculated by subtracting post-retrieval measurements from the pre- retrieval values in each corresponding location and direction.

**Statistical Analysis**

Data was analyzed using Medcalc software, version 22 for windows (MedCalc Software Ltd, Ostend, Belgium). Continuous data was explored for normality using Kolmogrov Smirnov test and Shapiro Wilk test. Continuous data showed parametric distribution and was described using mean and standard deviation. Intergroup comparison between tip types within each level was performed using independent t test. Intragroup comparison between levels within each tip type was performed using one-way ANOVA followed by Tukey post hoc test. Categorical data was described as frequency and percentage; intergroup comparison was performed using the Chi-Squared test and intragroup comparisons were performed using the Cochran's Q test followed by multiple comparisons. Spearman's correlation was used to assess the relationship between success, change in dentin thickness and change in heat. The confidence limit was set at 95% with 80% power and all tests were two tailed with statistical significance level set at ($P \leq 0.05$).

## III. RESULTS

**Reduction in dentin thickness**

**Effect of tip type on change in dentin thickness within each level:**

Intergroup comparison between tip types revealed statistically significant differences in change in dentin thickness between E6 and ET25 across all levels ($P < 0.05$). In the coronal third, ET25 exhibited a significantly lower mean value ($0.26 \pm 0.01$) compared to E6 ($0.37 \pm 0.02$), with a mean difference of - 0.11 (95% CI: -0.12 to -0.088; $P < 0.0001$). Similarly, in the middle third, ET25 showed a lower mean ($0.37 \pm 0.06$) than E6 ($0.45 \pm 0.06$), with a difference of -0.07 (95% CI: -0.12 to -

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0.016; P = 0.0144). In the apical third, ET25 showed a lower mean (0.48 ± 0.07) than E6 (0.57 ± 0.09), with a difference of - 0.09 (95% CI: -0.15 to -0.012; P = 0.0246). (Table 1)

**Effect of level on change in dentin thickness within each tip type:**

Intragroup analysis revealed a progressive increase in change in dentin thickness values from the coronal to the apical third for both E6 and ET25 systems (P < 0.001), indicating a level-dependent variation in performance. For the E6 group, mean values increased from 0.37 ± 0.02 in the coronal third to 0.45 ± 0.06 in the middle third, and peaked at 0.57 ± 0.09 in the apical third. Similarly, ET25 showed an upward trend with mean values of 0.26 ± 0.01, 0.37 ± 0.06, and 0.48 ± 0.07 across the coronal, middle, and apical thirds, respectively, suggesting that level influences dentin thickness. (Table 1)

Table 1: Mean and standard deviation (SD) of change in dentin thickness showing intergroup comparison between tip types within each level

| Level | E6 | | ET25 | | Difference | | P value |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Difference | 95% CI | |
| Apical (subgroup 1) | 0.57 | 0.09 | 0.48 | 0.07 | -0.09 | -0.15 to -0.012 | 0.0246* |
| Middle (subgroup 2) | 0.45 | 0.06 | 0.37 | 0.06 | -0.07 | -0.12 to -0.016 | 0.0144* |
| Coronal (subgroup 3) | 0.37 | 0.02 | 0.26 | 0.01 | -0.11 | -0.12 to -0.088 | <0.0001* |
| P value | P < 0.001* | | P < 0.001* | | | | |

Corresponds to statistically significant difference

**Effect of tip type on reduction in dentin thickness regardless of level:**

Intergroup comparison between the E6 and ET25 systems revealed a statistically significant difference (P = 0.0015). The E6 system exhibited a higher mean value of 0.46 ± 0.11, while ET25 showed a lower mean of 0.37 ± 0.10. The mean difference between the two systems was -0.088, with a 95% confidence interval ranging from -0.14 to -0.035. (Table 2)

Table 2: Mean and standard deviation (SD) of change in dentin thickness showing intergroup comparison between tip types regardless of level

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| E6 | ET25 | | Difference | | P value | |
|---|---|---|---|---|---|---|
| Mean | SD | Mean | SD | Difference | 95% CI | |
| 0.46 | 0.11 | 0.37 | 0.10 | -0.088 | -0.14 to -0.035 | 0.0015* |

Corresponds to statistically significant difference

IV.

## V. DISCUSSION:

Nickel–Titanium (NiTi) rotary files are widely used in endodontics due to their superior cleaning, shaping abilities, and mechanical properties. Over time, enhancements in metallurgy (e.g., M-wire, R-phase, CM-wire), surface treatments like electropolishing, and advanced motion modes (reciprocating, axial) have significantly improved their performance and flexibility, while reducing instrument separation risks. Despite these advancements, **instrument separation** remains a notable complication, mainly due to **flexural fatigue or torsional failure** Contributing factors include canal curvature, fragment length and location, and operator experience. Effective retrieval is crucial for maintaining access to the canal and ensuring treatment success .

**Ultrasonic techniques** are commonly employed for the retrieval of fractured instruments, with reported success rates between 88% and 95%.Successful removal is often dependent on exposing at least one-third of the fragment. However, several factors—such as severe curvature, incorrect ultrasonic tip usage, or inadequate irrigation—can reduce retrieval efficacy or cause further complications. Given these challenges, **ultrasonic tips** must be assessed not only for their retrieval efficiency but also for their impact on dentin structure.

This study aimed to evaluate and compare two commonly used ultrasonic tips — E6 (Woodpecker) and ET25 (Dentsply) — in terms of four key parameters Remaining dentin thickness.This evaluation provides a broader understanding of the safety and effectiveness of ultrasonic-assisted retrieval techniques.

Preserving radicular dentin is crucial to maintaining the **structural integrity and fracture resistance** of the tooth. Excessive dentin removal during fractured file retrieval can weaken the tooth and increase the risk of vertical root fractures. Therefore, one of the main aims of the present study was to compare **remaining dentin thickness** after ultrasonic-assisted retrieval using two different tips — **E6 (Woodpecker)** and **ET25 (Dentsply)** — to evaluate which tip is more conservative in dentin removal

In addition to dentin preservation, the study assessed **heat generation**, **success rate of retrieval**, and **frequency of procedural errors**, to provide a comprehensive comparison of these two tips that differ in **metallurgy, taper, diameter, and length**.

**ET25 (Acteon/Satelec)** is a standard endodontic ultrasonic tip with a **length of 20 mm** and a **taper of 3%**. It is made from a **Titanium-Niobium alloy**, allowing it to be **pre-bent** for improved access to curved or difficult canals. Its **rigid, durable design** and **robust working end** make it well-suited for the retrieval of larger separated fragments. ET25 is compatible with **Satelec ultrasonic units**, which are known for their high-frequency output and precise power control.

**E6 (Woodpecker)**, while the designation ―E6‖ may vary between manufacturers, is specified here as the model produced by **Woodpecker**, compatible with **EMS and UDS** ultrasonic units.It is made fron NITI alloy. It features a **slimmer working tip with a diameter of approximately 0.20 mm**, and a more **tapered, flexible design**, enhancing maneuverability within **narrow or curved canals**.

Although it appears less aggressive due to its finer profile, it has **more concentrated oscillation** and **aggressive cutting action**

To replicate clinical conditions, **instrument separation** was simulated in the mesiobuccal canals of **mandibular molars**, which often have narrow, curved canals and limited access — conditions associated with lower retrieval success compared to maxillary molars .All specimens were decoronated to 14 mm in length to standardize dimensions, and only canals with

moderate curvature (5–20°), as per **Schneider's method** , were included.

Instrument fragments were standardized to **3 mm in length** using size 25/.06 rotary instruments, as most clinical separations occur within 1–3 mm from the tip, this aligns with common fracture patterns and improves study reproducibility.

Samples were embedded in silicone molds to ensure consistent repositioning and **accurate CBCT-based evaluation**. Pre- and post-retrieval scans were superimposed to measure **dentin thickness at the mesial and distal walls**, taken from axial slices at **3 mm, 6 mm, and 9 mm from the apex**, corresponding to 1&2&3 subgroups CBCT was chosen for its 3D accuracy and small field of view (Endo mode), allowing high-resolution assessment of dentin loss. This method has been validated by previous studies showing **that** retrieval of apically located fragments leads to the greatest dentin loss

The **Ruddle technique**, modified by Ward et al ., was used for all retrieval procedures. After straight-line access with Gates Glidden drills (#1–3), a staging platform was created using modified GGs to expose the coronal portion of the fragment. Ultrasonic trephination was then performed around the exposed fragment, followed by controlled counterclockwise movement to dislodge the fragment with minimal damage Initially, retrieval was performed in dry conditions for better visualization. Once the fragment became visible, irrigant was introduced between activation intervals to reduce heat and enhance fragment dislodgement. This protocol balanced visibility and safety, aligning with some literaturebut differing from others that favor dry conditions

The **dental operating microscope** (16×–20× magnification) was used in all procedures, as it provides enhanced visualization and precision, reducing the risk of excessive dentin removal and perforation

**Effect of Ultrasonic Tip Type and Canal Level on Dentin Thickness Reduction:**

A comparison of ultrasonic tips showed that **ET25** caused significantly less dentin removal than **E6** across all canal levels. This aligns with Jepsen et al. (2004), who found that **narrower Slimline inserts** produced less root substance loss than wider ones—even though the context[29] was periodontal scaling, the principle remains applicable to endodontic procedures .

Within each tip type, dentin loss **increased progressively from coronal to apical thirds**, with the apical region showing the greatest reduction. This finding corresponds to Dummer et al. (2011), who reported that **ultrasonic activation results in more dentin loss in apical regions**, likely due to limited access and control .

When comparing overall dentin removal regardless of canal level, the **E6 tip** exhibited significantly higher values. This is consistent with Plotino et al. (2007), who reported that **larger and stiffer ultrasonic tips** tend to be more aggressive in dentin removal compared to smaller or more flexible designs .

## VI. CONCLUSION

Ultrasonic retrieval in endodontics demands a careful balance between effective fragment removal and the preservation of radicular dentin, especially in curved or deep canal regions where access is limited. As one of the most technique-sensitive procedures, instrument retrieval carries a heightened risk of dentin loss and thermal damage—risks that increase closer to the apical third, where ultrasonic techniques tend to remove more dentin and control is most difficult.

**Ethical Approval and Consent toParticipate**

This study's protocol was approved in advance by the Ethics Review Committee at the Faculty of Dentistry Ain Shams University (Approval No. FDASU- RecEM122103).

**Data Availability**

The datasets used and analyzed in this research are accessible from the corresponding author upon a reasonable request.

**Competing interests**

The authors declare that they have no conflicts of interest.

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