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CBCT evaluation of two endodontic instrument retrieval systems: An *in vitro* study

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Abstract:
The removal of fractured NiTi instruments from root canals poses a major challenge in endodontics due to the risk of excessive dentin loss and root perforation. Therefore, it is of interest to compare the Masserann kit and C-FR2 retrieval system using CBCT and digital stopwatch timing in 60 extracted mandibular premolars. While both systems showed similar removal times, the Masserann kit preserved significantly more root dentin structure. Thus, the C-FR2 system exhibited a significantly lower perforation rate, offering a safer clinical option despite causing greater dentin loss.

Keywords: Cone beam computer tomography (CBCT), retrieval of fractured instrument, masserann kit, nickel-titanium instruments, perforation incidence

Background:
Separation of endodontic instruments during root canal treatment remains an exceptionally challenging procedural complication in clinical endodontic practice **[1].** Canal blockages from fractured instruments prevent thorough cleaning, shaping and disinfection of the crucial apical root portions **[2].** This mechanical obstruction directly compromises treatment prognosis, especially in root canals presenting with pre-existing periapical pathology **[3].** While nickel-titanium (NiTi) rotary files offer enhanced flexibility, they are highly prone to unexpected intracanal failure **[4].** This heightened susceptibility is driven primarily by intense torsional stress and cyclic fatigue encountered during clinical instrumentation **[5].** Epidemiological reports show that the clinical incidence of instrument separation spans widely from 0.7% to 6% **[6].** Anatomically conservative biomechanical preparation maintaining sufficient radicular dentin thickness remains vital for achieving successful endodontic outcomes **[3].** Superelastic NiTi alloys improve canal-shaping efficiency and minimize severe canal transportation compared to traditional stainless steel **[7].** Unresolved fragment separation severely restricts apical debridement, reducing the likelihood of complete and predictable periapical healing **[8].** Fracture incidence depends on canal curvature, inadequate access, excessive pressure, repeated file use and operator skill. Most instrument separations occur within the restricted apical third of curved posterior teeth where visual access is poor **[9].** Consequently, the predictable management of separated intracanal fragments represents a key focus of modern endodontic retreatment **[10].** Clinicians face multiple options including instrument retrieval, fragment bypassing, or leaving the separated segment within the canal **[11].** Complete fragment retrieval remains the ideal choice as it restores access for comprehensive cleaning, shaping and obturation **[12].** Historical retrieval approaches rely heavily on ultrasonics, customized wire loops, microtubes, Masserann kits and specialized micro-forceps **[13].** Recently developed advanced systems, including the Terauchi and contemporary C-FR series, have expanded modern clinical options **[14].** Magnification-assisted ultrasonics exhibit high success rates by allowing relatively conservative dentin removal and improved operational visualization **[15].** However, aggressive dentin cutting during retrieval can weaken the root structure, precipitating perforations or vertical fractures **[16].** Preserving sound radicular dentin during retrieval procedures serves as a primary determinant of long-term tooth survival **[17].** The legacy Masserann kit is a classic mechanical retrieval system utilizing large trepan burs and matching extractor tubes **[18].** Existing literature associates the Masserann tool with excessive dentin sacrifice and elevated perforation risks, particularly apically **[19].** The modern C-FR2 kit utilizes ultra-slim micro-trepan burs and loop-assisted mechanisms to minimize unnecessary structural sacrifice **[20].** Cone beam computed tomography (CBCT) provides highly precise, non-destructive, three-dimensional volumetric evaluation of post-retrieval changes **[21].** Volumetric CBCT analysis offers a reproducible method to measure exact dentin loss and identify procedural root perforations **[22].** Despite growing clinical adoption, comprehensive comparative data assessing the Masserann and C-FR2 systems remains largely unavailable **[23].** Therefore, it is of interest to compare and evaluate the Masserann kit and the C-FR2 retrieval system regarding volumetric dentin loss, retrieval time and perforation incidence using three-dimensional CBCT analysis.

Materials and Methods:
Study design:
This *in vitro* comparative study was conducted to evaluate and compare the efficacy of Masserann kit and C-FR2 retrieval system for removal of separated endodontic instruments performed. The two systems were compared in terms of volumetric dentin loss, retrieval time and incidence of

perforation using cone beam computed tomography (CBCT) analysis.

Ethical considerations:
This laboratory protocol was reviewed and approved by the Institutional Ethics Committee (IEC) of the Maharishi Markandeshwar College of Dental Sciences and Research under approval number IEC–2966. The study was conducted in strict compliance with institutional and international ethical guidelines governing the use of human tissue specimens in dental research. All teeth utilized in this experiment were extracted human mandibular bicuspids collected as discarded biological waste following routine therapeutic extractions, ensuring that no teeth were extracted specifically for the purpose of this study. To maintain optimal biohazard safety and infection control standards before laboratory manipulation, all collected specimens were thoroughly washed under running water and disinfected in a 5.25% sodium hypochlorite solution for 1 hour.

Sample selection and preparation:
Sixty single-rooted mandibular premolars of humans with mature apices and normal root morphology were extracted and used in this study. Teeth with root caries, cracks, calcifications, internal or external resorption and incomplete root formation were excluded. Collected specimens were washed under running water to remove debris and disinfected in 5.25% sodium hypochlorite solution for 1h. Residual calculus and soft tissue remnants were removed with an Ultrasonic scaler. Thereafter all specimens were kept in normal saline to keep them hydrated and their structure intact during the experimental procedure.

Inclusion criteria:
[1] Single-rooted mandibular bicuspids.
[2] Teeth must have fully formed (mature) apices.

Exclusion criteria:
[1] Teeth with caries, cracks, or signs of resorption.
[2] Radiographic evidence of calcifications.

Sample size and grouping:
The sample size was calculated using power analysis with 95% confidence level and 80% power. Considering the tested variables, a minimum sample size of 30 specimens per group was considered adequate to detect statistically significant differences. The specimens were randomly distributed into two experimental groups (n = 30 each). All the details regarding the sample preparation and overview of methodology is shown in **(Figure 1)**. Wax models of horse-shoe shaped arches were made to mimic the maxillary and mandibular arches to standardise the position of the specimens during imaging. Ten specimens were fitted to each model and cast compound moulds were made for scanning procedures **(Figure 2).** This setup enabled reproducible positioning for the pre-operative and post-operative CBCT analysis (**Figure 3**). Representative CBCT images showing specimen positioning and standardized scanning orientation are shown in **(Figure 4).** All retrieval procedures were performed by a single operator using 7.5× magnification loupes (Admetec, Israel) to minimise procedural variability. For group A of Masserann set, a straight-line access was provided by Gates–Glidden drills. There was coronal overgrowth around the broken fragment, forming a staging platform. The separated instrument was trephined around the coronal aspect using Masserann trepan burs. Then, the fractured fragment was released with ultrasonic tips (ET25). After adequate access was achieved, the extractor tube and plunger assembly was used to engage and retrieve the broken instrument and similarly for Group B Retrieval System C-FR2, again, straight-line access was done with the NiTi path drill of the C-FR2 kit. A NiTi planar-tip drill was used to prepare a staging platform. Coronal enlargement around the fragment was performed with a micro-trepan bur in an anticlockwise direction. Then the separated fragment was loosened by ultrasonic activation. The lasso loop assembly and the extractor tube were then placed over the exposed fragment and locked in place with the central stylus to allow for retrieval. For Volumetric Analysis, baseline canal volumes were established using preoperative CBCT scans of all specimens. Post-operative CBCT images were taken in the same standardised conditions after retrieval of the fractured instrument **(Figure 5)**. To calculate the volumetric loss of dentin, the difference between the pre-operative and post-operative canal volumes was calculated using the CBCT volumetric analysis software. Retrieval time assessment was recorded with a digital stopwatch. Timing began at the beginning of the staging platform preparation and ended with complete retrieval of the fractured instrument. The total time of retrieval was recorded in minutes. Postoperative CBCT scans were examined for root canal wall perforation or procedural aberrations related to the removal of the instrument. The incidence of perforation was recorded as a binary outcome (yes/no). Volumetric measurements were obtained using dedicated CBCT software following three-dimensional segmentation of individual specimens.

Statistics analysis:
Statistical analysis of the data was performed using the Statistical Package for Social Sciences (SPSS v26.0, IBM Corp., Armonk, NY, USA) on the data obtained from all the samples. Descriptive statistics such as mean, standard deviation, frequency and percentage were used to analyse all variables. Comparison of retrieval time and volumetric dentin change between the Masserann and C-FR2 groups was performed using the independent t-test/Welch's t-test. The incidence of perforation between the groups was analysed using Fisher's exact test. The Pearson's correlation coefficient test was used to evaluate the correlation between the working length and the volumetric dentin change and between the volumetric change and the perforation incidence. A p-value of <0.05 was considered to be statistically significant.

Results:

A total of 60 extracted mandibular premolars were included in the study and equally distributed between the Masserann and C-FR2 groups (n = 30 each). All specimens completed the experimental protocol and were included in the final statistical analysis. The distribution of specimens according to working length range is presented in **Table 1**. In the Masserann group, 40.0% of samples demonstrated short working length, 40.0% demonstrated medium working length and 20.0% showed long working length. In the C-FR2 group, 56.7% of specimens exhibited short working length, whereas 43.3% demonstrated medium working length. No long working length specimens were observed in the C-FR2 group. The comparative evaluation of retrieval outcomes between the two retrieval systems is summarized in **Table 2.** The mean retrieval time for the Masserann kit was 3.63 ± 1.22 minutes, whereas the C-FR2 retrieval system demonstrated a mean retrieval time of 3.30 ± 1.15 minutes (**Figure 6**). The difference between the groups was not statistically significant (p = 0.280). Volumetric dentin change demonstrated a statistically significant difference between the groups. The Masserann kit exhibited significantly lower volumetric dentin loss (1.72 ± 0.74 mm³) compared with the C-FR2 system (2.73 ± 1.64 mm³) (p = 0.004) (**Figure 7**). Perforation incidence was significantly greater in the Masserann group, with perforations observed in 20.0% of specimens, compared with 3.3% in the C-FR2 group (p = 0.003). Correlation analysis between working length range and volumetric dentin change demonstrated no statistically significant association in either the Masserann group (r = 0.280, p = 0.175) or the C-FR2 group (r = −0.106, p = 0.578) (**Table 3**). Similarly, no statistically significant correlation was observed between volumetric dentin change and perforation incidence in either the Masserann group (r = 0.088, p = 0.675) or the C-FR2 group (r = 0.146, p = 0.441). The present study was conducted under *in vitro* conditions and therefore could not completely simulate the clinical oral environment, including factors such as saliva or blood contamination, restricted visibility and operator fatigue. Unequal distribution of working length among groups may also have influenced procedural difficulty and perforation incidence despite the absence of significant statistical correlation. In addition, all retrieval procedures were performed by a single operator to minimize inter-operator variability, which may have introduced operator-related bias. Furthermore, the study evaluated only immediate structural outcomes, while long-term parameters such as fracture resistance and sealing ability were not assessed. Within the limitations of the present study, the Masserann kit showed superior dentin preservation, whereas the C-FR2 retrieval system exhibited a significantly lower perforation incidence. Both retrieval systems showed comparable efficiency with respect to retrieval time.

Table 1: Baseline distribution of samples according to working length range

Working Length Range	Masserann n (%)	C-FR2 n (%)	Total n (%)
Short	12 (40.0)	17 (56.7)	29 (48.3)
Medium	12 (40.0)	13 (43.3)	25 (41.7)
Long	6 (20.0)	0 (0.0)	6 (10.0)
Total	30 (100)	30 (100)	60 (100)

Footnote: Short: <20.0 mm, Medium: 20.1–22.0 mm, Long: 22.1–24.0 mm

Table 2: Comparison of primary outcomes between masserann and c-fr2 systems

Outcome Measure	Masserann Kit (n=30)	C-FR2 Kit (n=30)	p-value
Retrieval time (minutes)	3.63 ± 1.22	3.30 ± 1.15	0.280
Volumetric dentin change (mm³)	1.72 ± 0.74	2.73 ± 1.64	0.004*
Perforation incidence n (%)	6 (20.0)	1 (3.3)	0.003*
No perforation n (%)	24 (80.0)	29 (96.7)	–

**Statistically significant at p < 0.05*

Table 3: Correlation analysis between working length, volumetric change and perforation incidence

Variable Correlated	Group	Correlation Coefficient (r)	p-value
Working length vs volumetric change	Masserann	0.280	0.175
	C-FR2	−0.106	0.578
Volumetric change vs perforation	Masserann	0.088	0.675
	C-FR2	0.146	0.441

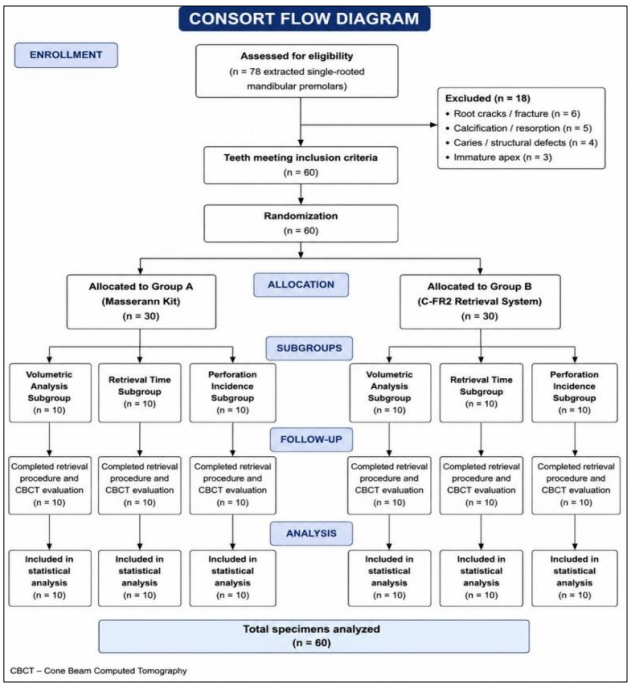


Figure 1: Consort flow diagram



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Figure 3: Wax models of horse-shoe shaped arches on CBCT machine

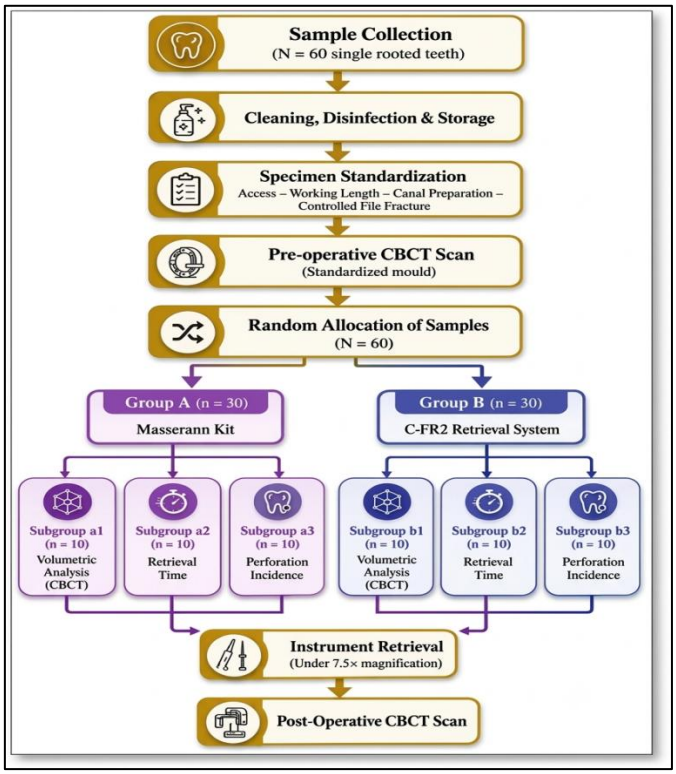


Figure 2: Schematic representation of the overview of methodology

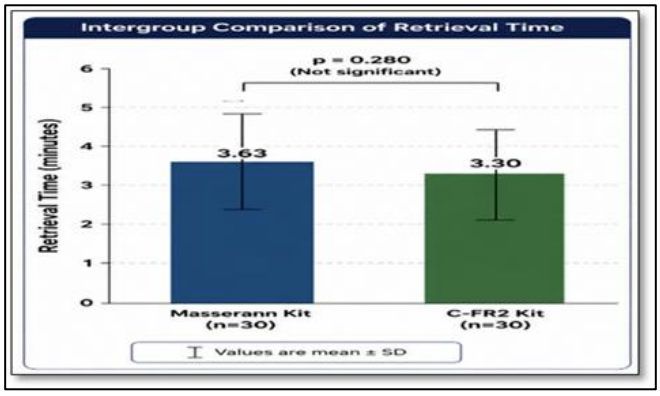


Figure 6: Intergroup comparison of retrieval time

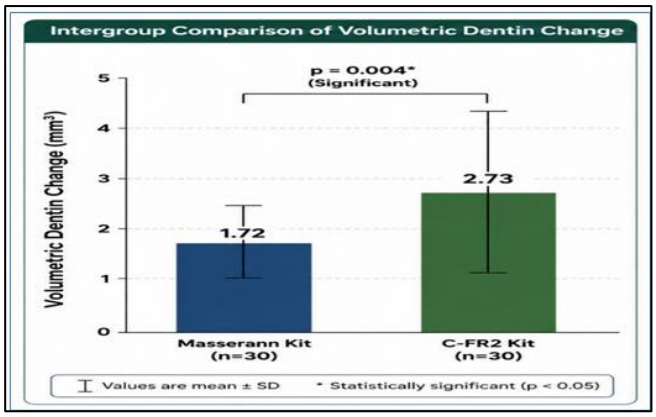


Figure 7: Intergroup comparison of volumetric change

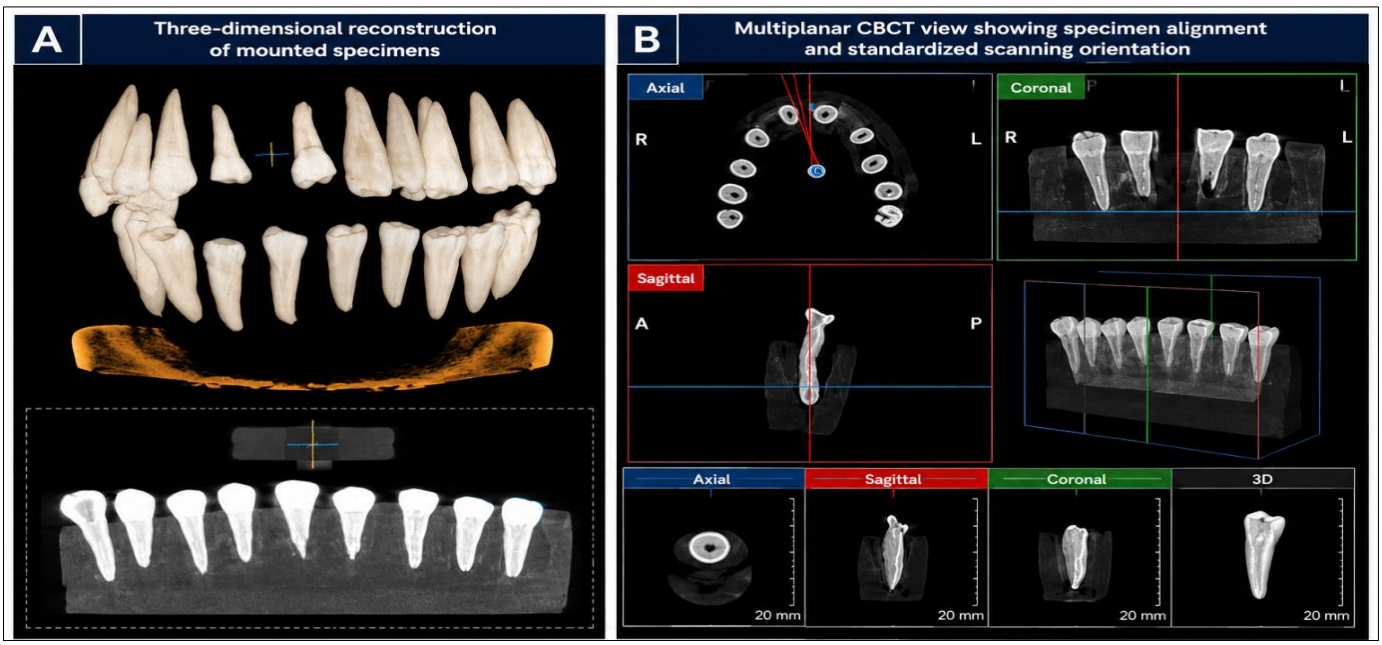


Figure 4: (A) Three-dimensional reconstruction of mounted specimens. (B) Multiplanar CBCT view showing specimen alignment and standardized scanning orientation

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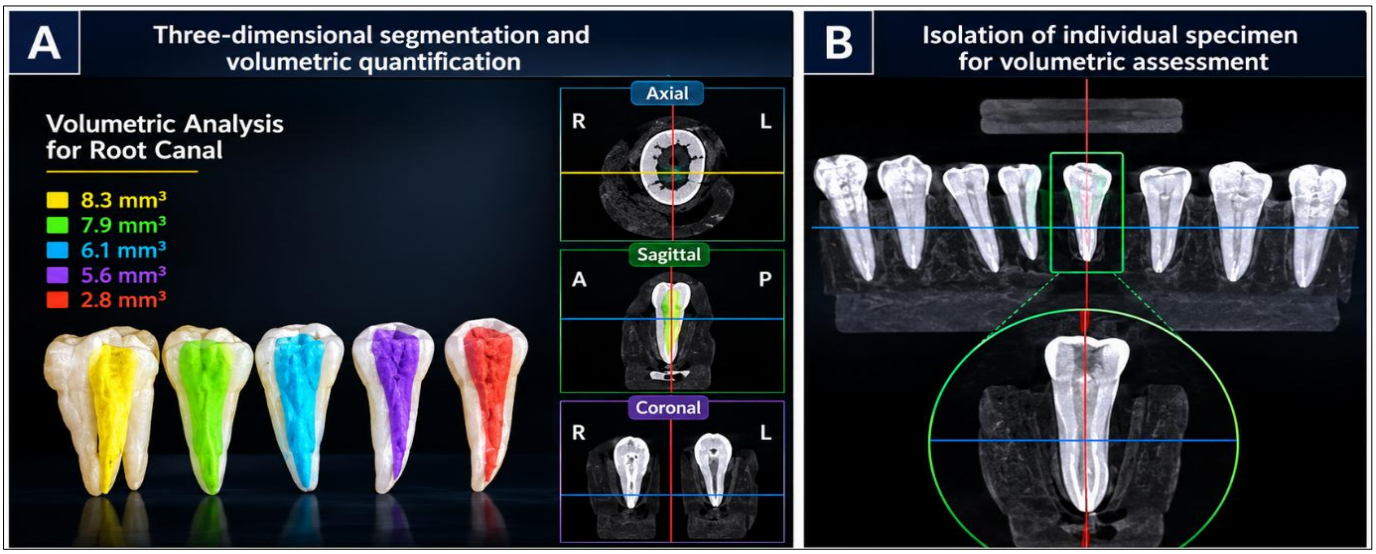


Figure 5: Representative images illustrating volumetric analysis using CBCT software. (A) Three-dimensional segmentation and volumetric calculation of root canal specimens. (B) Selection and isolation of individual specimens for volumetric assessment before and after instrument retrieval

Discussion:

The management of separated endodontic instruments remains one of the most challenging procedural complications in endodontic therapy because retrieval procedures must balance effective fragment removal with preservation of radicular dentin. The present *in vitro* study compared the Masserann kit and the C-FR2 retrieval system based on retrieval time, volumetric dentin loss and perforation incidence using CBCT analysis. The findings of the present study showed that the Masserann kit resulted in significantly lower volumetric dentin loss compared with the C-FR2 system. Preservation of dentin during retrieval procedures is clinically important because excessive dentin removal may compromise root strength and increase susceptibility to vertical root fracture. The reduced volumetric change observed with the Masserann kit in the present study may be attributed to the controlled mechanical engagement of the fragment and operator-guided retrieval under magnification. Similar observations regarding the importance of conservative dentin preservation during instrument retrieval have been reported by Yassa *et al.* (2025) **[21]**, who emphasized that excessive dentin removal adversely affects structural integrity and fracture resistance. Although the Masserann kit showed superior dentin preservation, the incidence of perforation was significantly higher compared with the C-FR2 retrieval system. This finding suggests that despite lower overall volumetric dentin removal, the trephining mechanism and deeper apical instrumentation associated with the Masserann technique may increase the risk of canal wall deviation and perforation, particularly in narrow canals. In contrast, the C-FR2 system showed a safer procedural profile with minimal perforation incidence, possibly because of its loop-assisted retrieval design and improved control during fragment engagement. Previous studies by Hülsmann (1990) **[24]** and Gencoglu and Helvacioglu (2009) **[12]** similarly reported that aggressive mechanical retrieval techniques may predispose to procedural errors and perforations during fractured instrument retrieval. The mean retrieval time did not differ significantly between the two systems, indicating comparable procedural efficiency. Both systems were able to retrieve fractured instruments within a clinically acceptable duration under magnification. This finding is in accordance with studies by Perez Morales *et al.* and Alomairy *et al.* (2009) **[25, 26]** and Pruthi *et al.* (2020) **[11]** who reported no significant differences in retrieval efficiency among various contemporary retrieval systems when proper visualization and ultrasonic assistance were employed. Correlation analysis in the present study showed no statistically significant association between working length and volumetric dentin loss or between volumetric change and perforation incidence. These findings suggest that retrieval outcomes were more likely influenced by retrieval technique and instrument design rather than working length alone. However, previous literature has indicated that apically positioned fragments and complex canal anatomy may increase retrieval difficulty and procedural complications **[27, 28]**. Within the limitations of this study, both retrieval systems demonstrated acceptable retrieval efficiency under magnification. However, the Masserann kit showed superior dentin preservation, whereas the C-FR2 system demonstrated a significantly safer perforation profile. Therefore, clinical selection of a retrieval system should be based not only on retrieval success but also on preservation of tooth structure and long-term prognosis. These findings highlight that the clinical selection of a separated instrument retrieval system should be based not only on retrieval success but also on the amount of tooth structure sacrificed and the risk of procedural complications. In this context, Jitesh *et al.* (2024) evaluated staging platform (SP) The study reported an overall retrieval success rate of 92.5%, with no significant difference between the SP technique (95%) and the BP technique (90%). The

authors emphasized that comparable retrieval success does not necessarily equate to equivalent preservation of root structure **[29]**.

Conclusions:
We show the Masserann kit and C-FR2 retrieval system using CBCT analysis to evaluate retrieval time, volumetric dentin change and perforation incidence. While both systems showed similar retrieval efficiency under magnification, the Masserann kit achieved superior dentin conservation with significantly lower volumetric loss. Conversely, the C-FR2 system exhibited a significantly lower perforation rate and a safer procedural profile, highlighting the need for future *in vivo* clinical studies to confirm long-term applicability.

Conflicts of interest: There are no conflicts of interest.

Funding statement: Nil

Advancement to knowledge:
This study provides the first three-dimensional, volumetric evaluation of dentin loss and safety between the Masserann kit and the contemporary C-FR2 system. It reveals that while the C-FR2 system offers a significantly safer perforation profile, the traditional Masserann kit achieves superior root structure preservation. These findings offer objective criteria to help clinicians effectively balance long-term tooth integrity against immediate procedural risks during fragment retrieval.

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No version of this manuscript or its data has been published, archived, or made available on any pre-print server (including but not limited to Research Square, bioRxiv, or medRxiv) prior to this submission. The primary source material has not been split or duplicated elsewhere.

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