

Innovation of disposable messing gun in endodontics: clinical simulation test

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Objectives: This study aimed to evaluate a novel disposable delivery system, the MDent Gun, by assessing postgraduate student operator satisfaction and comparing the quality of mineral trioxide aggregate (MTA) apical plugs produced using the MDent Gun versus the OrthoMTA carrier in standardized open-apex resin tooth models.

Materials and Methods: Sixty three-dimensionally printed resin tooth models with standardized open apices were fabricated. Thirty postgraduate endodontic students performed orthograde placement of 4-mm ProRoot MTA apical plugs using both the MDent Gun and OrthoMTA carrier in a randomized crossover design. The MTA was standardized (0.5 g powder:0.18 mL distilled water) and placed under dental operating microscopy. Operator satisfaction was evaluated using a questionnaire assessing: (1) ergonomic design, (2) ease of material extrusion, (3) convenience of intracanal delivery, and (4) suitability for MTA apical plug procedures. Apical plug quality was assessed radiographically using a 4-grade scoring system. Intraobserver reliability was calculated using Cohen's Kappa coefficient. Statistical analyses were performed using the Wilcoxon signed-rank test for both operator satisfaction and apical plug quality ($p < 0.05$).

Results: Intraobserver reliability for radiographic scoring demonstrated excellent agreement (Cohen's Kappa = 0.927, $p < 0.001$). Operators reported significantly higher ergonomic design satisfaction with the MDent Gun (median 4, IQR 4–5) compared to the OrthoMTA carrier (median 4, IQR 4–4) ($p = 0.016$). No statistically significant differences were observed for other satisfaction parameters. Radiographic void scores demonstrated no significant differences between the MDent Gun (median 2.5, IQR 1–3) and OrthoMTA carrier (median 2.0, IQR 2–3) groups.

Conclusions: Operators demonstrated significantly higher satisfaction with the ergonomic design of the MDent Gun compared to the OrthoMTA carrier, while MTA apical plug quality showed no significant differences between both delivery systems.

Keywords: disposable messing gun, mineral trioxide aggregate, MTA apexification, MTA apical plug

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Introduction

Non-vital immature permanent teeth present significant clinical challenges due to characteristically thin and fragile dentinal walls that preclude conventional mechanical instrumentation. Additionally, the absence of physiological apical constriction increases the risk of irrigant,

medicament, and obturating material extrusion beyond the apex. Moreover, obturation presents substantial difficulties in these cases. The lack of an apical stop renders material control within the root canal system more problematic. Consequently, obturating materials may be either excessively or insufficiently condensed due to the absence of a defined apical terminus [1,2].

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Apexification is a well-established treatment for managing these cases, aiming to induce calcified apical barrier formation or stimulate continued root development [3-5]. Traditionally, calcium hydroxide has been utilized for this purpose [6]; however, its limitations, including prolonged treatment duration, increased fracture risk, and unpredictable apical closure, have prompted adoption of mineral trioxide aggregate (MTA) as the preferred alternative [7,8]. The MTA, a bioactive hydraulic calcium silicate-based cements (HCSCs), demonstrates excellent biocompatibility, superior sealing ability, and capacity to stimulate hard tissue formation, making it favorable for single-visit apexification [9-13]. Its clinical application has substantially simplified treatment protocols, reduced treatment time, and improved prognosis compared with conventional calcium hydroxide techniques [14-15].

Despite its biological advantages, MTA placement remains technically demanding, particularly in confined apical regions where void formation commonly compromises sealing integrity [16-20]. Various delivery devices have been developed to address this challenge, including amalgam carriers, Messing guns, and lentulo spirals, each with distinct advantages and limitations [21-25]. Due to their small diameter and elongated tips, Messing guns provide convenient access for delivering MTA to the apical portion of the root canal.

However, they also present several drawbacks; for example, tip blockage caused by material setting can render the applicator unusable, as well as their high cost and the need for international importation.

The OrthoMTA carrier (BioMTA, Seoul, Republic of Korea), a commonly employed Messing gun, requires importation in Thailand. This system, measuring 17 cm in total length, utilizes straight 18-gauge, 2.5-cm-long disposable needle tips with an internal Nitinol dispensing core. Due to the straight configuration of the needle tips, an additional angulation accessory must be procured to achieve tip curvature when access to posterior or anatomically restricted regions is necessary (Figure 1). Furthermore, the relatively high cost of the disposable needle tips may constrain the device's practicality in routine clinical practice.

To address these limitations, the MDent Gun (MDent, Mahidol University, Bangkok, Thailand) was developed as a pre-sterilized and single-use Messing gun designed for HCSC placement. The device features a polypropylene body with flexible internal spring and 2.5-cm stainless steel tip (approximately 18-gauge diameter) pre-angulated at 30° to enhance apical access with a total instrument length of 10 cm (Figure 1). Its compact design, integrated pusher, and ergonomic grip facilitate precise handling and operator comfort.

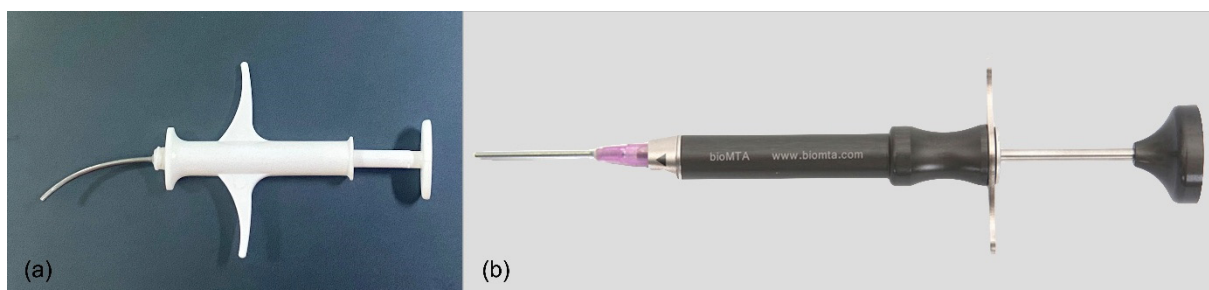


Figure 1 Comparison between the MDent Gun (a) and the OrthoMTA carrier (b), demonstrating differences in body design, tip angulation, and overall dimensions.

As newly developed instruments require comprehensive clinical evaluation, assessment by experienced practitioners is essential to simulate clinical application conditions. The MTA apical plug placement, recognized as a technically demanding procedure, represents an appropriate clinical scenario for evaluating this disposable delivery system. Therefore, this study aimed to evaluate the MDent Gun in comparison with the OrthoMTA carrier by assessing postgraduate student operator satisfaction and the quality of MTA apical plugs produced in standardized open-apex resin tooth models.

Materials and Methods

Ethics Approval

This study was approved by the Institutional Review Board of the Faculty of Dentistry and Faculty of Pharmacy, Mahidol University (MU-DT/PY-IRB 2025/023.0104).

Sample Size Calculation

Sample size calculation was performed using G*Power software (version 3.1.9.6, Heinrich Heine Universität Düsseldorf, Germany) based on pilot study data. To achieve 80% statistical power at a 5% significance level with an effect size of 0.571, a minimum of 27 postgraduate students was required. Accordingly, 30 postgraduate students were recruited to accommodate a potential 10% dropout rate and to ensure adequate statistical power. Each participant placed MTA apical plugs using both delivery systems in a crossover design.

Tooth Selection and Preparation

A human mandibular premolar with Vertucci Type I canal morphology and complete apical development was selected to standardize the access pathway and eliminate anatomic variability. Root canal configuration was confirmed radiographically in buccolingual and mesiodistal projections. The tooth was free from caries, cracks, fractures, resorption, and previous endodontic treatment. To simulate an open apex, the root tip was sectioned using a low-speed Isomet saw (Buehler, Lake Bluff, IL, USA) under continuous water cooling. An access cavity was prepared using a #014 round bur (SA CH-1338, Dentsply Maillefer, Ballaigues, Switzerland). Canal patency was confirmed with a #15 K-file (M-access, Dentsply Maillefer, Ballaigues, Switzerland). The canal was enlarged coronally with a No. 6 Peeso reamer and retrogradely with a No. 3 Peeso reamer to achieve a 1.1 mm apical diameter, modified from Lertmalapong *et al.* [26]. Final irrigation used distilled water.

Resin Tooth Model Fabrication

The prepared tooth was scanned using micro-computed tomography (Bruker microCT 1173, Kontich, Belgium). Reconstructed STL files were used to fabricate 60 standardized resin replicas via digital light processing printer (SprintRay Pro 95, SprintRay Inc., Los Angeles, CA, USA) with model resin (SprintRay Model White Resin, SprintRay Inc.) (Figure 2). Sixty resin models with standardized open apices and a uniform root length were produced and individually embedded in moistened floral foam to simulate periapical tissue conditions [14,27]. The floral foam provided light apical resistance without blocking material flow, functioning similarly to a collagen apical matrix used clinically.

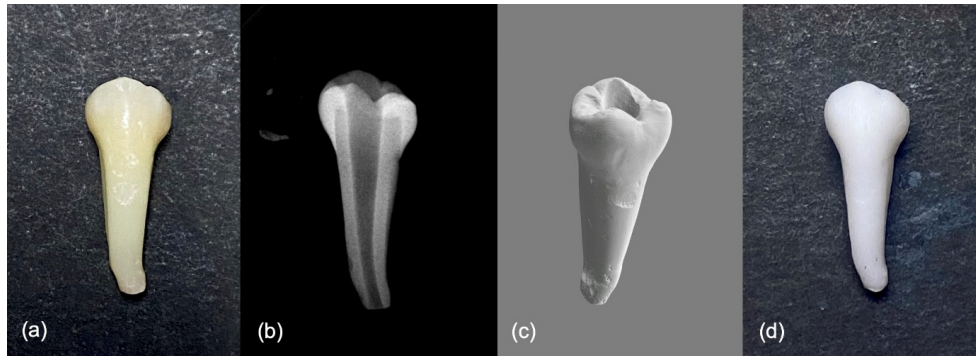


Figure 2 Fabrication process of the resin open apex tooth model: (a) immature tooth model, (b) radiographic image, (c) STL file, and (d) 3D-printed resin open apex tooth model.

MTA Apical Plug Procedure

The 60 resin tooth models were randomly divided into two groups of 30 specimens each. Each group received a 4-mm MTA apical plug [20] placed by postgraduate students using either the MDent Gun (MDent, Mahidol University, Bangkok, Thailand) or the OrthoMTA carrier (BioMTA, Seoul, Republic of Korea).

ProRoot MTA (White ProRoot MTA, Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) was prepared by mixing 0.5 g of powder with 0.18 mL of distilled water for 30 seconds on a glass slab using a cement spatula. The mixed material was loaded into the respective delivery device and placed orthogradely as follows:

- Group 1 (MDent gun): MTA was delivered and condensed vertically with fitted pluggers until a 4-mm apical plug was achieved.
- Group 2 (OrthoMTA carrier): MTA was delivered and condensed vertically with fitted pluggers until a 4-mm apical plug was achieved.

All procedures were performed under an operating microscope (OPMI pico, Carl Zeiss Meditec AG, Jena, Germany). Participants were permitted to obtain up to two radiographs during placement to verify apical plug position.

In a crossover design, 15 operators initially performed procedures using the MDent Gun while the remaining 15 operators used the OrthoMTA carrier. After a two-week interval, all operators switched devices and repeated the procedure. Following completion of each treatment session, participants completed a satisfaction questionnaire.

Operator Satisfaction Assessment

Operator satisfaction with the delivery systems was evaluated using a questionnaire addressing four parameters: (1) The shape and size of the instrument are ergonomically appropriate and facilitate comfortable handling during clinical application; (2) The instrument demonstrates ease of material extrusion, characterized by smooth plunger action, minimal resistance during activation, and unobstructed material delivery; (3) The instrument enables efficient and precise material placement into the root canal system; and (4) The instrument exhibits suitability and appropriateness for application in MTA apical plug procedures. Each parameter was scored on a five-level scale: 5 = highest satisfaction, 4 = high satisfaction, 3 = moderate satisfaction, 2 = low satisfaction, and 1 = lowest satisfaction (Table 1).

Table 1 Questionnaire for assessment of operator satisfaction with the delivery instruments.

Instrument		Satisfaction				
		Highest (5)	High (4)	Moderate (3)	Low (2)	Lowest (1)
<input type="checkbox"/> Mdent gun	<input type="checkbox"/> OrthoMTA carrier					
1. The shape and size of the instrument are ergonomically appropriate and facilitate comfortable handling during clinical application.						
2. The instrument demonstrates ease of material extrusion, characterized by smooth plunger action, minimal resistance during activation, and unobstructed material delivery.						
3. The instrument enables efficient and precise material placement into the root canal system.						
4. The instrument exhibits suitability and appropriateness for application in MTA apical plug procedures.						

The questionnaire was developed and validated before data collection. Content validity was established through evaluation by three experts in endodontics and dental education, yielding an index of item-objective congruence (IOC) of 0.87. Pilot testing was performed with 10 postgraduate students to refine item clarity and response interpretation. The final four-item scale demonstrated good internal consistency, with a Cronbach's alpha of 0.82.

In this study, ergonomic design was defined as the extent to which an instrument's external form promotes comfortable hand posture, stable grip, controlled manipulation, and reduced operator strain. In endodontic delivery devices, these characteristics are primarily influenced by instrument shape, size, and angulation, which directly affect access and handling precision during apical placement. The questionnaire item evaluating shape and size was therefore used to represent the ergonomic component of operator satisfaction.

To minimize potential conflicts of interest, all participants were informed that their responses and procedural performance would be anonymized and would not affect their academic evaluation or grading. Faculty members responsible for academic assessment were not involved in data collection or questionnaire administration. Participation was voluntary, and students were encouraged to provide candid responses regardless of device origin.

Evaluation of MTA Apical Plug Quality

Buccolingual and mesiodistal radiographs were obtained for each specimen (Figure 3) and evaluated for void presence using a modified 4-grade scoring system adapted from Aminoshariae *et al.* [28]: Grade 1 = absence of voids; Grade 2 = void extending less than half the specimen diameter; Grade 3 = void extending greater than half the specimen diameter; Grade 4 = void extending completely through the specimen diameter (Figure 4). When multiple voids were present, the highest score was assigned.

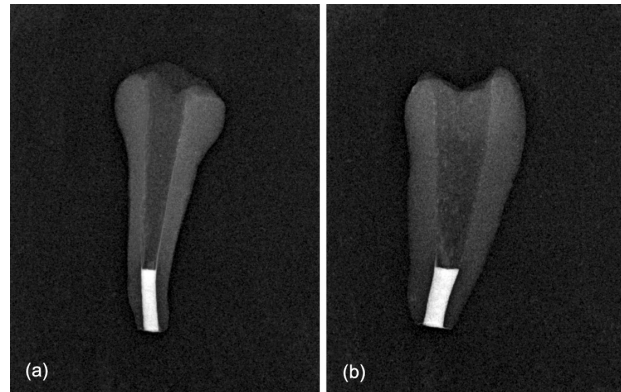


Figure 3 Representative radiographs of MTA apical plugs for void score assessment: (a) buccolingual view, (b) mesiodistal view.

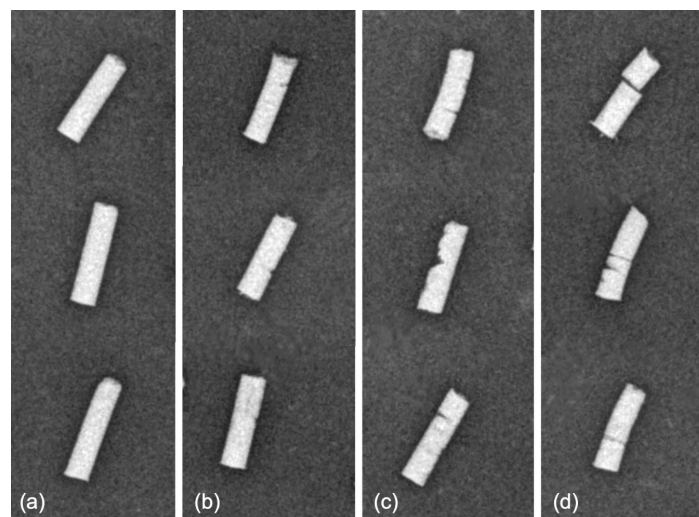


Figure 4 Representative radiographic images illustrating the grading criteria: (a) Grade 1: absence of voids, (b) Grade 2: void extending less than half the specimen diameter, (c) Grade 3: void extending greater than half the specimen diameter, (d) Grade 4: void extending completely through the specimen diameter.

All radiographic evaluations were performed by an experienced endodontist who was blinded to group allocation. The evaluator did not know which radiograph originated from which delivery system. Intraobserver reliability was assessed by re-evaluating all 60 radiographs after a two-week interval, and agreement was quantified using Cohen's kappa coefficient.

Statistical Analysis

Statistical analyses were performed using SPSS version 18.0 (IBM SPSS Statistics, Chicago, IL, USA). Intraobserver reliability for radiographic evaluation was assessed using Cohen's kappa coefficient. Normality of data distribution was evaluated using the Shapiro–Wilk test. Because both the satisfaction scores and void scores were ordinal and demonstrated non-normal distributions, the median and interquartile range

were used to summarize central tendency, and the Wilcoxon signed-rank test was applied to compare satisfaction scores and MTA plug quality between delivery systems for paired comparisons. Statistical significance was established at $p < 0.05$.

Results

Satisfaction with Instrument Usage

Regarding ergonomic design (Question 1), the MDent gun achieved a median satisfaction score of 4 (IQR: 4–5), whereas the OrthoMTA carrier received a median score of 4 (IQR: 4–4). A statistically significant difference was observed between devices ($p = 0.016$), with the OrthoMTA carrier demonstrating lower rankings (Tables 2 and Figure 5).

Table 2 Comparison of operator satisfaction scores between the MDent gun and OrthoMTA carrier (n = 30)

	MDent gun						OrthoMTA carrier						Adjusted P-value
	Satisfaction					Median (P ₂₅ -P ₇₅)	Satisfaction					Median (P ₂₅ -P ₇₅)	
	5	4	3	2	1		5	4	3	2	1		
Question 1	14	13	3	0	0	4 (4 - 5)	4	20	4	1	1	4 (4 - 4)	0.016
Question 2	13	14	3	0	0	4 (4 - 5)	11	15	4	0	0	4 (4 - 5)	0.544
Question 3	12	12	6	0	0	4 (4 - 5)	12	15	1	1	1	4 (4 - 5)	0.694
Question 4	16	13	1	0	0	5 (4 - 5)	10	18	1	0	1	4 (4 - 5)	0.090

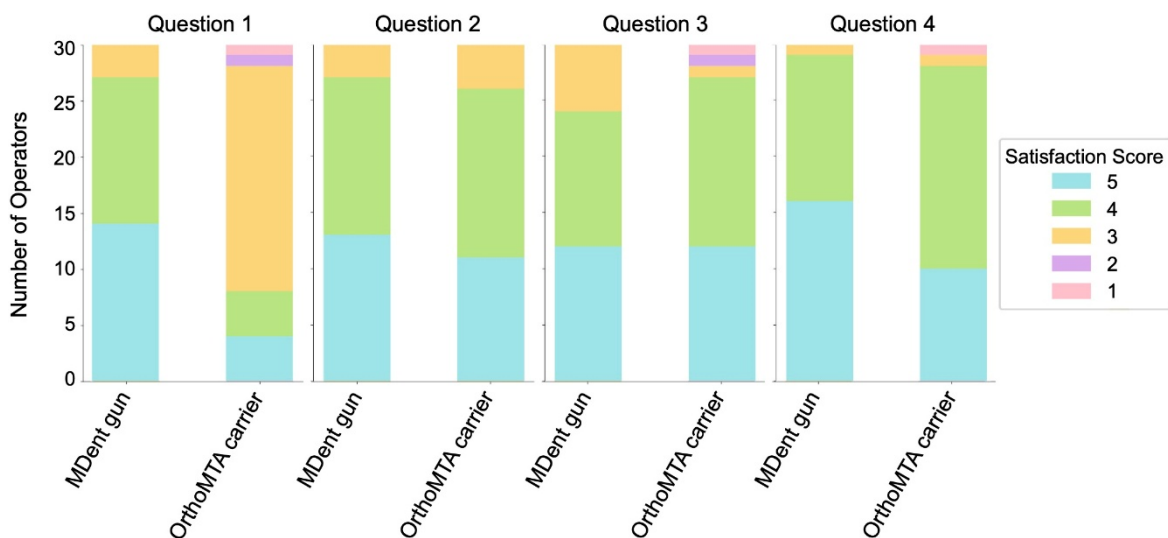


Figure 5 Distribution of operator satisfaction scores for the MDent gun and OrthoMTA carrier across four survey questions.

For ease of material extrusion (Question 2) and convenience of intracanal delivery (Question 3), both the MDent gun and OrthoMTA carrier achieved median satisfaction scores of 4 (IQR: 4–5). Regarding suitability for MTA apical plug procedures (Question 4), the MDent gun attained a median score of 5 (IQR: 4–5), while the OrthoMTA carrier scored 4 (IQR: 4–5). No statistically significant differences were detected between devices for Question 2 ($p = 0.544$), Question 3 ($p = 0.694$), or Question 4 ($p = 0.090$) (Tables 2 and Figure 5).

Quality of MTA Apical Plug

Intraobserver repeatability for radiographic evaluation demonstrated substantial agreement with a Kappa value of 0.927 ($p < 0.001$).

The MTA apical plug quality scores (void scores) were higher in the MDent gun group (median: 2.5, IQR: 1–3) compared to the OrthoMTA carrier group (median: 2.0, IQR: 2–3). However, no statistically significant difference in apical plug quality was observed between groups ($p = 0.796$) (Table 3).

Discussion

Comparative investigations examining MTA delivery systems remain limited in the current literature, particularly with regard to clinical handling characteristics and operator performance metrics. The present study evaluated a newly

developed disposable delivery system, the Messing gun (MDent gun), in comparison with the OrthoMTA carrier. The MDent gun, which was designed and manufactured locally, represents a more accessible and cost-effective single-use alternative that addresses several challenges associated with imported carrier systems, including limited availability, elevated cost, and sterilization requirements. This investigation specifically examined operator satisfaction levels and apical plug quality parameters under standardized experimental conditions.

With regard to study design, multiple strategies were employed to minimize potential bias. Resin open-apex tooth models were utilized to ensure standardized experimental conditions and uniform anatomical morphology, effectively eliminating confounding variables. All equipment for MTA apical plug procedures remained consistent across experimental groups, and MTA preparation was performed by a single operator to maintain material homogeneity. A crossover design was implemented in which participants were randomized to use both the MDent gun and OrthoMTA carrier in alternating sequence. This approach enabled direct comparison of both operator satisfaction and apical plug quality between the two delivery systems. Radiographic assessment demonstrated excellent intraobserver reliability (Cohen's Kappa = 0.927, $p < 0.001$), indicating "almost perfect" agreement [29], which validates the consistency and reliability of the void-scoring methodology employed.

Table 3 Comparison of median void scores and interquartile ranges between the MDent gun and OrthoMTA carrier groups (n = 30)

	N	Graded void		Mean rank	Adjusted P-value
		Median	P ₂₅ - P ₇₅		
MDent gun	30	2.5	1 - 3	7.2	0.796
OrthoMTA carrier	30	2.0	2 - 3	6.0	

Regarding operator satisfaction, a statistically significant difference was observed in the appropriateness of instrument shape and size for comfortable handling, with the MDent gun demonstrating superior satisfaction scores compared to the OrthoMTA carrier. Although both devices demonstrated the same median ergonomic score of 4, the MDent Gun showed a greater proportion of higher-ranked responses, resulting in a statistically significant difference in the Wilcoxon signed-rank test. These ergonomic differences reflect intrinsic instrument design rather than variations in tooth accessibility, which was controlled by standardizing the access pathway with a premolar model. The ergonomic design advantages of the MDent gun may be attributed to several factors: its disposable configuration allows for optimal shape customization without sterilization-related design constraints; its lightweight, contoured handle provides a stable and secure grip that enhances control during apical placement; and its pre-curved tip improves access to confined regions without requiring auxiliary angulation accessories, as typically needed with the OrthoMTA carrier. These features collectively contributed to improved tactile feedback, reduced operator fatigue, and enhanced precision during delicate MTA placement procedures. However, only selected ergonomic characteristics, specifically shape, size, and tip angulation, were evaluated in this study. Other ergonomic factors such as device weight, access angle, operating time, and operator muscle fatigue were not assessed and may be considered in future investigations.

However, no statistically significant differences were observed between delivery systems regarding material extrusion ease and intracanal delivery convenience, indicating comparable operational efficiency. Ergonomic advantages do not necessarily translate into

measurable improvements in intracanal delivery convenience. Intracanal delivery is influenced not only by external design features, but also by material rheology, tip lumen diameter, plunger resistance, and operator control during insertion. These factors may explain why the MDent gun demonstrated superior ergonomic ratings yet showed comparable intracanal delivery convenience to the OrthoMTA carrier. While overall instrument suitability for MTA apical plug procedures did not reach statistical significance, the MDent gun exhibited a numerically higher satisfaction trend, potentially attributable to its ergonomic advantages and their influence on perceived procedural suitability.

Radiographic evaluation of MTA apical plug quality demonstrated no statistically significant differences in void scores between delivery systems. These comparable outcomes indicate that the MDent gun maintains apical seal quality while offering simplified clinical application during MTA apical plug procedures. This is noteworthy considering the inherent technical difficulties of apical region obturation. The findings suggest that the MDent gun performs comparably to the OrthoMTA carrier with respect to root-end obturation integrity. Given these results in the challenging context of apical plug placement, the instrument may demonstrate equal or superior performance in less technically demanding clinical applications.

Because no previous studies have compared MTA delivery devices directly, the void scores observed in the present study were contextualized by comparing them with prior apical plug investigations that used similar radiographic grading systems. This comparison enables interpretation of whether the void levels produced in the current simulated open-apex model fall within an expected range. Void score variations across studies are attributable to methodological

differences. Substantially lower range void scores from (1.00-1.11) compared to the present study were reported, likely due to simplified polyethylene tube models (10 mm length, 0.7 mm apical diameter), which provided less anatomical complexity than resin tooth models (Aminoshariae *et al.*, 2003) [28]. Similarly, void scores of 1-2, slightly lower than our findings (2.0-2.5), were reported. Despite utilizing CBCT for three-dimensional evaluation and natural teeth with open apices, their models (crown-removed, 9 mm root length, 0.5 mm apical diameter) presented reduced procedural complexity (Ghasemi *et al.*, 2017) [30]. Furthermore, both studies employed 3-grade scoring scales versus our 4-grade scale and single-operator versus our 30-operator design, factors influencing score variability. These comparisons demonstrate that void scores depend on experimental model complexity, methodological approach, and operator number, with our results representing appropriate outcomes for complex clinical simulations.

Several limitations should be acknowledged. While standardized resin open-apex tooth models ensured experimental consistency, they do not replicate the anatomical variations inherent in natural dentition. In clinical situations, natural variation in root length may influence the working distance relative to the delivery-device tip. Additionally, all procedures were performed by postgraduate students in a controlled laboratory environment, which may limit the generalizability of findings to experienced clinicians or diverse clinical scenarios. Although participant responses were anonymized and grading faculty were not involved in data collection, the use of postgraduate students from the same institution in which the MDent Gun was developed may still introduce potential response bias. Future investigations should incorporate natural teeth exhibiting anatomical variability and ultimately advance to in

vivo clinical trials to provide comprehensive validation of these results.

Conclusion

Operator satisfaction with the ergonomic design of the MDent Gun was significantly superior to that of the OrthoMTA carrier, while both delivery systems demonstrated comparable performance in ease of material extrusion, convenience of intracanal delivery, and suitability for MTA apical plug procedures. Importantly, no significant differences in MTA apical plug quality were observed between the delivery systems.

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