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Editorial

Endodontics towards the future

Technological progress is making great strides among different area, as well as medical and dental fields. In the last years, dentistry is living a radical change thanks to development of advanced operative procedures, use of latest generation materials, modern imaging techniques up to 3D technology. In addition, the recent introduction in several fields of artificial intelligence (AI) would seem to be of a great interest even in dentistry. AI aid should provide solutions able to manage every event or variable, complex cases diagnosis and immediate and successful treatment plans. However, the real feasibility in dentistry is currently under debate. Main limitations might be not only related to ethical issue, but also to the consideration of patient as a person with several variables, risk factors and co-morbidities that have a certain impact on disease occurrence, its progress and prognosis. Specifically, endodontics could benefit from AI use for the morphological characterization of root-canal anatomy, as well as correct analysis of radiographic images and planning of a workflow able to optimize working time. On the other hand, the fundamental principles of "traditional" endodontics cannot be ignored as base of correct therapy and long-term success. In this light, in the present issue of Giornale Italiano di Endodonzia, are presented classic aspects such as irrigants, debridement and post-endodontic restoration, but is also published a very interesting review on AI in endodontics. Since the central role played by clinicians in the therapeutic choice, it'll be increasingly important to be updated and to develop the appropriate knowledge regarding the biological issue and the precious help provided by technological progress.

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ORIGINAL ARTICLE

Influence of the direct composite restauration on the fracture strength and failure modes of endodontically treated premolars restored with posts

ABSTRACT

Aim: *The long-term success of endodontically treated teeth requires maintaining structural integrity, functionality, and aesthetics. The combined use of endodontic fiber posts with resin-based micro- and nano-composites seems to be an intriguing solution for the reinforcement of the damaged tooth structures. This in vitro study aimed to evaluate the mechanical behavior and fracture patterns of premolars restored with different combinations of endodontic fiber posts and composite resins, subjected to thermomechanical aging and masticatory force simulation.*

Methods: *Fifty extracted maxillary premolars were divided into five groups, including a control group of healthy teeth and four experimental groups with two types of fiber posts (hollow and compact) and two composite resins with different elasticity (traditional and bulk-fill). After cyclic fatigue testing, fracture strength and failure modes were analyzed using statistical methods.*

Results: *The control group exhibited significantly higher fracture resistance (1909±177) than the experimental groups, with no significant differences among experimental groups (p. value >0.05). However, teeth restored with bulk-fill composites demonstrated slightly higher fracture resistance and a higher percentage of favorable fractures than other samples. The combination of bulk-fill composite and hollow fiber posts was associated with more favorable fracture outcomes (n=8 favorable fractures).*

Conclusion: *These findings suggest that bulk-fill composites, due to ease of use and favorable fracture behavior, may be a viable restorative option. Further studies with larger sample sizes are needed to confirm these results.*

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Introduction

Ensuring long-term structural integrity while preserving functionality and aesthetics of endodontically treated teeth is one of the main goals of modern dentistry (1-3). Although many restorative techniques have been studied and developed, the combined use of endodontic fiber posts with micro- and nano-resin-based composites seems to be a good solution to reinforce damaged tooth structures (4-7). Fiber posts provide support to the remaining tooth structure and at the same time facilitate the occlusal forces distribution, ensuring the longevity of the restoration by reducing the risk of root fracture (8). The strength and rigidity of fiber posts are crucial to achieve a homogenous restorative system and to balance stress distribution between the restoration and the surrounding tissues, thus preventing root fractures (9, 10). In recent years, hollow fiber-reinforced posts have been developed as alternatives to compact ones. These endodontic posts take advantage of the reverse extrusion of luting cement from the apex to the crown, ensuring a homogeneous distribution within the root cavity and minimizing air bubble formation. Due to their reduced stiffness, hollow fiber posts should prevent catastrophic root fractures (11-13).
Failure modes and fracture patterns are essential to understand and predict the mechanical and structural behavior of restorative systems involving endodontic fiber posts. Fracture types are strictly linked to the axial stiffness of posts. High axial stiffness promotes fractures below the cement-enamel junction (CEJ), which are considered unfavorable as they hinder tooth restoration. On the other hand, lower axial stiffness promotes favorable fractures above the CEJ, allowing for tooth restoration in the event of failure (14).
The selection of appropriate materials and techniques is critical for successful restorations, although the use of composite materials with endodontic fiber posts are well-established in restorative dentistry. Composite resins are a common choice for the direct restoration of endodontically treated teeth: they are aesthetic and versatile materials capable of offering excellent mechanical (15) and adhesive (16) properties.
Controlled aging and fracture tests are valuable methods for studying and defining the retention and strength of tooth restoration systems, since they are subjected to various functional forces during mastication (5).
But, to the best of authors' knowledge, there is a lack of evidence regarding the evaluation of the role of the direct composite restoration on the mechanical resistance and on the fracture patterns.
Therefore, the aim of this study was to define the mechanical behavior and fracture types of premolars restored with different combinations of endodontic fiber posts and composite resins subjected to thermomechanical aging and simulation of masticatory forces. By delineating the performance of restorative systems, clinicians can better comprehend clinical outcomes and accordingly select optimal materials and techniques for long-term success.

Materials and Methods

In this in-vitro study, 50 dental elements extracted for orthodontic reasons were selected. Subsequently, root canal treatment was performed, including cleaning, disinfection, shaping, and obturation. The dowel space was prepared, the post was cemented, and finally the dental reconstruction was carried out using a direct technique.
The dental elements were randomly divided into five groups: one control group consisting of healthy teeth, and four experimental groups created by combining two types of posts and two types of composites.
Following reconstruction, the teeth underwent cyclic fatigue testing, and their fracture resistance was evaluated. The data were then statistically analyzed using analysis of variance.

Endodontic Posts and Materials Selection
Two types of endodontic posts with identical composition but different characteristics were used: a hollow glass fiber post (HGP) and a compact glass fiber post (GP).

Table 1

Composition and geometrical details of endodontic fiber posts

Materials	Manufacturer	Code	Composition	D [mm]	d [mm]	E [GPa]	Axial Stiffness [kN]	Bendin Stiffness [kN·mm^2]
Hollow Glass Fiber Post – Tech21	Isasan (Italy)	HGP	- Silica fibers 55% - Diphenylpropane + methyloxirane 45%	1.2	0.5	38.80 (0.98)	36.47 (0.92)	3.83 (0.10)
Glass Fiber Post – Techole	Isasan (Italy)	GP	- Silica fibers 55% - Diphenylpropane + methyloxirane 45%	1.2		40.22 (0.95)	45.44 (1.07)	4.10 (0.10)

D and d represent the external and internal radius of hollow posts, respectively.
Numbers in brackets represent the standard deviation.

Table 2

Properties of composite materials according to manufacturer's data

Materials	Manufacturer	Code	Bending Stiffness [kN·mm^2]	E [GPa]	Polymerization depth [mm]	Shrinkage [%-vol]
Venus® Pearl ONE	Kulzer	K	145	10.7	2.4	1.9
Venus® Bulk Flow ONE	Kulzer	KB	120	120	6.2	1.59

Besides, the self-etching and self-adhesive dual cement G-CEM ONE™ (GC Dental, Tokyo, Japan) was employed to lute the posts inside the dowel space. Details of the selected posts are reported in Table 1. The mechanical properties (Young's Modulus, Axial Stiffness and Bending Stiffness) of the fiber posts were previously defined through a three-point bending test by analyzing the load-displacement curves (14).
For the direct restorations, two different resin-based composite materials were utilized: Venus Pearl ONE (Kulzer, Hanau, Germany) (K) and Venus Bulk Flow ONE (Kulzer, Hanau, Germany) (KB). Details of the selected materials are reported in Table 2.

Maxillary first premolar selection
Fifty maxillary first premolars were chosen for this study. The teeth were extracted for orthodontic reasons. The study was approved by the Ethics Committee of the University of Naples Federico II (protocol number 137/2017) and conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all patients.
Inclusion criteria comprised the absence of carious lesions, comparable crown and root dimensions, presence of two root canals, absence of abfractions, cracks, or erosions. Subsequently, the teeth were immersed in a 5% NaOCl solution for 5 minutes and then stored in a physiological solution at room temperature to avoid dehydration.

Root canal treatment and obturation
The dental specimens underwent root canal treatment, excluding the control

group (healthy teeth). The access cavity was created using a pear-shaped diamond bur with a 1.6 mm diameter mounted on the high-speed handpiece Fona8080 (Fonadental, Assago, Italy). Canal scouting to the working length was performed using size 10 K-files (Kerr Corporation, CA, USA). The glide path was established using a PathFile P2 (Maillefer, Ballaigues, Switzerland). The canals were instrumented to working length using the crown-down technique with ProTaper•Next X1-X2-X3 rotary files (Maillefer). Following each file change, the canals were irrigated with a 5.25% NaOCl solution. The canals were dried with ProTaper•Next X3 paper points (Maillefer) and obturated with ProTaper•Next X3 gutta-percha cones (Maillefer) employing a single-cone technique. The specimens were stored at 37 °C and 100% humidity. Every tooth was consistently prepared by the same operator. Samples were randomly divided into five groups (n=10) as shown below and different fiber posts were employed for the restoration.

MOD cavity preparation, post cementation and restoration

Group 1 (Healthy Teeth): teeth in this group served as the control group (n=10) and underwent no procedures.

Group 2 (K-GP). A 1.4 mm diameter cylindrical diamond bur mounted on a high-speed handpiece was used to prepare MOD cavities with predetermined dimensions measured with a digital caliper: buccal-palatal width was set at 3 mm, while in the coronal-apical direction preparations extended to the CEJ. The post space was prepared in the palatal root using a Gates Glidden bur No. 4. For post cementation, the self-adhesive resin cement G-CEM ONE (GC Dental) was utilized following the manufacturer's instructions. For compact posts (Tech21, Isasan, Como, Italy), cement was initially placed inside the post space using a Lentulo spiral (Dentsply Sirona, North Carolina, USA), followed by the post itself. After a 3-minute self-polymerization phase, cement was light-polymerized using the Bluephase PowerCure lamp (Ivoclar, Schaan, Liechtenstein) at 1200 mW/cm2 for 40 seconds. The post was reduced in the coronal-apical direction using a 1.4 mm diameter cylindrical diamond bur mounted on a high-speed handpiece to ensure it was 2 mm apical to the occlusal table. After post cementation, teeth underwent adhesive procedures: etching with 37% orthophosphoric acid on both enamel and dentin for 15 seconds, followed by rinsing for 60 seconds, thorough drying of dental tissues, application of the one-bottle universal adhesive G-Premio BOND (GC Dental), and light-polymerization using the Bluephase PowerCure lamp (Ivoclar) at 1200 mW/cm2 for 20 seconds. Subsequently, reconstruction was performed by incrementally applying Venus Pearl ONE (Kulzer) to restore dental anatomy. Each composite increment presented a thickness lower or equal to 2 mm and was light-polymerized using the Bluephase PowerCure lamp (Ivoclar) at 1200 mW/cm^2 for 20 seconds.

Group 3 (K-HGP): the procedures for this group mirrored those of group 2 in terms of post housing and restoration. The only distinction lies in the use of a hollow post (Techole, Isasan, Como, Italy) and its cementation. After inserting Techole into the post-space, cement was applied through the central hole in a single step via a reverse extrusion mechanism. Following post cementation, Venus Pearl ONE (Kulzer, Hanau, Germany) was employed for the direct restoration of teeth, as in group 2.

Group 4 (KB-GP): in this group, identical procedures to those in group 2 were applied, except for using Venus Bulk Flow ONE (Kulzer, Hanau, Germany) for restoration. For group 4 and 5, each increment of composite presented a thickness of about 4 mm in order to assess the mechanical properties of this type of composite following the advertised features.

Group 5 (KB-HGP): identical procedures to those in group 3 were followed, except for the use of Venus Bulk Flow ONE (Kulzer, Hanau, Germany) for restoration.

Cyclic Fatigue and Fracture Testing

A low-temperature self-polymerizing

Figure 1
Compression test set-up.

acrylic resin was used to fix the premolars into 16 mm diameter aluminum cylinders. Teeth were cemented 2 mm below the CEJ to simulate alveolar bone. Specimens were then subjected to an aging protocol: cyclic fatigue testing was conducted in a controlled environment (H_2O at 37 °C) for one million cycles by simulating masticatory loads via a sinewave ranging from 10 to 100 N at 2 Hz frequency. The cyclic fatigue load was applied between the two cusps of each premolar through a horizontal stainless cylinder (D=6 mm). As in real conditions, the dynamically vertical load is combined of a vertical compound (compression) and a horizontal compound (bending). This means that a complex fatigue stress cyclic loading is applied to specimens, consisting of compressive and bending loads. After controlled aging, specimens underwent static mechanical testing utilizing the Instron 5566 dynamometer (Instron Ltd., High Wycombe, UK) at a speed of 1 mm/min (Figure 1). The compliance of the dynamometer was initially determined experimentally by assessing its compression stiffness based on the stress–strain curve steepness in the elastic region.

Statistical Data Analysis
The data underwent statistical analysis employing two-way ANOVA, followed by Tukey's test at a critical value of 0.05; mean values and standard deviations (SD) of fracture resistance were calculated for each group. For the fracture patterns statistical significance, a Chi-squared test and a Fisher's Exact test for larger tables were employed.

Optical Microscopy and Fracture Pattern Analysis
In order to define and classify fracture types, the optical microscope Motic AE21 (Motic Ltd., Kowloon, Hong Kong) equipped with a Nikon D3200 camera was employed. Fractures were categorized as either favorable or unfavorable based on the position of the lower edge of the fracture surface relative to the cement-enamel junction (CEJ) (Fig. 2). Specifically, fractures with the edge positioned above the CEJ were deemed favorable, as they are more likely to be easily restorable. Conversely, fractures with the edge positioned below the CEJ were classified as unfavorable, as restoration of the premolar would require a more complex and multidisciplinary approach, or not be feasible at all (9, 17, 18).

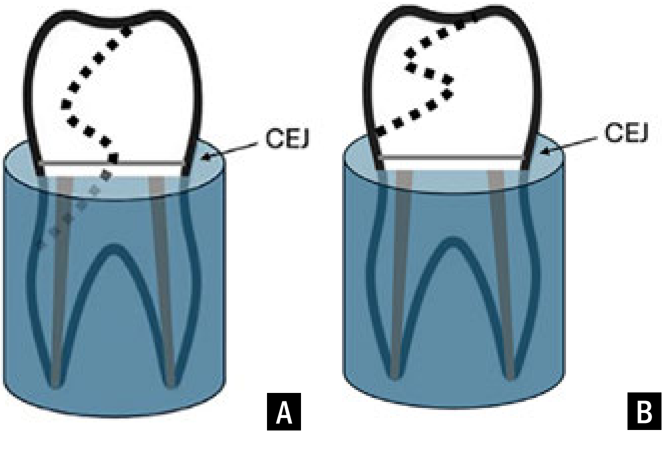

Figure 2
Comparison between an unfavorable fracture **(A)** and a favorable fracture **(B).**

Results

Figure 3 illustrates the mechanical behavior after aging of both healthy teeth (Group 1) and premolars restored using the investigated endodontic posts and composite materials (Groups 2 to 5), while Table 3 reports the values of mechanical strength for all groups recorded after fatigue. After the cyclic fatigue protocol, fracture strength was assessed by analyzing the maximum load achieved by the specimens. The control group (Group 1)

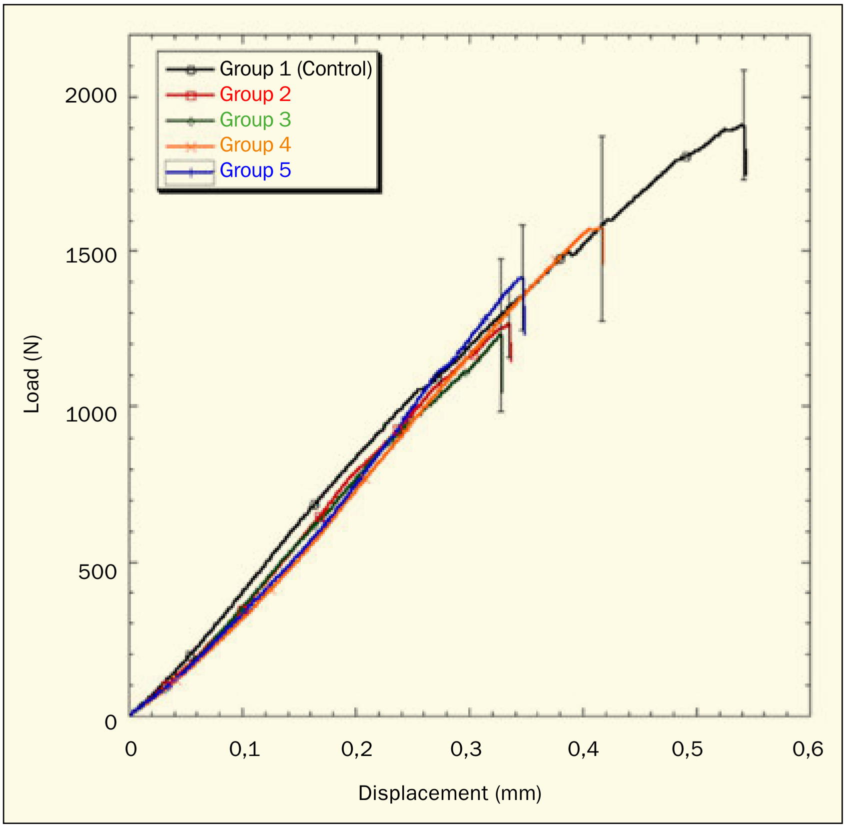

Figure 3
Mechanical behavior after fatigue of control group (Group 1), K-GP group (G2), K-HGP group (G3), KB-GP group (G4) and KB-HGP group (G5).

exhibited significantly higher strength compared to all other groups ($p<0.05$). No statistically significant difference in strength was observed among premolars restored with different endodontic posts and composite materials (Groups 2 to 5).

Table 4 displays the fracture pattern results of the investigated groups after compression testing. All groups exhibited a majority of favorable fractures. A Chi-squared test was performed to investigate potential differences between the groups; the computed chi-squared statistic was 1.287 with a p-value of 0.864, indicating no statistically significant difference among the groups. For completeness, a generalized Fisher's Exact test was employed, yielding a p-value of 0.956, consistent with the chi-squared test results. Figure 4 shows the images of the favorable and unfavorable fractures of the evaluated five groups taken with the digital microscopy.

Discussion

The fracture resistance of the dental elements selected in this in vitro study was evaluated by analyzing the maximum load-at-break values obtained using a specialized testing machine.
The control group exhibited significantly higher fracture resistance compared to the other groups. It must be considered that the endodontically treated tooth undergo significant biological changes, such as a decrease in water content (19, 20), and the loss of cross-links between collagen fibers (20). However, some studies suggested that these factors do not specifically cause al-

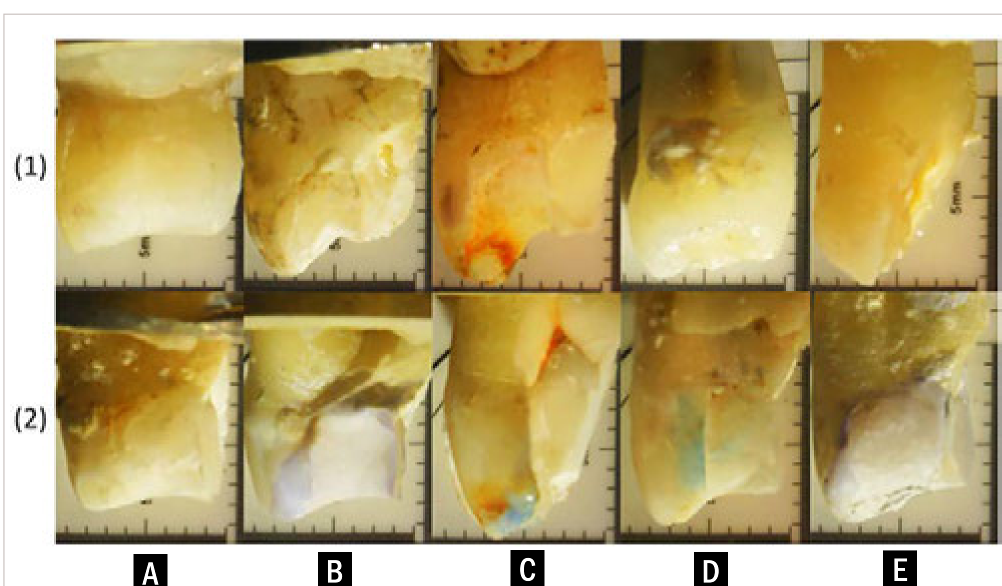

Figure 4
Digital microscopy to define 1) favoable and 2) unfavorable fractures of **A)** control group, **B)** K-GP group, **C)** K-HGP group, **D)** KB-HGP group and **E)** KB-HGP group.

Table 3

Fracture strength of investigated teeth after fatigue

	Group 1 (Control)	Group 2 (K-GP)	Group 3 (K-HGP)	Group 4 (KB-GP)	Group 5 (KB-HGP)
Load [N]	1909 (177)[b]	1252.89 (110.40)[a]	1219.53 (247.78)[a]	1575.03 (300.12)[a]	1411.09 (169.66)[a]

Numbers into brackets denote the standard deviation.

Table 4

Failure mode observed frequencies for each group

Group	Favorable		Unfavorable		*p*-Value
	n	%	n	%	
Control	7	70.00	3	30.00	
K-GP	6	60.00	4	40.00	p>0.05[1]
K-HGP	7	70.00	3	30.00	p>0.05[2]
KB-GP	6	60.00	4	40.00	
KB-HGP	8	80.00	2	20.00	

[1]A chi-squared test was used to determine whether there was a statistically significant difference between the groups in terms of observed frequencies.
[2]For completeness, a generalized Fisher's Exact test for larger tables was also employed.

terations in the mechanical and physical properties of dentin (21); as a matter of fact, the endodontically treated tooth is likely to undergo other changes that compromise its behavior, such as carious lesions, fractures, and access cavities, which proportionally reduce its biomechanical resistance based on the amount of tissue removed (22). In particular, the factor that most significantly affects the structural weakening of the tooth is the loss of marginal ridge integrity, which can lead to a stiffness reduction of up to 63% for a mesio-occluso-distal cavity (22). According to previous studies (23-28), the fracture strength of healthy premolars consistently surpassed that of endodontically treated teeth, irrespective of the restoration strategy employed. On the other hand, it was found out that endodontically treated teeth restored with composite resins showed fracture resistance values statistically similar to those of healthy teeth (29-31).
The mechanical performance and the relevance of the materials employed can be evaluated by comparing the results observed in groups where teeth were restored with the same composite resin but different posts, and in groups where teeth were restored with the same post but different composite resins.
Composite resin is typically applied using an incremental technique, involving the placement of composite layers no thicker than 2 mm: layers thicker than 2 mm do not allow UV light to penetrate deeply enough to initiate and complete the polymerization of the deepest portion of the composite (32). Additionally, smaller amounts of composite resin experience less shrinkage, thus resulting in lower contraction stress. However, layering in increments of up to 2 mm is time-consuming and technique-sensitive (33). That's why bulk-fill resin composites have been introduced to the market, as they are designed to allow layering in increments of 4-5 mm (34-37). The manufacturers of these composites claim that they offer greater depth of cure and reduced polymerization stress compared to traditional composites (38, 39). No statistically significant difference was found between groups restored with the traditional composite and groups restored with the bulk-fill one, in accordance with other studies (26, 40-45). Although not statistically significant, the groups in which specimens were restored with VenusÒ Bulk Flow ONE exhibit, on average, higher fracture resistance (1575.03 N and 1411.09 N) compared to those restored with VenusÒ Pearl ONE (1252.89 N and 1219.53 N). These results reflect the properties of bulk-fill composites and holds significant clinical value as it reassures the operator about the possibility of using bulk composites, with all their associated advantages in terms of ease of use, without sacrificing the physical properties of the restoration (33, 36, 37, 39, 46-48) and, there-

fore, the medium- to long-term success.
With regards to the role of the fiber post in the fracture resistance of the endodontically treated teeth, it's quite intriguing to observe how, even though posts with different characteristics are employed, results in terms of fracture resistance overlap. Likely, this can be attributed to the lower probability of air bubbles formation, but mainly to the cementation mechanism of the hollow post: the cement occupies the hollow post central portion and prevents phenomena of ovalization and bending that occur when a circular tube is subjected to flexural stresses, allowing it to exhibit mechanical behavior and fracture resistance values comparable to those of the compact post (14).
Regarding the fracture modes showed by the investigated groups, the statistical analysis carried on using a chi-squared test didn't show any statistically significant difference among the groups ($p>0.05$). In order to provide a thorough assessment of the data, considering the small sample size, a generalized Fisher's Exact test for larger contingency tables was employed. The results confirmed that there were no significant differences between the groups. Despite the results of the statistical analysis, a trend towards a higher number of favorable fractures can be observed among all the groups, with the KB-HGP group scoring the higher percentage of favorable fractures (80%).
Posts, and in particular their axial stiffness, play a critical role in determining the failure mode and the fracture type of premolars. Unfavorable fractures beneath the cement-enamel junction result from posts with high axial stiffness, which transfer higher stress to the root canal walls; repair and reconstruction of the tooth are not possible in case of unfavorable fractures. Compact glass fiber posts present higher axial stiffness compared to hollow fiber posts, thus exhibiting a higher percentage of unfavorable fractures (40% of specimens). Conversely, lower stress concentration at the root canal walls is obtained with endodontic posts featuring a lower axial stiffness as hollow fiber posts, leading to a more uniform and less destructive stress distribution to the coronal dentin. The stress conditions induced by these posts determine a lower percentage of unfavorable fractures (25% of specimens), allowing for more favorable outcomes in terms of tooth integrity and potential for subsequent repair.
The role of the composite regarding fracture mode should also be taken in consideration. The groups restored with the conventional composite showed a 65% of favorable fractures, while those restored with the bulk-fill one had a slightly higher percentage (75%) of favorable fractures. These results were in common with those observed in two studies (31, 40), while other two studies (43, 45) found no differences in fracture patterns between teeth restored with conventional and bulk-fill composites.
The results emerged from the analysis suggest that the use of the investigated materials, especially the combination of bulk-fill composite and hollow fiber post, may be associated with a more favorable fracture outcome.
Larger studies are needed to investigate in depth the most effective direct restorative approach in terms of materials employed to improve medium- to long-term success, since the sample size of this in-vitro study may not have been sufficient to identify meaningful differences or outcomes.

Conclusions

The following conclusions may be drawn, considering the limitations of the present investigation.
The fracture strength of healthy teeth is significantly greater than that of teeth restored using endodontic posts. This suggests that, regardless of the direct restoration strategy employed for damaged teeth, their strength will always be lower than that of healthy teeth.
There is no statistically significant difference in fracture resistance among the four treated groups; however, the use of a bulk-fill composite as restoration material determines an average higher fracture strength, making it a viable, or even the preferred option for tooth restoration due to its superior ease of use.

The use of a hollow post together with a bulk-fill composite may increase the likelihood of a favorable fracture, allowing a further tooth re-treatment.

Clinical Relevance

The use of bulk-fill composites and hollow fiber posts may improve the fracture resistance and failure mode outcomes of endodontically treated premolars. These materials provide an easier and more efficient restoration process while maintaining favorable biomechanical properties. Clinicians can consider this approach for better long-term success in direct composite restorations.

Conflict of Interest

None.

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None.

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ORIGINAL ARTICLE

Influence of different torque control and apex locator settings on apical debris extrusion

ABSTRACT

Aim: *This study evaluated the effects of torque control settings and automatic stop functions on apical debris extrusion during root canal preparation using a continuous rotation file system.*
Methodology: *Forty-eight extracted human lower premolars were randomly divided into four groups based on two torque control settings and two auto-stop functions. The extruded debris was collected in pre-weighed Eppendorf tubes and subsequently quantified.*
Results: *Statistical analyses were conducted using SPSS, and the Kruskal–Wallis test and the Mann–Whitney U test revealed that the auto-stop mode significantly reduced debris extrusion, while the torque control settings did not.*
Conclusion: *These findings suggest that clinicians can potentially minimise debris extrusion by utilising the auto-stop mode during root canal procedures.*

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Introduction

During the chemomechanical preparation of root canals, dentinal chips, pulp tissue residues, microorganisms, and irrigation solutions could be extruded from the root canal, causing postoperative pain, inflammation, and delayed periapical healing (1, 2).

All contemporary preparation techniques result in some degree of debris extrusion. The factors influencing the degree of debris extrusion include the number and structure of the files used in root canal preparation (radial lands, the number and width of flutes, and cross-sections), kinematics, preparation technique, tooth anatomy, and working length (WL) (3, 4). Although Ni-Ti rotary file systems have been shown to generate less debris extrusion than other systems, there exists no consensus regarding the comparative efficacy of rotational versus reciprocation movements (5-7).

Developed in 2017, One Curve (MicroMega, Besancon, France) is a single file system made of Ni-Ti alloy and that operates with continuous rotations. Since it is made using C-wire technology, it possesses shape memory properties, offering clinicians the option of pre-curving for root canals with complex anatomies. Available in four different sizes (25/0.04, 25/0.06, 35/0.04, and 45/0.04) and three different lengths (21 mm, 25 mm, and 31 mm), this file system features variable cross-sections along its cutting edges, which enhance its centring ability and cutting efficiency (8, 9).

Integrated endodontic motors can monitor a file's position in the canal, allowing simultaneous canal preparation (10, 11). The VDW Gold Reciproc (VDW GmbH, Munich, Germany), an endodontic motor that can be controlled by a foot pedal, has adjustable torque and speed settings and is integrated with an electronic apex locator. Since it can be used with reciprocating and rotating Ni-Ti rotary file systems, clinicians can simultaneously control the WL during root canal preparation. Once it reaches a predetermined level in the root canal, it can perform different kinematics, including automatic reverse (ASR) upon reaching the set torque limit is reached, automatic stop upon reaching the apex ('Auto Stop On'), and no automatic stop upon reaching the apex ('Auto Stop Off'). These settings can be adjusted according to the clinician's preference (12).

Numerous studies have investigated the quantity of apically extruded debris produced when root canals are prepared using Ni-Ti file systems (4, 13-15). However, to our knowledge, there is only limited data about the impact of the various torque settings and apex-locating modes of integrated endodontic motors on apical extrusion during root canal preparation. Our study aimed to evaluate the effects of using a file system with continuous rotation under different torque control settings and auto-stop functions on apical debris extrusion. The null hypothesis stated that there would be no difference in the amount of apical debris extrusion produced by the various torque control settings and auto-stop functions hypothesis.

Materials and methods

Specimen Selection

Our study protocol was approved by the Ethics Committee of Kutahya Health Sciences University (No: 2023/14–24). The sample size was calculated using an effect size of 0.5, a type 1 error of 0.05, and a power of 0.80 using G* Power (version 3.1.9.7). We meticulously examined 60 extracted human mandibular premolars using a dental operating microscope (OMS 2350, Zumax Company, China) to exclude specimens with any signs of caries, cracks, or fractures. We obtained periapical radiographs (NewTom AG, Marburg, Germany) in both buccolingual and mesiodistal directions to confirm the absence of internal resorption, calcification, and previous root canal treatment and verify the presence of a single root canal. We included 48 extracted mandibular premolars that met the established criteria: approximately similar dimensions, single-rooted morphology, and without caries, fractures, calcifications, resorptions, or anatomic anomalies. All the collected samples were extracted for orthodontic or periodontal reasons, with informed consent, at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Kutahya Health Sciences University.

Experimental Design

After creating the access cavity, we performed the initial canal entry using a stainless steel #10 K-file (Dentsply Maillefer). The WL was determined by withdrawing the file 1 mm from the point where it first appeared at the apex under the dental operating microscope. To standardise our length measurements, we flattened the cutting edges to achieve a uniform root canal length of 18 mm (16). We carefully adjusted silicone stoppers to the flattened surfaces and used a digital caliper (Hogetex, Germany) to measure, under magnification, the distance between the stoppers and the file tip. We took each measurement thrice to confirm a root canal length of 18 mm. Teeth with any inconsistencies in these measurements were excluded and replaced.

We modified the previously described method of Myers and Montgomery (17) to collect the extruded debris and integrate an electronic apex locator into the experimental model, as described by Tınaz et al. (6). To measure the quantity of the extruded apical debris, we prepared Eppendorf tubes, and the weights of empty tubes, with their covers removed, were measured thrice using an electronic balance (Precisa XB 220A, Precisa Instruments) with an accuracy of 0.0001 g. We created a hole in the plastic covers of the Eppendorf tubes, through which we placed the teeth and fixed them using cyanoacrylate. A 21-G needle was then inserted into the cover as a drainage cannula. After we filled the tubes with 0.9% saline solution, we placed them in bottles and covered them with aluminium foil to ensure operator blinding.

Table 1
Experimental groups and different integrated endodontic motor functions

Groups	Torque Setting and Auto-Stop Function
Group 1	ASR Off/Auto Stop Off
Group 2	ASR Off/Auto Stop On
Group 3	ASR On/Auto Stop Off
Group 4	ASR On/Auto Stop On

ASR Off: 'Auto stop only' (the file stops when it encounters resistance and rotates in the opposite direction with pedal movements).
ASR On: 'Auto stop reverse' (the file automatically stops and reverses when it encounters resistance).
Auto Stop Off: The file continues to rotate when it reaches the apex.
Auto Stop On: The file stops automatically when it reaches the apex.

Shaping Procedures

The One Curve #35.04 Ni-Ti system with the VDW Gold Reciproc endomotor (VDW GmbH, Munich, Germany) was used for the root canal preparation of all the samples at the manufacturer's recommended speed and torque settings (300 rpm and 2.5 N.cm). The samples were divided into four groups according to the two different torque control settings and two different auto-stop functions (Table 1). When the device was in rotation mode, the 'Automatic Stop Reverse' (ASR) mode was adjusted by pressing the ASR button. During preparation in ASR-on mode, the micromotor automatically rotated counterclockwise upon reaching the pre-set torque value, as specified by the manufacturer's instructions. Once the file no longer encountered resistance, the micromotor resumed clockwise rotation automatically. In ASR-off mode, the micromotor rotated counterclockwise without torque control. When the file encountered resistance, the micromotor stopped automatically and resumed counterclockwise rotation when the foot pedal was pressed again. When the auto-stop on mode was active, the file automatically stopped upon reaching the apical termination point. However, in auto-stop off mode, the file did not stop at the apical termination point, and the working length was controlled manually by the clinician. The same clinician performed all the preparation procedures. After every three pecking motions, the file was removed and cleaned. The root canals were irrigated with 2 mL of distilled water using a 30-gauge endodontic irrigation needle (EndoEze, Ultradent, UT), and recapitulation was performed using a #15 K-file. This sequen-

ce was repeated until the WL was attained. To ensure a similar number of apical pecking motions for each file across all specimens, the WL was advanced in three increments: coronal third, middle third, and apical third. The total volume of the saline solution used for cleaning and shaping was standardised to 10 mL per sample. Once the ASR mode was deactivated, the file encountered resistance in the root canal and stopped rotating. Once the foot pedal was reactivated, the file first rotated in the reverse direction and then in the forward direction to resume canal preparation.
Conversely, when the ASR mode was activated, the file automatically reversed its rotation upon encountering resistance without foot pedal reactivation. Once the resistance ceased, the file automatically resumed its forward rotation. When the auto-stop mode was deactivated, a predetermined WL was marked on the file using a digital caliper and a tight stopper. Upon reaching the reference point on the tooth, the file continued to rotate and was manually removed from the root canal under operator control. When the auto-stop mode was activated, the file automatically stopped rotating upon reaching the apex, and using foot pedal activation, the file was removed from the root canal. Following root canal preparation, we removed the samples from the model and rinsed the root surfaces with 5 mL of distilled water. To evaporate the water and measure the dry debris weight, we placed the Eppendorf tubes in an incubator at 70 °C for 5 days. For each sample in all the experimental groups, we took three consecutive measurements and calculated their average. By subtracting the weight of the empty Eppendorf tubes from the weight of the tubes with debris, we determined the weight of the apically extruded debris.

Statistical analysis
We used the SPSS software (SPSS Inc, Chicago, IL, USA) to conduct statistical analyses and the Kolmogorov–Smirnov test to assess data normality. We analysed the data using the Kruskal-Wallis one-way analysis of variance and the Mann-Whitney U test. A p-value of less than 0.05 was considered statistically significant for all comparisons.

Results

The preoperative data analysis conducted using the Kolmogorov-Smirnov test confirmed the normal distribution of specimen morphology and group comparability ($p>0.05$).We observed debris extrusion in all groups. Table 2 presents the mean, standard deviation, minimum, and maximum values of the debris amounts (mg).
When comparing the auto-stop modes (‘Auto-stop on’/‘Auto-stop off’), significantly lower amounts of debris extrusion were observed in the ‘Auto-stop on’ groups (0.0002642 mg and 0.0002350 mg in group 2 and group 4, respectively; $p<0.05$). In ‘ASR-off’ mode, there was a statistically significant difference between the ‘Auto-stop on’ mode (group 2) and the ‘Auto-stop off ’ mode (group 1), with less debris extrusion observed in the ‘Auto-stop on’ (group 2) mode ($p<0.05$). Similarly, in ‘ASR-on’ mode, a statistically significant difference was noted between the ‘Auto-stop on’ mode (group 4) and the ‘Auto-stop off’ mode (group 3), with less debris extrusion observed in the ‘Auto-stop on’(group 4) mode ($p<0.05$).
However, no statistically significant differences were found between ASR modes (‘ASR on’/‘ASR off’) within the ‘Auto-stop on’ mode (groups 2 and 4) ($p>0.05$). Similarly, in the ‘Auto-stop off’ mode, there were no statistically significant differences between ASR modes (‘ASR on’/‘ASR off’) (groups 1 and 3) ($p>0.05$). The lowest amount of debris extrusion was observed in the ‘ASR on’/‘Auto-stop on’ group (group 4), while the highest was observed in the ‘ASR off’/‘Auto-stop off’ group (group 1) ($p<0.05$).

Discussion

We investigated the influence of different torque control settings and auto-stop functions on apical debris extrusion using the One Curve single file system. While the

Table 2
Mean and standard deviation of apically extruded debris by group

Groups	n	Mean (mg)	Standard Deviation	Minimum	Maximum
Group 1	12	0,0004233[a]	±0,00011268	0,00023	0,00059
Group 2	12	0,0002642[b]	±0,00005534	0,00016	0,00036
Group 3	12	0,0003933[a]	0,00009538	0,00027	0,00055
Group 4	12	0,0002350[b]	0,00006375	0,00014	0,00038

**Different alphabetical letters indicate a significant difference for groups (p<0.05).*

automatic reverse mode did not significantly affect debris extrusion, the apex locator modes affected it. The null hypothesis was thus partially accepted.

The One Curve file system features three cutting angles at the tip and two cutting angles near the shaft, facilitating debris removal and reducing apical extrusion (18, 19). While numerous studies have compared this file system to other Ni-Ti file systems in terms of apical extrusion (13, 18, 20), only one study has investigated its use with different kinematics (16). In addition, a study that examined the effects of Ni-Ti instrument kinematics on the accuracy of root canal WL measurements performed using an integrated endodontic motor reported more accurate results when the WL was measured using rotary kinematics (21). We also preferred the rotary system in this study and used the same file system in all the groups to standardise them and exclude other variables that could affect our findings.

Apical foramen size is one of the factors affecting debris extrusion. Tınaz et al. (6) observed that debris extrusion increased with an increase in apical foramen size. To standardise our samples and minimise the effect of apical foramen width on our results, we examined the apical foramen size using a dental operating microscope with a #10 K-file during tooth selection. We achieved apical patency with a #15 K-file during root canal preparation. Following previous research, a #35.04 file, three sizes greater than the initial file, was thus chosen as the master apical file. The quantity of debris extruded into periapical tissues can vary based on the file system design and preparation techniques. Numerous studies have investigated the impact of rotary and reciprocation movements on apical debris extrusion (14, 22-25). However, a consensus on the superiority of either system remains elusive, with conflicting reports of increased debris extrusion associated with both. Importantly, only one study has independently evaluated the influence of apical movement on debris extrusion, disentangled from preparation kinematics, across the different apex locator modes of integrated endodontic motors (26). The versatility of integrated endodontic motors with customisable apex locator modes enables files to execute diverse kinematics upon reaching their predetermined root canal levels. These modes, which clinicians can adjust according to their preferences, include the cessation of file movement with reverse rotation or automatic reversal upon encountering resistance and automatic stop or continued rotation upon reaching the apex (12).

We found a significant reduction in debris extrusion when using the ‘Auto stop on’ mode. Kılıç et al. (26) examined how apical debris extrusion is affected by the use of different apical movements (apical stop, apical reverse, continuous rotation, and slow-down rotation) during root canal preparation with an integrated endodontic motor. The apical stop mode, the authors found, reduced debris extrusion, which they attributed to the lack of an integrated mode support for continuous rotation preparation in the automatic stop mode, which relies solely on rubber stoppers to determine the WL. This increases the risk of overpreparation and subsequent apical debris extrusion. Conversely, the automatic stop mode was found to offer an integrated mode support for apical control, thereby enhancing operator control. These findings are consistent with our findings.

We also found that using ASR modes (ASR on and ASR off) did not significantly influence debris extrusion. ASR modes provide valuable feedback to clinicians, particularly the 'ASR on' mode: the file is automatically reversed when encountering resistance, thus preventing excessive force. When ASR is activated, the micromotor automatically reverses its direction upon reaching a preset torque value and returns to its original direction when resistance ceases. In the 'ASR off' mode, the micromotor rotates counterclockwise without torque control, stopping when resistance is encountered. Upon reactivation by the clinician, it resumes its counterclockwise rotation and reverses its direction when resistance ceases (12). This automated or clinician-controlled reverse motion helps prevent file fracture. Though concerns have been raised regarding increased debris extrusion due to dentin shedding during file reversal, our results, consistent with those of previous studies (26), suggest that reverse motion does not significantly impact debris extrusion.

We used the experimental setup developed by Myers and Montgomery to collect the debris extruded from the apical region (17). However, a limitation of this method is its inability to simulate the physical backpressure at the root apex. Two solutions have been proposed to solve this: either use an artificial material to simulate the periapical tissues or conduct the study on cadavers or patients. When floral foam was used to simulate the periapical tissues, it was found to absorb the irrigant and debris, thus altering the results (14). Moreover, the studies conducted on patients have suggested that debris extrusion can be determined by adding a contrast agent to the irrigant or by measuring the concentration of inflammatory markers in the periapical fluid. However, the contrast agent may induce allergic reactions in some patients, and periapical radiographs alone may be insufficient for assessing bone quality and quantity (27). Additionally, cone-beam computed tomography exposes patients to unnecessary radiation (28). In light of all this, we chose Myers and Montgomery's experimental setup, which deemed the most practical and reproducible option for such measurements and allowed us to compare them with that of other studies (29).

The most commonly reported symptom that immediately follows root canal treatment is postoperative pain, often described as an uncomfortable sensation associated with an inflammatory response in the periapical tissues. Factors including age, gender, pre-treatment pulp status, tooth type, microbial load, and operative factors (such as chemical and mechanical instrumentation) influence postoperative pain (30, 31). Among these factors, chemical and mechanical instrumentation fall under the clinicians' control and can be manipulated to minimise postoperative pain. During the instrumentation and irrigation of root canals, the transport of infected dentin debris, pulp tissue, microorganisms, and irrigation solutions to the periapical region can generate postoperative complications such as pain and swelling (31). In addition to the instrumentation techniques used to prevent the apical extrusion of infected materials, accurately determining the WL and maintaining the apical construction are of paramount importance (32).

Based on our findings, we hypothesise that using the auto-stop mode of an integrated endodontic motor could reduce postoperative pain.

Another limitation of our study is that we did not use sodium hypochlorite. Though, owing to its organic tissue-dissolving and disinfecting properties, sodium hypochlorite is the gold standard irrigant in endodontic procedures, it might influence the weight of the extruded debris and generate sodium hypochlorite crystals, thereby compromising the accuracy of the findings. We thus chose distilled water as the irrigant solution (33). Despite the limitations of our study, we observed debris extrusion in all groups, although the automatic stopping of the file at the apex in the 'auto-stop on' mode significantly reduced debris extrusion. Debris extrusion is of great importance in terms of postoperative pain and healing, but, as in the in-vitro extrusion studies, our study does not fully reflect clinical conditions, as factors such as periodontal tissue pressure and host defence were absent (33). Extrapolating our findings to clinical practice should thus be cautiously approached. Using different endodontic motors, files with varying kinematics, or different tooth groups can produce a range of outcomes. Future clinical studies should focus on the effect of integrated endo-motors with different torque and apical mode settings on the acute flare-ups and postoperative pain associated with apical debris extrusion.

Conclusion

Variations in the auto-stop functions of integrated endodontic motors have been shown to influence debris extrusion. Our findings, however, indicate that alterations in automatic reverse mode not significantly impact debris extrusion. Clinicians may mitigate debris extrusion by utilising the auto-stop mode during root canal preparation.

Clinical Relevance

Debris extrusion in endodontic treatment significantly impacts the prognosis of the treatment and post-operative pain. The use of integrated endo-motors, which are widely used today, in different settings has shown different results in terms of debris extrusion. The auto-stop mode significantly reduced debris extrusion. In clinical practice, the use of the auto-stop mode may be effective in reducing post-operative pain.

Conflict of Interest

All authors declare that they have no conflicts of interest related to this study.

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Ethical approval

Ethical approval was obtained from the research ethics committee of Kutahya Health Sciences University (No: 2023/14-24).

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ORIGINAL ARTICLE

Histological evaluation of root canal cleaning by different final irrigation protocols

ABSTRACT

Aim: *This study aimed to evaluate in vitro the ability to remove pulp tissue from the mesial root canals of mandibular molars using three different protocols for the final activation time of irrigation with the Easy Clean (EC) rotary instrument.*

Materials and Methods: *Thirty mandibular molars with vital pulp were instrumented with the ProDesign Logic rotary system and divided into three experimental groups according to the protocol for the final activation time of the irrigants (n=10). Group EC1: the final rinse was performed with 5 mL of 2.5% sodium hypochlorite (NaOCl), followed by 5 mL of 17% ethylenediaminetetraacetic acid (EDTA) and another 5 mL of 2.5% NaOCl solution, with each rinsing agent activated in 3 cycles of 20 seconds. Group EC2 used the same sequence of solutions as group EC1, with each irrigant activated in 6 cycles of 20 seconds. In group EC3, the operation technique and the sequence of solutions were the same as in groups EC1 and EC2, with each rinsing agent being activated in 9 cycles of 20 seconds. At the end, samples from all groups were washed with 20 mL of distilled water using a NavigTip 30-G syringe and needle. The samples were fixed in 10% formaldehyde, cut into micrometers, fixed on histology slides and stained with hematoxylin-eosin (HE). The total area of the canal and remaining tissue was determined using the Image J program to determine the percentage of remaining pulp.*

Results: *In the cervical third, all groups had similar results. In the middle and apical thirds, EC1 and EC2 had similar percentages of pulp remnants and differed from EC3 (p<0.05).*

Conclusions: *It can be concluded that the removal of pulp tissue increases with longer contact time of the NaOCl.*

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Introduction

Effective chemical-mechanical preparation in endodontic therapy is crucial for removing both infected or uninfected hard and soft tissues as well as microbial biofilms, with endodontic files and irrigation solutions (1). The advent of rotary or reciprocating endodontic instruments has enhanced the speed of root canal shaping; however, it has not necessarily improved the thoroughness of cleaning (2). The inability of these instruments to touch the entire canal surface (3) resulting in uninstrumented areas and consequently to the failure to remove contaminated or uncontaminated organic tissue (2). Clinically, the thorough removal of pulp tissue is vital, particularly within anatomically complex regions like isthmuses and recessed areas. Isthmuses are narrow connections between two canals, prone to harbor microorganisms and debris. Their challenging accessibility complicates cleansing efforts, potentially compromising endodontic treatment success if efficient disinfection is not achieved (4, 5).
Endodontic irrigation plays a key role in cleaning both the main canal and the isthmus. To this end, it is important that the irrigant penetrates the entire length of the root canal, especially in areas inaccessible to endodontic instruments (6). To achieve better efficacy, irrigants should remain in direct contact with the entire root canal wall for a longer period. In this way, it is possible to improve cleaning efficiency (7).
Factors such as the limited contact area, volume, and renewal of the irrigant solution, individually or in combination, may limit the effectiveness of NaOCl in its tissue-dissolving property (8). NaOCl is most effective up to the first 5 mm, where the canal is wide and allows for solution exchange, whereas in the apical region and in narrower canals, tissue dissolution is less efficient (9). The devices and systems for agitating the irrigant in the canal aim to increase the efficiency of the irrigant by potentiating its action. The Easy-Clean (EC) system (Bassi/Endo, Belo Horizonte, Brazil) is a plastic instrument based on acrylonitrile-butadiene-styrene polymer, with a tip diameter of 25 and a taper of 04, driven by an automatic motor in a reciprocating or rotating motion at speeds between 500 to 15.000 rpm to agitate the irrigant mechanically (10). Histological analysis is a method to measure the removal of the remaining pulp tissue after cleaning and shaping the root canal (11). Due to their anatomical complexity, higher prevalence of isthmuses, mesial roots of mandibular molars were select for this study. The aim of this study was to histologically analyze the capacity of pulp tissue removal from the mesial root canals of mandibular molars using the Easy Clean instrument at three different activation times: The hypothesis was that the different irrigation times would be similar in terms of pulp tissue removal.

Materials and Methods

Study design
This study was conducted as a laboratory-based *in vitro* experiment using extracted human mandibular molars to simulate clinical endodontic conditions. Based on pilot tests, the sample size calculation to achieve a power of 95% and a significance level of 5% (alpha, type I error) was conducted using the G*Power 3.1.9.4 program. The effect size was 0.760, indicating the need for at least 7 mesial roots of mandibular molars per group. Due to the risk of sample loss, an additional 20% was employed, resulting in 10 specimens per group.

Sample selection
This study was approved by the São Leopoldo Mandic research ethics committee (CAAE: 0589119.2.0000.5374). Thirty mandibular molars were used. All teeth were diagnosed as having a vital pulp (positive response to the cold test) and were indicated for exodontia. The teeth were explicitly donated by the patients and immediately placed in distilled water at the time of extraction and stored in a freezer at -18 °C for a maximum period of 3 months.

Inclusion criteria
The inclusion criteria were teeth with vital pulp, fully formed roots, mesial canals with distinct and independent pathways, intact

apices, no previous endodontic treatment, curvatures between 10° and 20° according to the method of Schneider (12).

Exclusion criteria
Exclusion criteria were teeth with calcifications, lacerations, root resorption, mesial canals exhibiting confluence, internal or external perforations in the furcation area, root caries and previous endodontic treatment.

Preparation of the teeth
After endodontic access, a #10 K file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the mesiobuccal and mesiolingual canals until its tip was visible in the apical foramen. A silicone stop was placed at the tip of the corresponding cuspid to obtain the first canal measurement. The occlusal surface was ablated with a double-sided diamond disk No. 7020 (KG Sorensen, Barueri, Brazil) attached to a straight handpiece at low speed and under constant water cooling, obtaining a length of 19 mm. The working length (WL) for instrumentation was set 1 mm up to the foramen (18 mm).
The distal root of the specimen was cut under cooling with a double-sided diamond disk # 7020, discarded, and the remaining coronal part was sealed with composite resin Z350 (3M, Sumaré, Brazil).
To simulate a clinical situation, the teeth were inserted into a PVC container filled with condensation silicone (Coltene, Altstaetten, Switzerland) and treated according to the manufacturer's recommendations. This allowed the tooth to be fixed and a closed irrigation and aspiration system to be formed.

Preparation of the root canal
The canals were instrumented by the same operator using the ProDesign Logic system (Bassi/Easy) in conjunction with the Easy Endo SI motor (Bassi/Easy). A hand file type K #10 (Dentsply) was inserted up to the apical foramen, followed by a file 25/01 at 350 rpm and 1 N torque to achieve patency of the foramen. Then, instrument 25/.05 was inserted at 600 rpm and 1.5 N torque with smooth in-and-out movements with a maximum amplitude of 3 mm until WL was reached. Apical shaping was performed with files 30/.01, 35/.01 and 40/.01 (Bassi/Easy) at 350 rpm and 1 N torque.
At each instrument change, the K #10 file was used to confirm patency. The canals were flushed with 5 mL of 2.5% NaOCl (Asfer, São Caetano do Sul, Brazil) at each file change. For this purpose, a NavigTip 30-G syringe and needle (Ultradent Products Inc, South Jordan, UT) was positioned up to WL, with a total volume of approximately 30 mL of irrigation fluid. Final rinsing was performed with 10 mL of distilled water.

Experimental protocol for the final irrigation
At the end of the chemical-mechanical preparation, the teeth were randomly divided into three groups according to the experimental time protocol (n=10) (Figure 1).
The Easy Clean instrument was inserted

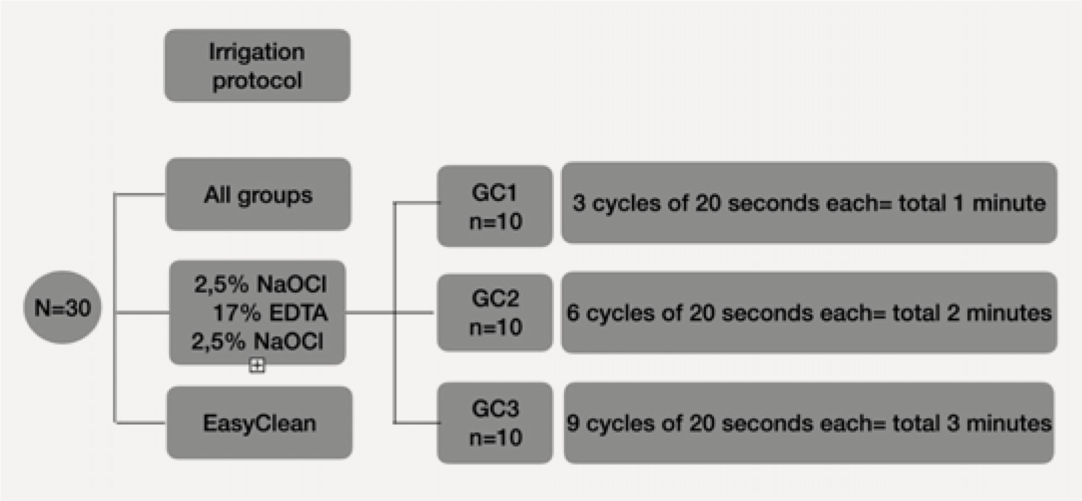


Figure 1
Organizational chart of the experiment.

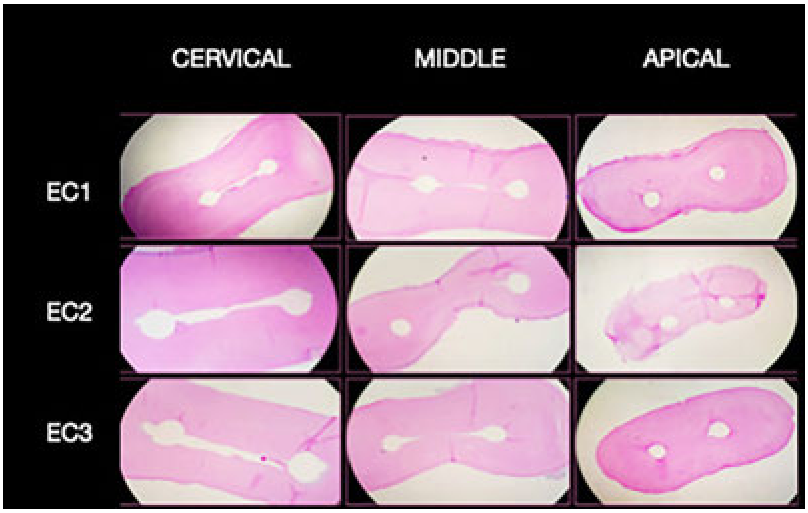


Figure 2 Histological findings of the examined areas with pulp remnants, 4x magnification.

into the WL and rotated with an Easy motor at a speed of 950 rpm. At the end, the canals were rinsed with 20 mL of distilled water using a NavigTip 30-G syringe and needle (Ultradent). The canals were dried with absorbent paper and specimens from all groups were stored in a 10% formaldehyde solution (Anidrol, Diadema, Brazil) without coronal sealing to ensure penetration of the formaldehyde solution throughout the length of the root canal.

Histomorphology analysis
Samples were fixed in 10% buffered formaldehyde for 24 hours and then demineralized in a 20% formic acid solution (Merck, Darmstadt, Germany) for 10 days. After the demineralization step, samples were dehydrated in ascending alcohol chain (70%, 80%, 90%, and absolute), diaphanized in methyl salicylate, and embedded in paraffin. The blocks were mounted on a microtome and sectioned to obtain histological cross sections with a thickness of 4 µm of the cervical, middle, and apical thirds of the root. The obtained sections were placed on glass slides and stained with the hematoxylin-eosin technique to analyze the main histological aspects. The slides with depressions and isthmuses representative of the analyzed areas were selected. The slides were viewed with a Nikon Eclipse Ci-S microscope (Nikon Corporation, Tokyo, Japan) and photographed with a camera attached to this device, at an initial 4x magnification for viewing and overall analysis of the root canal and at a 10x magnification for analysis of the canal alone.
Images were captured, stored on a USB flash drive, and opened in Image J software (Bethesda, Maryland, USA). The cursor was used to delineate and determine the total area of the canal. Then, using the same procedure, the area of the remaining tissue was delineated and determined. In the presence of fragmented areas, all were delineated and added at the end to obtain the final total area of remaining tissue. The percentage

Graph 1 Comparison between the means obtained from each of the studied measurements among the groups.

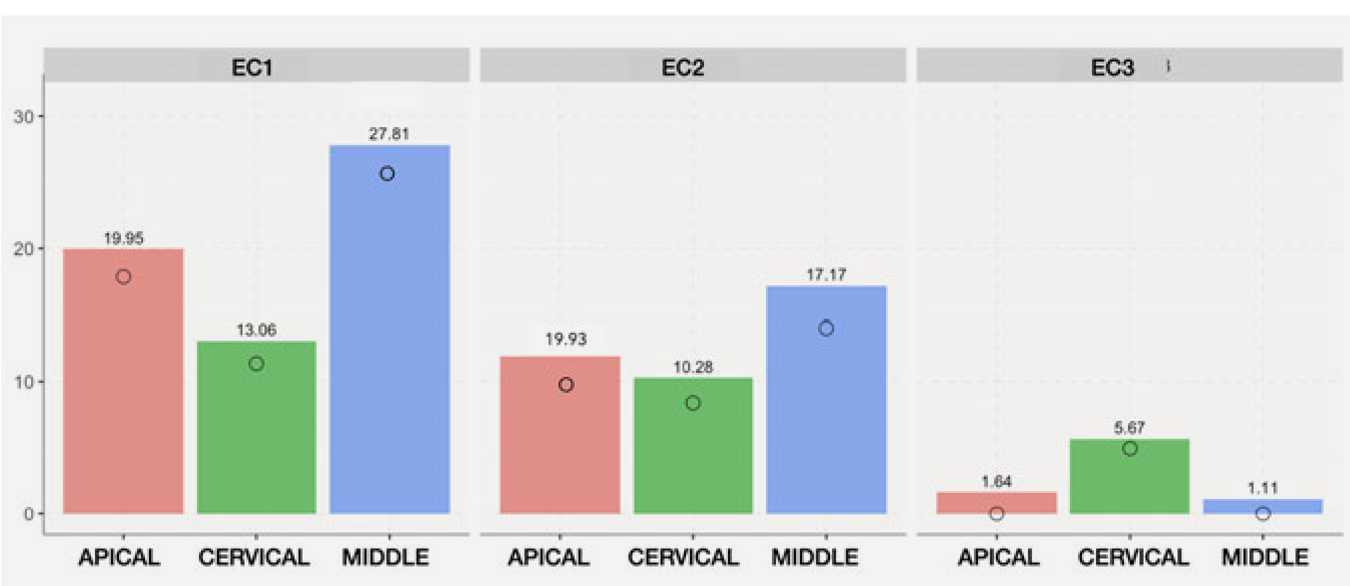


Table 1

Mean and standard deviation of the percentage of pulp remnants related to the analyzed group and the respective third (Wilcoxon Mann-Whitney U test for p<0.05

Group	EC1	EC2	EC3
Cervical	13.06^{aA} (8.46)	10.28^{aA} (5.21)	5.67^{aA} (4.65)
Middle	27.81^{aA} (12.94)	17.17^{aA} (10.27)	1.11^{bA} (1.58)
Apical	19.95^{aA} (9.54)	11.93^{aA} (7.42)	1.64^{bA} (2.36)

Lowercase letters indicate the statistical difference between the thirds of each experimental group (within a line).

Capital letters indicate the statistical difference between the thirds within each experimental group (within a column).

of remaining tissue was calculated using the following formula:

$$X\% \text{ (percentage of remaining tissue)} = \frac{\text{area of remaining tissue} \times 100}{\text{Total area of the canal}}$$

These data were tabulated and statistically analyzed in an Excel spreadsheet (Microsoft Corporation, 2016 Redmond, USA). All evaluations were performed by the same calibrated investigator.

Statistical analysis

Two comparative analyzes were performed: Between experimental groups (EC1, EC2, and EC3) in each third (cervical, middle, and apical) and within each group in relation to the analyzed third (cervical, middle, and apical). The data obtained were subjected to the nonparametric Wilcoxon Mann-Whitney U test. The analysis was performed using R. software (formerly AT &T, now Lucent Technologies). The assumed significance level was 5% ($p<0.05$).

Results

Histological Findings

Analysis of Remaining Tissue in Different Root Thirds

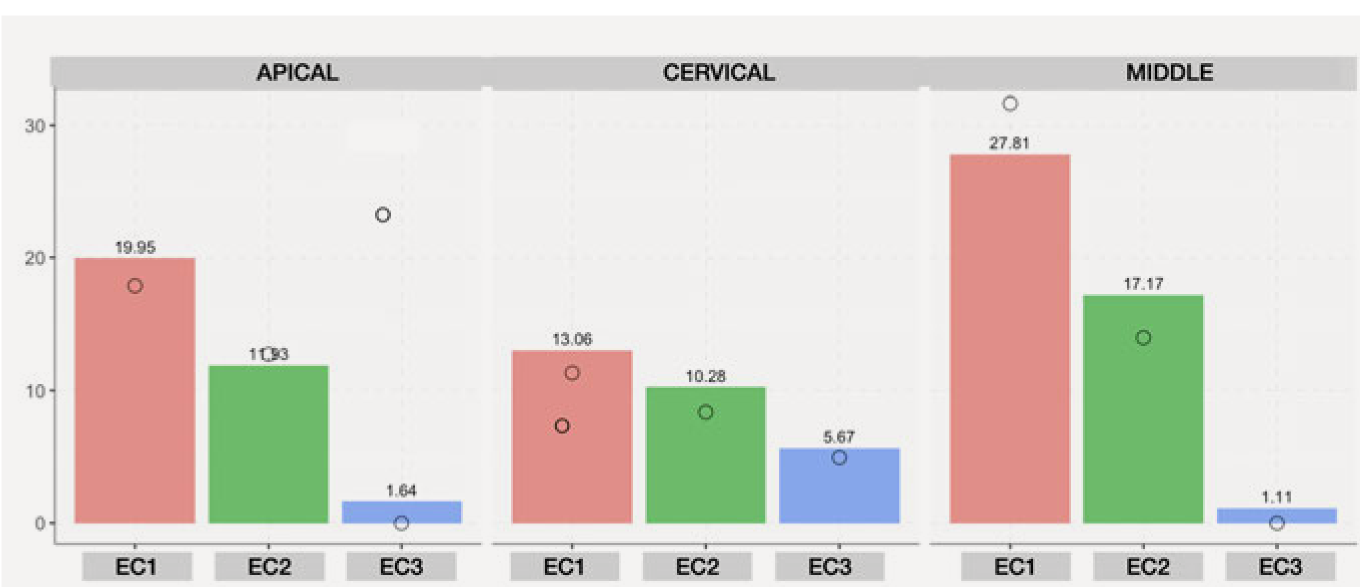
Regarding the analysis between groups in the cervical third, all showed similar results. In the middle and apical thirds, groups EC1 and EC2 had similar percentages of pulp remnants and differed from group EC3, in which the percentage of tissue remnants was lower ($p<0.05$) (Figure 2 and Graph 1).

Comparative Analysis Between Groups

In all groups, there was no difference between the thirds of the same group ($p>0.05$) (table 1 and Graph 2).

Discussion

In the present study, the cleaning ability of root canals in mesial roots of mandibular molars was evaluated after three different agitation times of NaOCl 2.5% and EDTA 17%. The null hypothesis tested was rejected



Graph 2
Comparisons of tissue remnants across the cervical, middle, and apical thirds.

as a statistically significant difference was found between the experimental groups.
One major clinical implication is that personalized irrigation protocols can enhance pulp tissue removal, particularly in complex canal anatomies where residual tissue is common (13). Clinicians might consider adapting their strategies based on the specific characteristics of each case, considering the anatomical challenges presented by isthmuses and recessions. By optimizing agitation times, practitioners can potentially improve treatment outcomes and reduce the risk of endodontic failures caused by inadequate cleaning (14).
To ensure the reliability of the results, several methodologies were employed to minimize bias in the histological analysis. The study focused on standardizing variables, allowing the inclusion of teeth with similar internal anatomy, size, and curvature. This careful selection process mitigated variability that could confound results. Additionally, teeth were all preserved under controlled conditions (frozen) to maintain pulp structure integrity, further enhancing the reliability of histological evaluations. Different methodologies have been proposed to evaluate the outcome of flushing agent activation in relation to canal cleaning: bacteriological culture methods (2), scanning electron microscopic analysis (15), optical microscopy (16), histological sections (17), micro-CT (18) and diaphanization (19). In the present work, the methodology of histological analysis was used to evaluate the capacity of pulp tissue removal by the irrigant in mesial canals of mandibular molars. The methodology used aimed to standardize variables that could in any way affect the results obtained. Therefore, teeth with similar internal anatomy, size and degree of curvature were selected.
All teeth were diagnosed as having a vital pulp (positive response to the cold test) and were stored in the freezer for a maximum period of 3 months. This procedure aimed to keep the pulp structure intact through the freezing method, in which microbial activity is paralyzed and the rate of chemical reactions is significantly reduced, which is an effective method for tissue preservation (20).
In this study, a single chemical agitation system called Easy Clean was used, mechanically driven in a rotary motion at 950 rpm (10,15). The Easy Clean tips were positioned in the WL (21) and acted directly on the last apical millimeters.
The hypothesis and focus of the study were whether the agitation time of the 2.5% NaOCl would result in more pulp tissue removal, especially in the uninstrumented areas of the canal, such as the recessions and isthmus. The cervical, middle, and apical thirds were sectioned with a thickness of 4 µm, and those showing these anatomical features in each third of the canal were selected from each specimen. Based on the results obtained, we can conclude that the pulp tissue dissolution in the middle and apical thirds of the canal was lower than in the 3-minute excitation group by the time of 2-minute excitation. This result can be explained by the fact that the strength of tissue dissolution is related to other factors, such as the dentin structure, the surface of the contact area, and the exposure time of the irrigant to the remaining pulp tissue (9). The dissolution time of the tissue is directly related to the contact time, and EDTA have a negative effect on the action of NaOCl (22). Incorporating EDTA into irrigation protocols is crucial for removing the smear layer and ensuring thorough cleaning. However, its effects on dentin, particularly concerning demineralization and collagen modifications, must be taken into account (23). All irrigation protocols have been shown to significantly decrease dentin microhardness, highlighting the important relationship between these protocols and dentin properties. Effective root canal cleaning must balance these factors while preserving dentin integrity. Additionally, research indicates that certain irrigation techniques, along with the use of calcium hydroxide, can notably impact the microhardness of root canal dentin (24). Dentin has a high concentration of carbonates, which promote neutralization of the acid-base effect that occurs during pulp tissue saponification (25). Thus, neutralization of the NaOCl may occur, rendering the substance ineffective in terms of its dissolution properties. Therefore, longer renewal cycles and more time are required to achieve the desired effect. Regarding the percentage of tissue in each third within the group, similar results were observed, showing that the effect

of the substance is uniform inside the canal. An important clinical observation related to the results obtained was the presence of remaining pulp tissue in group EC1. A total of 30 mL of NaOCl 2.5% was used throughout the mechanical preparation process, supplemented by stirring for 1 minute with the Easy Clean System. This study suggests that the removal of pulp tissue from the root canal, particularly in the isthmus and recession areas, is dependent on the irrigant and requires further study and the development of more appropriate protocols.
The results of this study suggest that the activation time and the durability of the rinsing substance influence the process of organic tissue removal from inside the root canal, especially in non-instrumented areas such as isthmuses and recessions.
Despite the positive implications of the study, it is important to acknowledge some limitations. The sample size and the specific inclusion criteria may limit the generalizability of the findings. The study assessed only mesial roots of mandibular molars; therefore, results might differ in other tooth types or in cases with more complex canal systems. Furthermore, histological analysis primarily captures the immediate effects of the irrigants on tissue removal, without necessarily reflecting long-term outcomes related to canal disinfection and healing.
Future research should explore various irrigants and agitation techniques, as well as the optimal concentrations and volumes required for effective cleaning in diverse anatomical scenarios. Long-term studies evaluating the healing outcomes of treated canals and the impact of irrigation protocols on the success rate of endodontic treatments would further advance the field. Additionally, exploring combined approaches that integrate chemical and mechanical cleaning may yield enhanced results in tissue removal and canal disinfection.

Conclusion

In conclusion, this study highlights that longer irrigant activation times enhance the removal of pulp tissue from root canals, indicating a need for endodontic practitioners to refine their irrigation protocols to ensure optimal cleaning, especially in challenging anatomical areas.

Clinical Relevance

The findings emphasize the significance of irrigation technique in endodontics and provide practical insights for improving the procedural outcomes in root canal therapy.

Conflict of Interest

None.

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None.

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REVIEW ARTICLE

Artificial Intelligence in Endodontics

ABSTRACT

Recent development in the field of artificial intelligence has influenced dentistry, and particularly endodontics. Such AI-driven algorithms show great promise in improving the accuracy of diagnostics, treatment planning, and the actual conduct of endodontic treatment, as well as predicting treatment outcomes. AI has already started to prove itself useful in endodontics by improving the detection of periapical pathologies and root fractures, the estimation of root canal anatomy, the determination of working lengths, and the prediction of treatment outcomes. Further development and dissemination of this technology could significantly enhance endodontic practice and contribute to natural dentition conservation. However, despite AI bringing a better success rate and efficiency in the field of endodontic treatments, further studies are still needed to keep on validating their reliability and practicality for wider clinical integrations. This review is undertaken with the purpose of discussing recent advances in AI and describing their applications in the field of endodontics.

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Introduction

Artificial Intelligence-A cutting-edge technology that mimics human cognitive functions-became another crucial breakthrough of the century in most medical streams. Conceived by John McCarthy in 1956, AI has undergone various metamorphoses such as neural network architecture adaptations based on the functionality and operation of the human brain, hence allowing to manipulate complex data and problems to find a solution (1, 2).

In this narrow, high-precision, diagnostic field of endodontics, AI is especially transforming. The usual ways cannot catch the fine tune of the root canal anatomy and variability in the responses of the patients. This gets very much heightened with the use of AI and its advanced data processing and learning to achieve unparalleled accuracy in diagnosing periapical pathologies and root fractures, treatment planning, and prognostication (3). Besides, AI utilizes multimodal data where various forms of data are utilized in learning to diagnose conditions not achievable by human intelligence (4). The growth in computer technology with advancements in special algorithms has enabled the increasing application of machine learning and deep learning, subsets of AI. Machine learning applies statistical learning algorithms in the development of intelligent systems that improve on their own without explicit programming (5). Contrarily, DL handles information like the filtering process of the human brain by using examples to learn through artificial neural networks. As such, these models can classify and predict multiple layers of data without necessarily requiring domain experts to do so manually.

This article discusses in detail the applications of AI in endodontics and how different models of AI improve the accuracy of diagnosis, treatment planning, and its execution. Further, by citing examples of current technologies and results, the article describes the tremendous potential impact AI is going to make on future endodontic practice in terms of improved patient outcomes and the maintenance of natural dentition.

Review

Key features of AI

1. Types of AI

Applications of artificial intelligence can broadly be divided into two categories: physical and virtual. Physical AI involves robotics and automated systems that are employed clinically, while virtual AI refers to the algorithms used in clinical decision-making (6). In the broader medical and dental contexts, AI is further divided into weak AI-or narrow AI-and strong AI. Weak AI is specialized and designed to solve specific tasks or problems. In contrast, strong AI, which remains largely theoretical at this stage, aims to perform tasks across multiple domains with human-like intelligence and capabilities (7, 8).

2. Machine Learning and Deep Learning

Both ML and DL are subsets of AI, and they have really revolutionized data handling and analysis. ML utilizes statistical algorithms for model building, which glean from data for better decision-making without direct human intervention. It includes various learning types like supervised, unsupervised, and semi-supervised learning, each with unique applications and capabilities (9). Deep learning, a more advanced form of machine learning, incorporates multi-layered neural networks into operation and enables deeper learning and recognition capabilities than any other type of machine learning, hence being closely related to complex human thought processes (10).

3. Application in Dentistry

Various ML and DL algorithms are utilized in dentistry to analyze big data sets for extracting useful information for diagnosis, prognosis, and treatment planning and have significantly streamlined various clinical work processes (11). It finds its application in the field of clinical diagnosis, radiology, histopathology, among many others, and does hold promises of changing dental practices by improving the precision and speed of work (12, 13).

Role of AI in pulpal diagnosis

Precise pulpal diagnosis is the very basis of ideal treatment planning in endodontics. Differentiation of reversible from irreversible pulpitis and pulp necrosis is imperative but challenging because of diagnostic signs and symptoms that are usually ambiguous (14, 15).

Advances with AI

Artificial Intelligence integrated into pulpal diagnosis has uplifted the study field significantly. It has been shown that all the stages of pulpitis, starting from early pulpitis to extensive pulpitis, can be diagnosed highly sensitively by the AI models (15, 16). Recently, in a study conducted on digital radiographs, Tumbelaka et al. proved that AI can diagnose both reversible and irreversible pulpitis, which is very useful for further validation (17).

Role of AI in Clinical Practice

Other applications of AI range from diagnosis itself to predicting the course of a disease and the outcome after treatment. Multimodal deep learning models, including ResNet, combined with clinical parameters, have considerably improved diagnostic precision in diseases like deep caries and pulpitis. This is based on comprehensive analysis of datasets that include training and testing phases for refining the predictive capabilities of the AI.

Limitations and Integrative Approach

Although these results seem promising, it is also important to take into consideration that a pulpal diagnosis based exclusively on radiographic examination has several shortcomings. AI should support, but not replace, classic clinical and radiographic examinations and other diagnostic techniques, such as pulp vitality tests, in order to ensure an overall assessment and enhance the accuracy and reliability of diagnoses made within the clinical setting (18).
The use of artificial intelligence is a game-changing event in pulpal diagnosis, providing valid diagnostic tools for accurate decision-making by clinicians. Further development of this will promise finer tuning of diagnostic procedures, advances in patient care for endodontics (19).

Diagnosis of Periapical Lesions: Enhancing Accuracy with AI

Overview

Originally, Peri-apical lesions occurred due to untreated caries, in addition to post treatment diseases which represent a significant portion of jaw lesions, characterized by necrosis of the dental pulp and subsequent inflammatory diseases around the tooth root apex. These lesions, which constitute approximately 75% of jaw radiolucencies, critically influence both treatment planning and outcomes (20).

Diagnostic Techniques

Traditional image modalities such as panoramic and two-dimensional periapical radiographs have commonly been used for their detection (21). The visibility of periapical radiolucency closely depends on the degree of mineral bone loss, estimated at typically an average of 7.1%, but also from the location of the lesion confined to cancellous bone or incoming cortical bone (22). These traditional approaches, however, are insufficient to reveal precisely the complete extent of such lesions.

Imaging with CBCT

Advanced cone beam computed tomography affords the three-dimensional view of the maxillofacial skeleton. Consequently, this resource largely outperforms conventional radiography in diagnosing the periapical lesions. Systematic reviews and meta-analysis studies established that CBCT obtains higher accuracy bringing detection scores decisively higher than traditional and digital intraoral periapical radiography systems (23).
Recent developments have also seen AI models being created that further enhance the detection of periapical pathology from CBCT images (24).
Deep learning segmentation-based models have high accuracy in the detection of periapical radiolucencies, sometimes as high as 93% accuracy with 88% specificity (25). Because AI can investigate minute changes even at the pixel level, it enables a very fine-grained understanding of the various pathologies around the periapical region, which might further help in differentiating between granulomas and cysts, thus aiding clinical decisions on treatment like root canal therapy without surgical interventions (26).
The integration of AI into the diagnostics of endodontics heralds a quantum leap in our efforts at diagnosis and treatment of the perplexing dilemma of the periapical lesions and

further emphasizes the transformative impact of AI on enhanced clinical outcomes in dentistry.

Detection of Vertical Root Fractures (VRF)
VRFs can frequently be found in teeth that have undergone endodontic treatment, though they mostly occur in upper premolars and molars (27). Since these fractures are subtle, the use of conventional diagnostic methodology can hardly clinically detect them (28, 29).

Advanced Imaging Techniques
While conventional radiographs have been the standard, Cone Beam Computed Tomography has been able to outperform in the detection of VRFs, thus providing a clearer and more detailed view of the structure of the tooth (29, 30).

Innovations of AI in VRF Detection
Recent development in AI has greatly supported the ability to trace VRFs. There have been several studies done using AI models on VRFs for better detection accuracy: Machine Learning, Convolutional Neural Networks, and Probabilistic Neural Networks (31, 32). In one of these studies, Johari et al. reported that PNN models have more potential in identifying VRFs in CBCT images, and the results are significantly more satisfying than those obtained from radiographic images in a 2D format (33).

Improved diagnosis using AI
Further work by Vicory et al. presented the usage of an AI algorithm with wavelet features in the detection of microfractures. This points out the ability of AI in detecting even minute details about fractures (34). A study conducted by Hu et al. compared the performance of DLMs, which was till date performed by ResNet50 in VRF in vivo diagnosis using CBCT images (35). Whereas the introduction of AI into the detection of vertical root fractures significantly improves diagnostic accuracy and treatment planning, it provides the clinician with valuable tools for better management of such endodontic complications (36).

Morphology of Root and Root Canal System
Successful non-surgical root canal therapy relies on detailed knowledge of the morphology of the root canal system. Although CBCT imaging is more accurate than 2D radiography, its use as a routine examination in daily practice is still limited due to radiation concerns (32).

Complex Canal Configurations
The C-shaped canal configuration, particularly when it is present in the lower second molar, represents one of the most complicated endodontic configurations. These canal configurations are very challenging to deal with during root canal treatment because of their highly complex anatomy (36).

Advancements in AI Detection
Recent studies have highlighted the effectiveness of AI systems in enhancing the detection and treatment planning for complicated canal shapes. Studies like Jeon et al. and Yang et al. demonstrated that Deep Learning systems significantly outperformed classic CNNs in identifying C-shaped canals on panoramic and periapical images (37, 38). Besides, Hiraiwa et al. presented 87% accuracy using algorithms with DL when diagnosing roots in mandibular first molars (39).
While assessing the morphology of roots and canals, the integration of AI significantly enhances the precision and efficiency of endodontic diagnosis and helps in complicated cases where traditional methods cannot yield an effective outcome.

Determination of Working Length in Endodontics
Accurate determination of the working length is essential in the root canal treatment for the success of the treatments. It helps to be certain that the canal will be sufficiently cleaned, prevent the extrusion of debris, reduce post-operative pain, and affect the treatment outcome as a whole.

Current Techniques
WL is usually determined by using electronic apex locators in combination with the periapical radiographs. These methods,

despite their effectiveness, are highly dependent on the clarity of the digital radiographs and are bound to have their share of errors due to wet canals or metallic restorations of teeth among other conditions (40).

Limitations and Challenges
The position of the cementodentinal junction, the place where instrumentation should ideally terminate, lies 0.5 to 2 mm from the radiographic apex. Misinterpretation of this very important point may result in suboptimal cleaning or overextension of the canal filling materials, resulting in treatment failure.

Advances in AI
Artificial Intelligence, especially using Artificial Neural Networks, has transformed the determination of working length by guaranteeing higher accuracy and reliability. Saghiri et al. reported that for the detection of minor anatomical constrictions, ANN models provided an accuracy rate of 96%, while with traditional radiographic approaches, the accuracy was 76% for endodontists (27). It therefore not only supports traditional methods but adds more accuracy to them by reducing human error and hence gives more precise diagnostic output in working length determination. This makes AI very vital in contemporary endodontic practices (41).

AI in Endodontic Retreatment Prediction
The improvements made in the field of AI have opened new avenues in endodontics, one of which is the predictability in the outcome of retreatment. Artificial intelligence models combine clinical symptoms, patient history, demographic, lifestyle, and genetic factors comprehensively into the planning of treatment (42).

Applications of Predictive Modeling by AI
AI can process large volumes of information. It therefore holds the capability to discover patterns and risk factors not easily attainable or noticeable through conventional means (43). Works like that of Lee et al. and Hung et al. illustrate how AI has advanced diagnosis and treatment (19, 24). Lee et al. employed a case-based reasoning paradigm and achieved prognostic results equal to multi-disciplinary clinical teams. Using machine learning algorithms like SVM and RF, Hung et al. developed AI predictive models which were likely to perform better in identifying patients at risk for tooth surface loss and root caries (19).
Campo et al. also reported the usage of AI in the non-surgical endodontic retreatment through the case-based reasoning approach, which relies on statistical probability and performance recall (43). This technique predicts the outcome of a treatment based on historical data from similar treatments and, therefore, holds a great promise for accurate forecasting of retreatments.

AI in Endodontic Microsurgery
AI also demonstrated effectiveness in predicting the outcomes of endodontic microsurgery. Qu et al. indicated that a GBM model showed an ultra-high sensitivity of 91.39% and hence might be of significant impact on clinical decision-making in complicated surgical situations. The inclusion of AI in endodontic retreatment proposes a revolutionary strategy toward dental care; precision medicine is facilitated through in-depth analysis and improvement in predictability (44).

Regenerative Endodontic Procedures
Regenerative endodontics is a new area of research in which the lost or pathologically damaged physiological tissues of dentine, root, and cells from the pulp-dentin complex are restored. These biologically-based methodologies further promote the morphological and functional development of teeth (43).

Important Factors Involved in REPs
Three factors are considered to be crucial for successful REPs. These factors involve the triad of: Stem Cells, Scaffolds, and Activators. These factors allow the differentiation of cells or secretion of enzymes for the regeneration of tissues of teeth (44).

Technological Integration into REPs
Advanced technologies involved, such as the neuro-fuzzy inference technique increase the percentage of accuracy in treatment. For example, researchers in previous experimental studies had used this neuro-fuzzy infer-

ence technique to assess the vitality of the dental pulp stem cells against various variables and forecasted the results with a high percentage of accuracy (44).

Application and Results

REPs have shown promise in treating teeth with pulp necrosis by using vital adult stem cells in the apical region to drive tissue regeneration. This, therefore, promises great structural and functional recovery of teeth and thus improves the predictability and outcomes of endodontic treatments.

Regenerative endodontics represents a paradigm shift toward more natural and sustainable dental therapies, leveraging biological processes in concert with advanced computational techniques to further enhance treatment efficacy and patient outcomes.

Ethical Considerations and Limitations of AI in Dentistry

While the greater inclusion of AI within dentistry means significant strides are made forward, there are many challenges that accompany this action and have to be resolved in order to further strengthen the reliability, performance, and applicability of AI-based models (45).

Availability and Validity of Data

The application of AI in dentistry faces several key challenges, where the datasets need to be complete and well-structured. Dental data is fundamentally complex, sensitive, and multivariate; hence, it really needs to be supported with strong systematic algorithms in handling and validation.

Reliability and Generalizability

Special attention is usually given to the reliability of AI models used in the clinical setting, which indeed has been found wanting on most occasions regarding clarity in the sample sizes used for both training and testing of the model. Beyond that, however, are the issues associated with generalizability of models-very serious concerns about adherence to clinical guidelines (46). Continuous improvements are needed to enhance the accuracy of the AI systems and increase patient trust.

Ethical and Legal Considerations

There is, however, a possible ethical dilemma with the integration of AI in dental care: taking over long-established dental services and considerations on healthcare privacy. One needs to be very careful regarding the privacy and confidentiality issues arising from AI algorithms once these become integrated into medical practice (45). The accountability issue is another legal consequence, since AI applications-currently both supervised and unsupervised-do not have any accountability whatsoever. Where AI promises the next revolution in dental care, it is the development of clear guidelines and ethical standards regarding its use that will play a crucial role in guaranteeing its safety and effectiveness, while protecting the patients and the integrity of the dental profession (47).

Future Considerations

Nevertheless, apart from the promising outlook, further studies are being called for in terms of reliability, relevance, and cost-effectiveness with regard to these models of AI. Indeed, such characteristics must be critically scrutinized if AI is to be accepted into routine clinical practices that would make the technology practical and effective in managing patients.

Conclusion

Artificial Intelligence, or AI, has increasingly been a pivotal tool in the area of endodontics. Quite a large number of studies have demonstrated its high degree of accuracy in both diagnostic and prognostic assessments. This makes AI an enabling technology that further improves treatment planning and, therefore, probably the success rate of endodontic treatments. Adoption in endodontics is minimal when put in comparison with other dental specialties; however, AI's capability for processing and extracting significant information from voluminous data sets tells about the growing importance of the role of this technology in this sector. Since the technology excels at applying structured knowledge, hence promising applications can be realized which might extend its adoption in the field. AI embodies a transformative factor in endodontics, whose wider dissemination requires caution and validation. Advances and rigorous testing continue to define its role in the reformation of endodontic procedures and outcomes.

Clinical Relevance

Endodontics faces a paradigm shift with AI which enhances diagnostic capabilities and streamlines both treatment planning and procedural execution. The system provides more consistent results by locating periapical lesions along with root fractures and complex canal anatomy. The technology serves to determine working lengths as well as predict retreatment success rates and optimize outcomes in microsurgery procedures. To validate its reliability and clinical integration research must continue beyond current developments. Evidence-based clinical decisions become more robust because of AI which improves patient outcomes thereby helping maintain natural dentition.

Conflict of Interest

None.

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None.

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CASE SERIES

Endodontic Micro-Surgery by means of two different surgical templates performed with selective Piezosurgery® root resection: a report of two cases

ABSTRACT

Aim: *The aim of this case series is to introduce a new surgical template designed for static endodontic microsurgery using Piezosurgery®. The template, created with computer-aided design/computer-aided manufacturing (CAD-CAM) technologies, aims to enhance the precision of root-end resections by providing individualized guidance for the surgical procedure. This approach seeks to reduce invasiveness, minimize bone loss, and improve surgical outcomes in cases of persistent apical periodontitis or other post-treatment endodontic complications.*

Summary

Conventional endodontic treatments can fail in 14-16% of cases due to persistent infections within the root canal system or extraradicular factors. In such cases, endodontic microsurgery, especially when guided by advanced technologies, offers a high success rate of up to 89%. Recent innovations in piezoelectric devices and CAD-CAM-based surgical templates enable more precise, less invasive procedures. The new surgical template presented in this study allows for accurate root-end resections, ensuring optimal root sealing while minimizing damage to surrounding tissues. The template's design aims to improve accuracy and reduce the risk of surgical errors compared to freehand procedures, promoting better healing and fewer complications.

Key Learning Point

- *Persistent apical periodontitis after root canal treatment can often be resolved with microsurgical techniques.*
- *The integration of CAD-CAM technology with Piezosurgery® enhances surgical precision, reducing bone loss and tissue trauma.*
- *Surgical templates designed for static endodontic microsurgery provide individualized, accurate guidance, leading to improved surgical outcomes.*
- *The use of piezoelectric devices offers precise cutting with minimal damage to soft tissues, crucial for surgeries near sensitive structures.*
- *Advances in guided endodontic surgery are improving success rates and minimizing post-operative complications.*

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Introduction

The primary goal of a conventional endodontic treatment is to prevent or resolve root canal infections through the processes of cleaning, shaping and three-dimensional sealing of the root canal system (1, 2).
Although shown to be a predictable procedure with a high degree of success, with initial root canal therapy there have been occurrences of failure after the treatment: data reports failure rates of 14-16% (3).
Lack of healing is attributed to persistent intraradicular infections residing in previously uninstrumented canals, dentinal tubules, in the complex irregularities of the root canal system or iatrogenesis (4).
Furthermore, there are extraradicular factors – located within the inflamed periapical tissue – that can interfere with post-treatment healing of apical periodontitis, i.e. extraradicular infection, generally in the form of periapical actinomycosis; extruded root canal filling or other exogenous materials, that can cause a foreign body reaction; accumulation of endogenous cholesterol crystals, that irritate periapical tissues; true cystic lesions (5, 6).
The prevalence of apical periodontitis and other post-treatment periradicular disease, reported in cross-sectional studies, exceed 30% of all root-filled teeth (7).
Endodontically failed cases with persistent apical periodontitis, reported as periapical radiolucent areas with or without symptoms, after nonsurgical root canal treatment can be managed by nonsurgical (orthograde) re-treatment through the access cavity, surgical (retrograde) procedure, or tooth extraction (8).
Lesions may persist even after orthograde re-treatment, sustained by bacteria established within the root canal system or at extraradicular sites. In these cases, apical microsurgery seems to be the only possible solution, with an excellent success rate, up to 89% (9).
Surgical treatment should be preferable in extremely compromised teeth and in those where endodontic therapy can be considered acceptable.
Sometimes, due to restoration-related (number and position of teeth involved, presence of metal or fiber post) or anatomical-related issues (apical delta, root canals with significant curves, calcifications, open apex, radicular resorption, etc.), even if re-treatment seems to be the first-choice option, surgical treatment must be considered. Root canal perforations, presence of broken instruments inside the root canal, ledges and false canal and other iatrogenic complications also require retrograde treatment.
On the other hand, in specific clinical situations it is, however, contraindicated to proceed with surgical treatment of the teeth: i.e., orthograde endodontic treatment clearly incongruous, in this case orthograde retreatment is advisable; independent lateral lesion, sign of the presence of an accessory anatomical system; presence of long endocanal posts, which means insufficient space to retain the retrograde filling once the apical part of the root has been resected; inadequate clinical crown-root relationship.
Endodontic surgery involves the raising of a mucoperiosteal flap, an ostectomy performed in the inflamed apex area, the resection of a certain amount of apex and root, and the placing of a root-end filling to guarantee the perfect sealing of the canal system. This allows to remove biofilm from unreachable infected areas, by placing a tight root-end filling following the root-end resection, allowing for the restoration of healthy periapical tissues (10, 11).
The success rate of endodontic microsurgery is higher than conventional apical surgery, due to magnification and illumination, ultrasonic tips for retropreparation, microsurgical instruments, and new root-end filling materials (9). Literature analyses report a success rate of modern endodontic microsurgery between 88.9% and 100% (12).
In order to reduce invasiveness and post-operative discomfort, in 1998 Tomaso Vercellotti introduced the first surgical piezoelectric device (13-15). Piezoelectric devices operate in a similar way to piezoelectric dental scaler devices but are capa-

ble of selective cutting through hard tissues, preserving soft tissues such as blood vessels, nerves and mucosa (15).
The tips of this devices work in a linear motion, which is ideal for endodontic surgery. The application of a slight pressure to bone tissue results in a cavitation phenomenon, a mechanical cutting effect that occurs only in mineralized tissues (8). The integrated saline coolant solution maintains a low temperature and allow clear visibility of the surgical site. The field is bloodless during bone cutting thanks to air-water cavitation (10).
The creation of dentinal cracks during root-end resection is a key concern, as these cracks can compromise treatment success by providing pathways for bacterial infiltration or weakening the tooth structure. Otterson S. et al. (16) found no significant differences between trephine and multipurpose burs in terms of crack formation, though the two burs have different cutting mechanisms. Piezoelectric cutting systems, known for their precision and minimal heat generation, could potentially reduce the risk of crack formation.
Cone-beam computed tomography (CBCT), typically employed for prosthetically guided implant surgery, is needed in order to determine the exact location and severity of endodontic lesions.
The novelty of this new surgical endodontic procedure starts with the use of computer-aided design/computer-aided manufacture (CAD-CAM) softwares, which obtain 3D imaging data employed in order to develop an individually specific surgical template. This makes it possible for the surgeon to perform a less invasive and less traumatic approach, minimizing bone loss compared to traditional osteotomy techniques. This approach lets the clinician plan with utmost accuracy the position and size of the ostectomy and of root-end section in accordance with the guidelines of modern microsurgical apicectomy, including the recommended 3-mm root-end resection approximately perpendicular to long axis of the root.
In the field of implant therapy, it can be pointed out that the accuracy of static computer-aided implant surgery is within the clinically acceptable range in the majority of clinical situations. Even if, taking into account the possible deviations between virtual and real, it is preferable to keep a safety marge from noble structures of at least 2 mm (17).
A systematic review showed that with the aid of digital template, implant surgery accuracy can be achieved with the distance deviation of <2 mm (most <1 mm) and angular deviation <8° (most <5°). (18)
Compared to freehand surgery, it has been shown that using a surgical template significantly reduces the chance for a positional error at the time of implant placement (19). Arisan et al, reported a 6% probability of a positional error using a computer guided template, and an 88% probability of having a positional error with a freehand approach (20).
Similarly, accuracy in guided endodontic surgery has been investigated in both preclinical and clinical studies. The study by Fan et al. found that the deviation of apical resection guided by grid position was 0.66±0.54 mm, and the deviation of apical resection without template was 1.92±1.05 mm (21).
Zhao et al. compares the accuracy of endodontic microsurgeries performed with and without 3D-printed surgical guides. The deviation of the apical resection length of the experimental group (0.467±0.146 mm) was better than that of the control group (1.743±0.122 mm) (P<0.0001), and the deviation of the apical resection angle of the experimental group (9.711±3.593°) was significantly less than that of the control group (22.400±3.362°) (P<0.0001). Thus, showing that the section length and angle have been significantly improved (22).
Gaffuri et al. (23), on a human cadaver study, highlights the critical role of surgical guides in enabling non-expert operators to achieve accuracy levels comparable to experienced practitioners. Results showed no significant difference in performance between experienced and inexperienced operators. Both achieved clinically successful outcomes, demonstrating that surgical guides ensure precision and reduce operator-dependent variability, even in challenging conditions such as posteri-

or teeth. Previous reports have used guided endodontic surgery to identify an ideal ostectomy site, providing a significant improvement in bone removal, but none of them have used a specific template to perform a selective and accurate root-end resection in length and angle, critically important to minimize trauma and enhance surgical results.
Aim of this case series is to describe a new surgical template design, suitable to static endodontic microsurgery when performed by Piezosurgery®.

Case Report

Case 1: Maxillary central incisors with 2 surgical templates
A 24-year-old man was referred to the department of periodontology of IRCCS Agostino Gemelli Polyclinc foundation in Rome.
The patient's anamnesis indicated an absence of systemic diseases and no reactions to dental anesthetics or antibiotics.
The CBCT revealed periapical radiolucent lesions on each maxillary incisor (Figure 1). Both central incisors were endodontically treated 10 years ago and covered by fixed prosthodontics that the patient refused to replace. The decision to perform conventional endodontic treatments on lateral incisors and endodontic microsurgery on central incisors was made.
The CBCT images were imported to a dental CAD software (Implant 3D®, Media Lab s.p.a). According to the indications offered by the oral surgeon, two dental and bone supported surgical templates were made.
The first one was characterized by two circular slots with a diameter of 6mm. The centre of the circle was located 1mm coronally to the root end of each tooth. These slots were used to realize a minimally invasive ostectomy upon dental apex. The second one was characterized by two rectangular slots (6 mm x 1 mm) perpendicular to the y-axis of each tooth. According to guidelines of endodontic micro-surgery, each slot was located at 3mm coronally to the anatomical root apex (9, 24).
All surgical procedures were performed under 20x magnification (M320 D, Leica®). The fit of the 3D-printed surgical templates was verified intraorally before starting surgery by checking the position of the teeth through the occlusal holes of the template (Figure 2, Figure 3)
The patient was anaesthetised using 4% articaine with 1:100.000 epinephrine (Pierrel®). 3 cartridges of anaesthetics were used during the whole surgery.
A modified Widman flap with vertical bevelled incicions distally to both right and left canine teeth was performed, using a 15c blade, due to the presence of mild re-

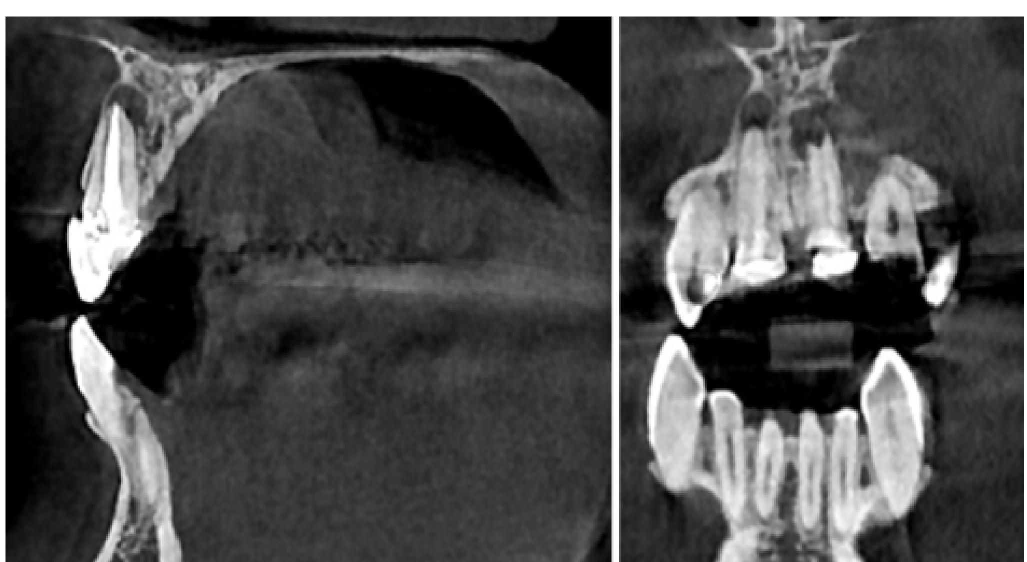


Figure 1
CBCT evaluation.

Figure 2
Surgical template #1 try-on.

Figure 3
Surgical template #2 try-on.

Figure 4
Full-thickness flap elevation.

Figure 5
Ostectomy using OT13 tip and surgical guide #1.

Figure 6
Ostectomy using OP7 tip and surgical guide #1.

Figure 7
Root apexes exposed.

Figure 8
Root-end resection using OT7S-3 tip and surgical

sidual periodontal pockets, allowing for simultaneous treatment of both periodontal pockets and endodontic lesions. The use of this flap didn't affect the aesthetic outcome due to the presence of recessions and associate exposition of the metal frame of the prosthetic crowns, prior to the surgery.
A full-thickness flap was elevated using tissue elevators (Figure 4). The fit check of templates was repeated after flap elevations. Using the surgical template #1 and piezoelectric tips OT13 and OP7 (Piezosurgery®, Mectron), ostectomies were performed (Figure 5 and 6). Root apexes appeared clearly exposed after ostectomy (Figure 7). The template #1 was removed and replaced with template #2.
The surgical template #2, tailored to piezoelectric tip OT7S-3 (Piezosurgery®,Mectron) allowed to resect root-ends (Figure 8 and 9). Root apexes were carried off using root tip picks (Figure 10).
A root-end retrocavity of 3mm (9) was prepared with a piezosurgery diamond-coated retrotip EN3(Piezosurgery®, Mectron) (Figure 11) and filled using a

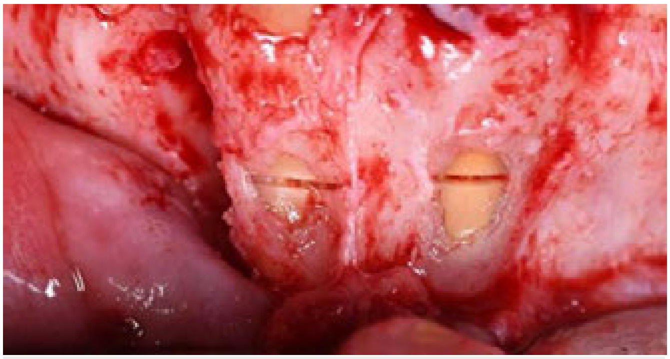


Figure 9
Root-ends resected.

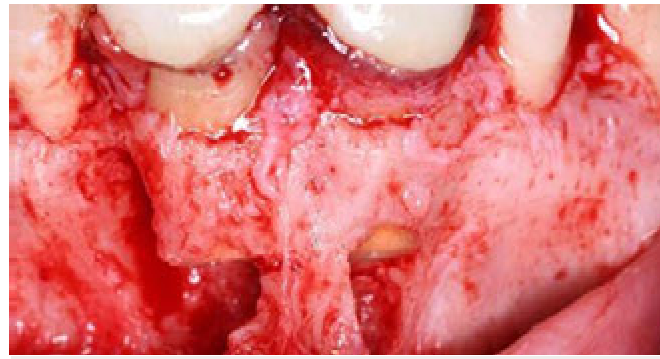


Figure 10
Root-ends carried off.

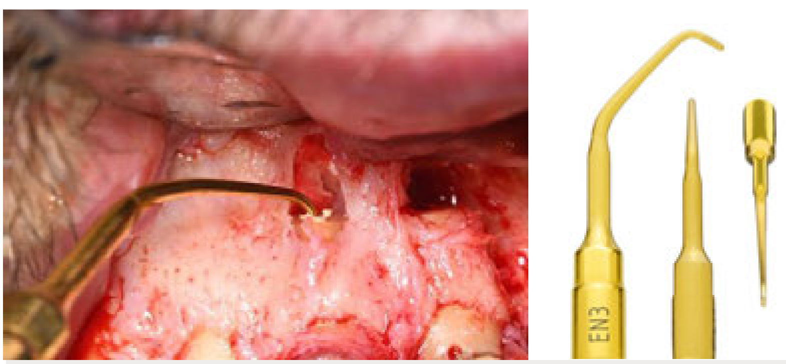


Figure 11
Root-end cavity preparation using EN3 tip.

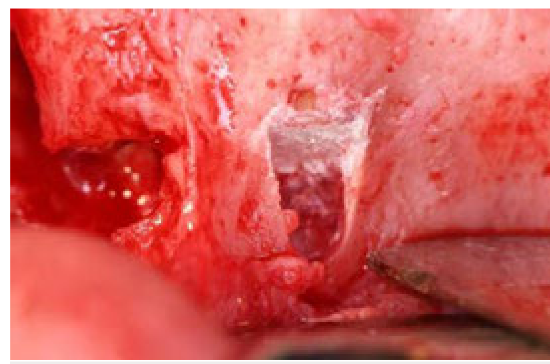


Figure 12
Root-ends filling using premixed bioceramic putty.

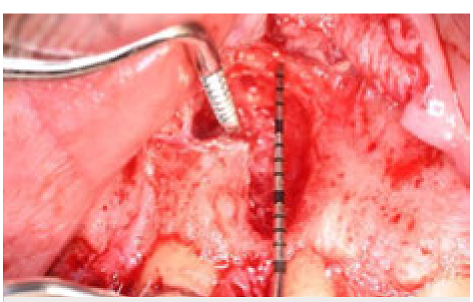


Figure 13
Residual bone defect.

Figure 14
Bone defect filled with bone graft.

Figure 15
Collagen membrane positioned.

Figure 16
Flap suture.

Figure 17
Day of surgery, 6 and 12 months radiographic follow-up.

premixed bioceramic putty (Well-Root PT®, Vericom) (Figure 12).
The residual bone defect, (Figure 13) was filled with bovine bone graft (Bio-Oss®, Geistlich) (Figure 14) and covered with a resorbable bilayer collagen membrane (Bio-Gide®, Geistlich) (Figure 15), in order to prevent an incomplete healing owing to ingrowth of connective tissue (25). Considering the extension of the residual bone defect, a collagen membrane was used to obtain a barrier effect to ensure undisturbed and uninterrupted bone healing and a bone graft was placed in order to prevent a collapse of the collagen membrane into the defect.
The flap was sutured with single sutures using polyglycolic acid (PGA) 5.0 (Figure 16) and sutures were removed 7 days after surgery.
Radiographic and clinical evaluation was performed 6 and 12 months after surgery, showing the absence of neither symptoms nor radiolucent lesions on treated teeth thus proving the treatment's stability (Figure 17).

Case 2: Maxillary central and lateral incisors with a modular surgical template
A 33 years old woman was referred to the department of periodontology of IRCCS Agostino Gemelli Polyclinc foundation in Rome, with sporadic discomfort, swelling and tenderness to percussion in the premaxilla region.
The patient suffered from valvular heart disease which imposes the eradication of each possible infectious outbreak included the periapical lesions on each maxillary incisor confirmed by CBCT (Figure 18).
Due to the urgency of the treatment and the presence of a fixed prosthesis covering the endodontically treated teeth, the decision to perform a microsurgery approach was made.
DICOM files and STL data obtained from an extraoral cast scanning were imported to a dental CAD software (Implant 3D®, Media Lab s.p.a). According to indications offered by the oral surgeon, this time only one modular surgical template was made.
The surgical template was composed by a single dental and bone supported frame, non-removable during surgical procedures, to which two secondary removable templates (A and B) were connected through magnets (Figure 19):
-the first one (#A) was characterized by four circular slots 6mm in diameter. The centre of the circle was located 1mm coronally to the root end of each tooth. These slots were used to realize a minimally invasive ostectomy in the periapical hard tissues.
-the second one (#B) was characterized by four rectangular slots (6mm x 1mm) perpendicular to the long axis of each tooth. Each slot was located at 3mm to the root apex, defined on CBCT images, in order to perform root resection (9, 24).
All surgical procedures were performed under 20x magnification (M320 D, Leica®)
The fit of 3D-printed surgical templates was verified intraorally (Figure 20, 21).
The patient was anaesthetised using 4%

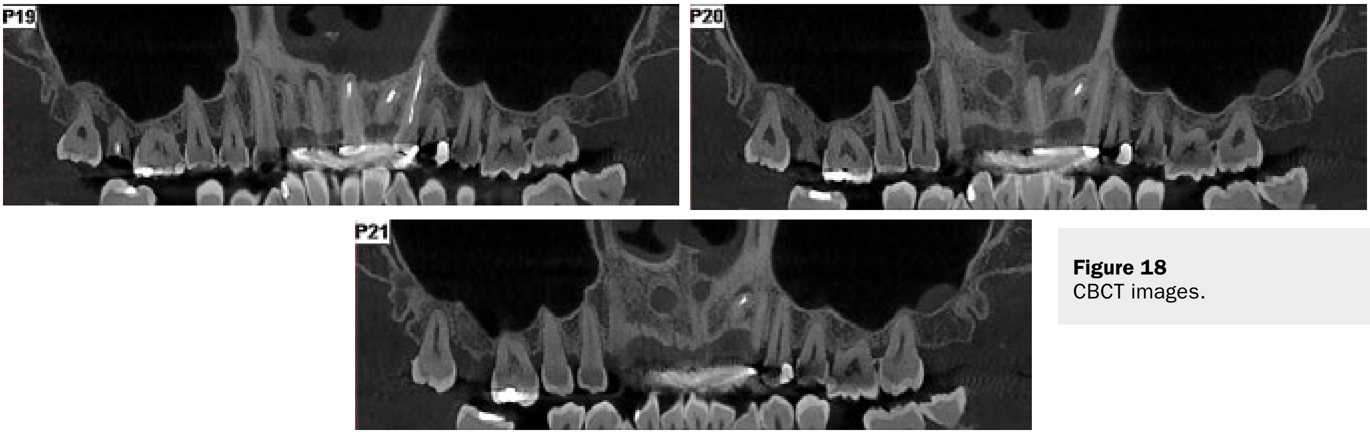


Figure 18
CBCT images.

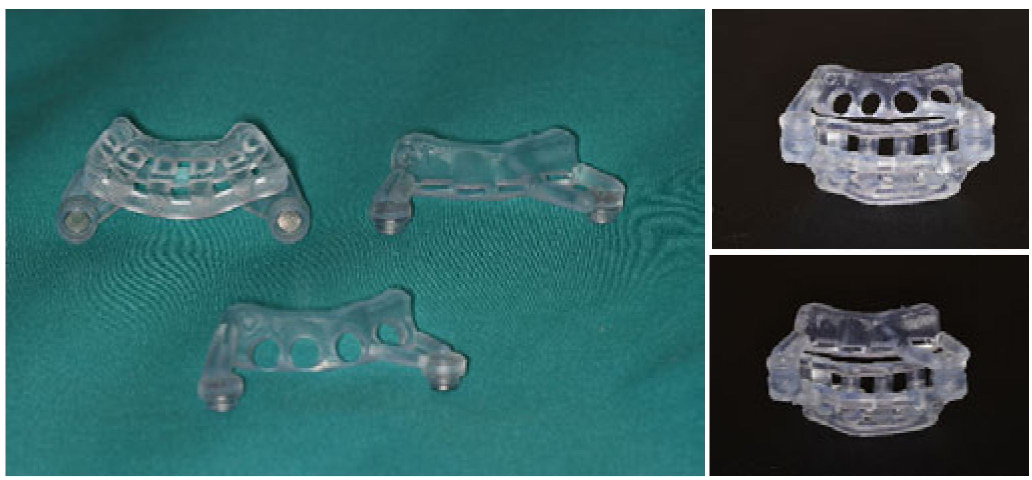


Figure 19
Surgical template #0, #A and #B.

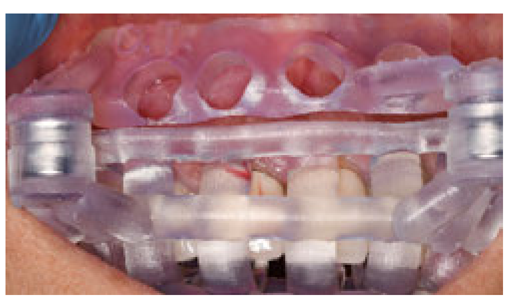


Figure 20
Surgical template #0 and #A try-on.

Figure 21
Surgical template #0 and #B try-on.

Figure 22
Full-thickness flap elevation.

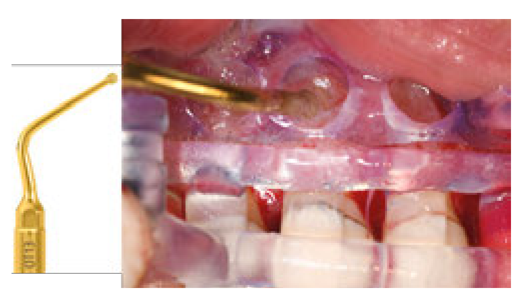


Figure 23
Ostectomy using OT13 tip and surgical guide #A.

articaine with 1:100.000 epinephrine (Pierrel®). 5 cartridges of anaesthetics were used during the whole surgery. A modified Widman flap with vertical bevelled incicions distally to both right and left canine teeth was performed, using a 15c blade, due to the presence of mild residual periodontal pockets.

Figure 24
Root apexes exposed.

Figure 25
Root apexes exposed.

Figure 26
Root-end resection using OT7S-3 tip and surgical template #B.

Figure 27
Root-ends resected.

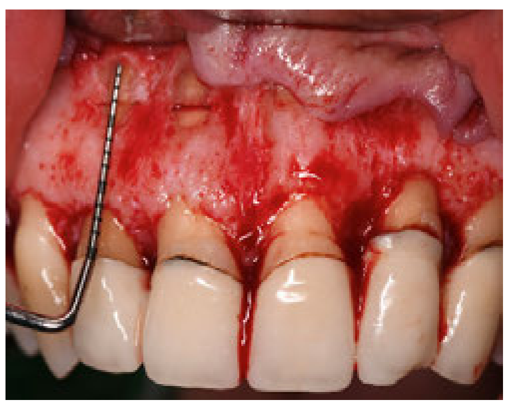
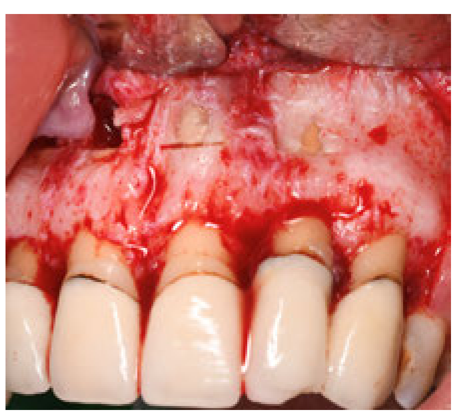


Figure 28
Root-ends resected at 3 mm from the apex.

Figure 29
Root-ends resected.



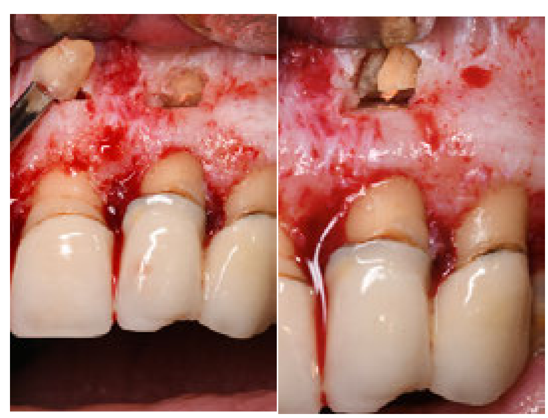


Figure 30
Root-ends carried off.

Figure 31
Roots-ends carried off.

A full-thickness flap was elevated using tissue elevators (Figure 22).
Template #0 was positioned intraorally, and the correct fit was checked.
The surgical template #A was connected to Template #0 and ostectomies were performed using piezoelectric tips OT13 and OP7 (Piezosurgery®, Mectron) (Figure 23). After ostectomies, root apexes are clearly exposed (Figure 24, 25).
The surgical template #A was then replaced by surgical template #B, and by means of a piezoelectric tip OT7S-3

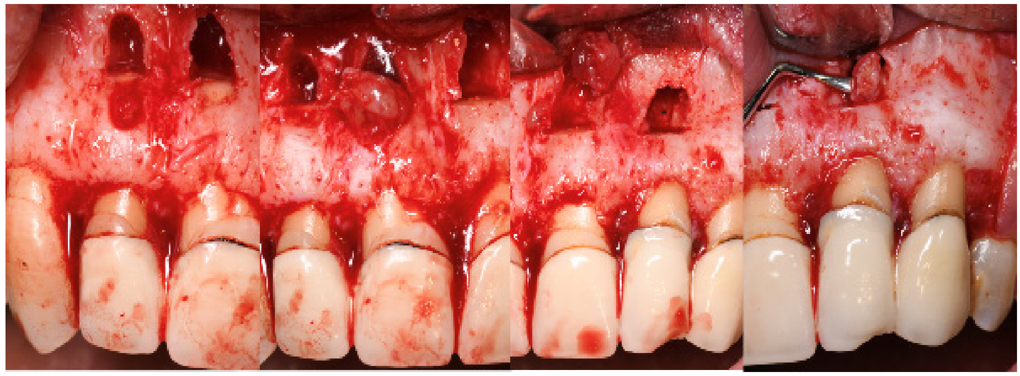


Figure 32
Roots-ends carried off and apical lesions removal.

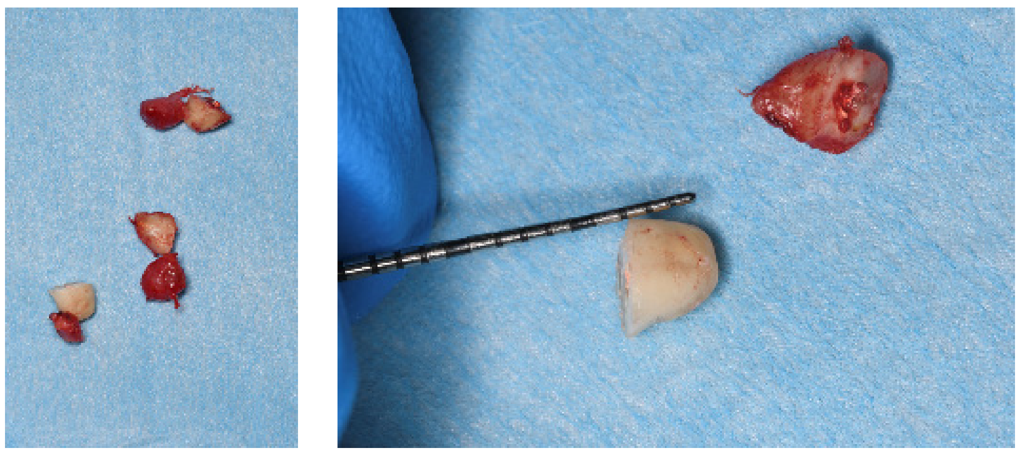


Figure 33
Apical lesions and root-ends resected.

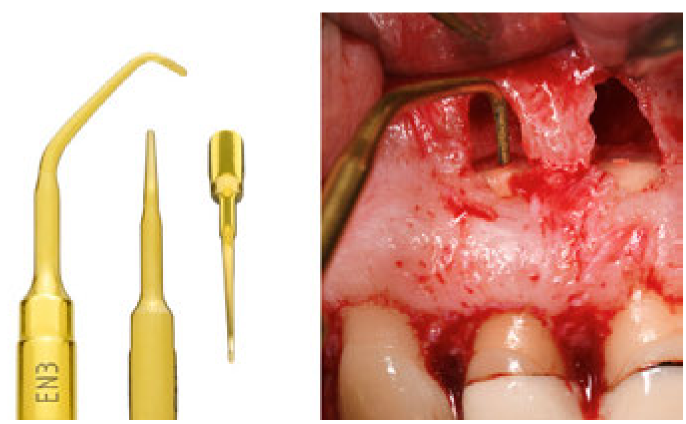


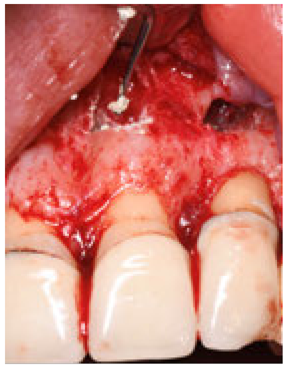
Figure 34
Roots-end carried off.

Figure 35
Root-end cavity preparation using EN3 tip.

(Piezosurgery®, Mectron) root-ends were resected (Figure 26, 27).
Root-ends were extracted using root tip picks (Figure 29, 30, 31). Piezosurgery diamond-coated retrotip EN3(Piezosurgery®, Mectron) was used to retroprepare the last 3mm of the root-end cavity (Figure 35).
The Root-end cavities were filled using a premixed bioceramic putty (EndoSequence BC Sealer®, Brasseler USA) (Figure 36).
As in the previous case, the residual bone defect (Figure 38) was filled with bovine bone graft (Bio-Oss®, Geistlich) (Figure 39) and covered with a layer of collagen (Condress®, Smith&nephew) (Figure 40) (25).
Flap was sutured with single sutures using Polyglycolic acid (PGA) 5.0 (Figure 41).
Sutures were removed 7 days after surgery.
Radiographical and clinical evaluations were performed 3, 6 and 12 months after surgery, showing the absence of radiolucent lesions on treated teeth thus proving the treatment’s stability (Figure 43-46).

Figure 36
Root-end filling using premixed bioceramic putty.

Figure 37
Root-ends filling.



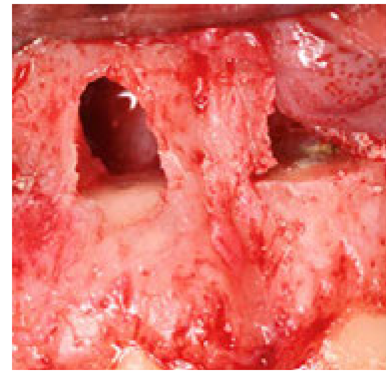


Figure 38
Residual bone defect.

Figure 39
Bone defects filled with bone graft.

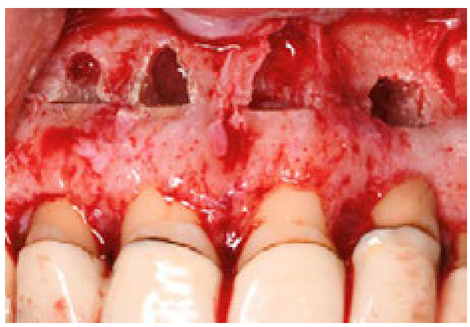


Figure 40
Bone defects covered with a layer of collagen.

Figure 41
Flap suture.

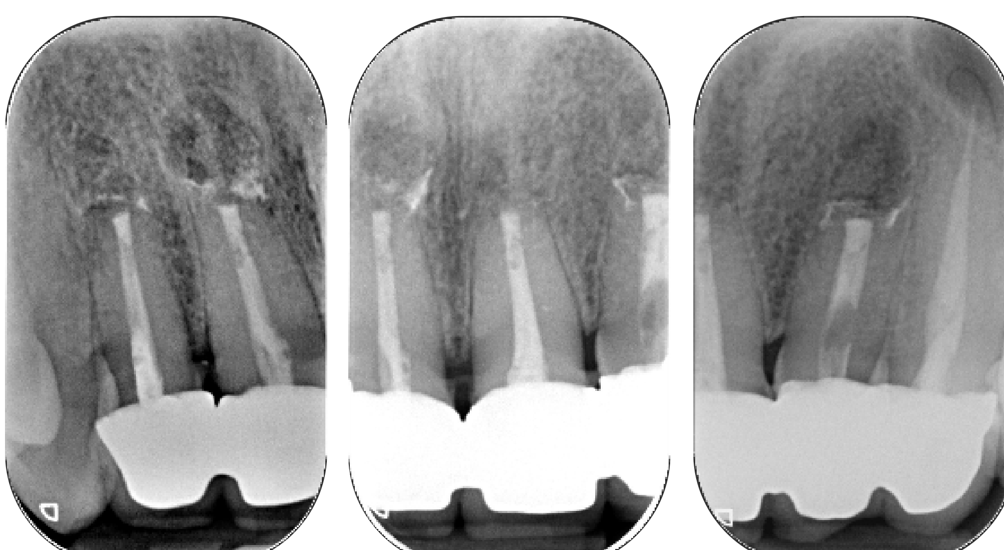


Figure 42
Rx performed at the end of the surgery.

Figure 43
Clinical evaluation 3 months after surgery.

Figure 44
Radiographical evaluation performed 3 months after surgery.

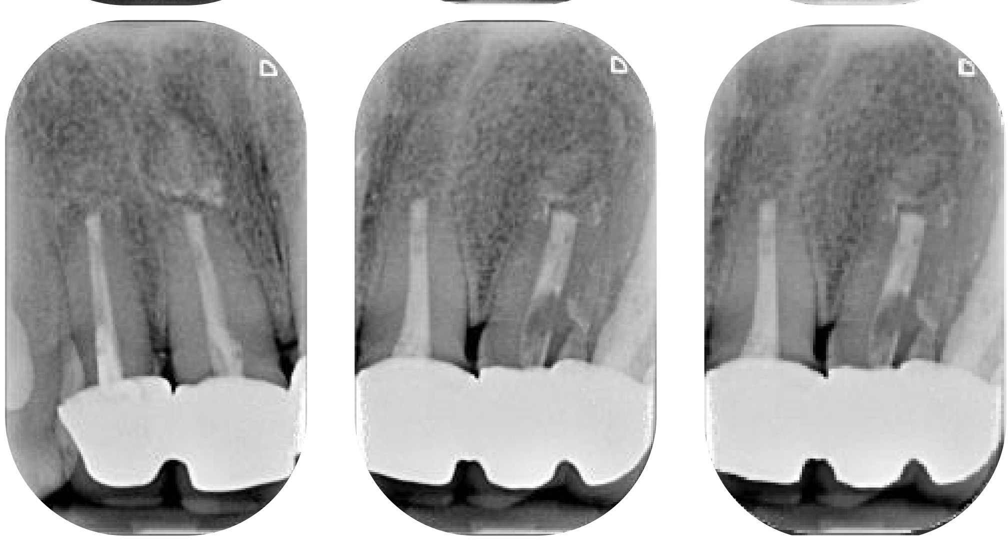


Figure 45
Radiographical evaluation performed 6 months after surgery.

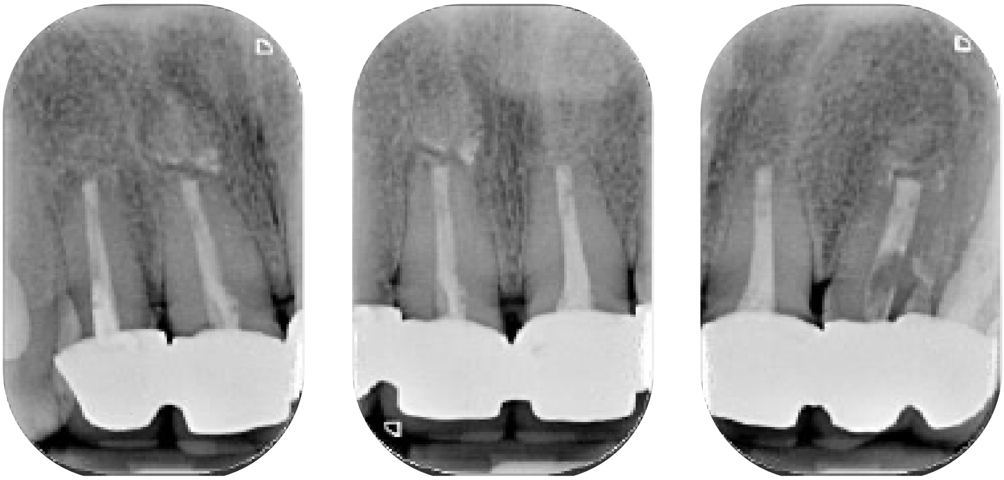


Figure 46
Radiographical evaluation performed 12 months after surgery.

Discussion

The development of surgical templates designed through a CAD software on the basis of patient CBCT provides precise apex and surgical site location, reducing surgical timing, avoiding access errors, damage to neighboring teeth, and injury to healthy tissue. The high precision guaranteed by the templates makes the procedure particularly suitable to the treatment of anatomically complex scenarios including lesions close to the nerve, the maxillary sinus, and arteries.
Guided endodontic microsurgery has the potential to be a more accurate and conservative apical surgery that can, in most of the cases, replace the more invasive traditional apicoectomy procedures.
Drawbacks need to be considered before using guided endodontic surgery, in fact, fracture template or poorly fitting template can occur. Moreover, the size of the surgical templates requires both a more extended flap design, which can be particularly tricky in the posterior areas, and a sufficient opening mouth, making it difficult to correctly fit the surgical template and the instrumentation during the surgery; dynamic navigation systems (3D-DNS) represent a viable alternative to static surgery, especially where spatial limitations makes template use challenging. It enables precise, real-time adjustments, ensuring accurate execution in tight spaces (26).
Even if, it is a more expensive approach, requiring advanced dental solutions such as CBCT imaging, specialized dental software for digital designs, and 3D printing capacity, the assistance provided by specialised 3D Studio Engineering, such as Media Lab S.p.A. help clinicians to overcome such adversity.
Piezoelectric surgery represents one of the most important evolution in bone surgery in the last decades. This technology provides maximum intraoperative control and cutting precision. The most important clinical feature of Piezoelectric surgery is selective cutting. Ultrasonic mechanical micro-vibrations are effective only when coming into contact with tissue that displays a high mechanical resistance, such as mineralized tissues. When in contact with soft tissues, which are typically elastic, the mechanical energy cannot be converted into cutting action, so it’s immediately transformed into thermal energy. These advantages over rotary instruments configure piezoelectric surgery as a gold standard device to use in proximity of high-risk structures (27).
Guided surgery using prefabricated 3D printed templates has become a common treatment option in endodontic surgery because of its potential to reduce surgical intervention time and postoperative complications during treatment procedures, to perform guided osteotomy, apex localization, and root-end resection as planned and according to recommended guidelines for modern surgical endodontic treatment.
In the attempt of adapting the general principles of minimally invasive surgery to

surgical endodontics, over the past few decades, different surgical approach and template design have bene described.
In literature, the use of surgical guide is well described, both for the creation of the bone access to minimizes the removal of bone tissue without diminishing the possibility to correctly visualise the root-end and the lesion (28-30), and for executing safely the root-end resection, removing exactly the planned amount of structure (28). The so-called "targeted endodontic microsurgery" adopts a three-dimensional pre-printed surgical guide that allows the use of a trephine bur, that performed at a certain predetermined depth both ostectomy and root-end resection (31).
According to the authors, the use of specific templates to perform independently ostectomy and root-resection allows a less invasive surgical approach, considering that the diameter and the circular shape of a bur is not comparable to that of the root apex.
Moreover, templates developed for these cases were customized for the access of the piezoelectric tips employed during the stages of the surgery. For example, templates #2 and #B were both characterised by binaries, located 3mm coronally to roots apexes, and tailored to OT7S-3 tip. Those binaries allowed a precise cut of root apexes, enhancing the features of piezoelectric cutting precision, and reducing operative times and surgical stress.
In the case series described, the modular surgical template employed in case 2 represents an evolution of that used in case 1. The main advantage consists in the stabilization of the template #0, performed at the beginning of the surgery, without the need of template #2 and its fit check. Once the template #0 has been placed, the connection of templates #A and #B is easy and accurate, which further reduces surgical timing.
Guided endodontic approach seems to be very promising; it allowed to perform an endodontic surgery according to the study of the case and to recommended guidelines, minimizing invasiveness, reducing surgical timing and increasing accuracy. Digital guided surgery aimed at reducing the influence of operator's skill and the so-called "technique effect" during the surgery, minimizing the risk of errors during the procedure.

Conclusions

The development of surgical templates based on CAD software and patient-specific CBCT imaging represents a significant advancement in endodontic microsurgery. These templates provide precise localization of the apex and surgical site, minimizing surgical errors, reducing treatment time, and protecting adjacent healthy tissues. This approach is particularly advantageous in complex anatomical cases, such as those near the maxillary sinus, nerves, or arteries, where high precision is essential. Guided endodontic microsurgery offers a more conservative alternative to traditional apicoectomy, with the potential to improve accuracy and reduce invasiveness.
Piezoelectric surgery enhances the precision of bone resection by selectively cutting hard tissues without damaging soft tissues, making it especially useful near sensitive structures. Combined with 3D printed surgical templates, piezoelectric surgery improves the precision of osteotomy and root-end resections, reducing surgical time and postoperative complications.
In conclusion, guided endodontic microsurgery, with its use of digital templates and piezoelectric technology, holds great promise for enhancing the accuracy, efficiency, and safety of apical surgeries. It offers a minimally invasive, highly accurate approach that reduces operator-dependent variability and improves clinical outcomes.

Clinical Relevance

The study highlights the clinical relevance of a novel CAD-CAM-designed surgical template for static endodontic microsurgery combined with Piezosurgery®. This innovation enhances precision in root-end resections, minimizes bone loss and tissue trauma, and improves surgical outcomes compared to traditional freehand techniques. By reducing invasiveness and post-operative complications, it promotes faster recovery and higher success rates in treating persistent apical periodontitis and other endodontic complications. This advancement underscores the potential of guided technologies to refine microsurgical procedures and improve patient-centered care.

Conflict of interests

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

Acknowledgments

None.

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Società Italiana
di Endodonzia

24 MAGGIO 2025
BARI

Centro Congressi Hotel Parco dei Principi

OLTRE L'APICE

GIORNATA SIE ENDO-GAME

9.00-9.45 **Dr. M. F. MANFREDONIA**:
La cavità d'accesso: il primo step nel successo endodontico.

9.45-10.30 **Dr. G. MESSINA**:
Il serbatoio radicolare un nuovo concetto in endodonzia. Con i MEA si può.

10.30-11.15 **Dr. G. SQUEO**:
Il ruolo della detersione nell'era delle leghe martensitiche e dei cementi bioceramici: cosa è cambiato?

11.15-12.00 Coffee Break

12.00-12.45 **Dr. G. CASTORANI**:
Otturazione Canalare: vecchie certezze e nuove possibilità.

12.45-13.30 **Prof. G. CANTATORE**:
Piano di Trattamento nei casi endodontici complessi.

13.30-14.30 Brunch

14.30-15.15 **Dr. G. CARRIERI**:
Apical Plug vs Rivascolarizzazione.

15.15-16.00 **Dr. F. MAGGIORE:**
Ritrattamenti chirurgici e non chirurgici.

16.00-16.45 **Dr. V. PICCIARIELLO-DR.SSA M. DI GIULIO CESARE**:
Il recupero dell'elemento gravemente compromesso.

PROGRAMMA CULTURALE 2025

EXPO DENTAL	RIMINI 15/17 MAGGIO
ENDO GAME	BARI 24 MAGGIO
CLOSED MEETING	FIUGGI 20/22 GIUGNO
CONGRESSO NAZIONALE	VERONA 21-22 NOVEMBRE
READY TO WORK	MILANO - FROSINONE - BARI
CADAVER LAB PLUS	19-20 SETTEMBRE 10-11 OTTOBRE
ENDO HOUR-UN SORSO DI CULTURA	7 WEBINAR
GIORNATE CULTURALI MACROAREE	

Società Italiana di Endodonzia

Lettera DEL PRESIDENTE

Cari Soci della Società Italiana di Endodonzia, é con grande orgoglio e profondo senso di responsabilità che vi scrivo all'inizio del mio mandato come Presidente della SIE.
Questo traguardo rappresenta per me non solo un grande onore ma anche un'opportunità unica per contribuire alla crescita e al rilancio della nostra amata Società. Desidero innanzitutto ringraziarvi per il sostegno e la fiducia che avete accordato al nostro gruppo, cose che mi spingono a lavorare con ancora maggiore dedizione e impegno per il bene comune.
Il **nostro obiettivo primario sarà dare nuovo slancio alla Società**, valorizzando i suoi punti di forza e implementando i progetti pensati per il suo rinnovamento. Lavoreremo per una SIE più giovane, inclusiva e innovativa, rafforzando le attività culturali, potenziando il coinvolgimento dei Soci Attivi e incrementando la visibilità della nostra società a livello nazionale e internazionale.
La SIE è da sempre sinonimo di eccellenza, professionalità e ricerca della qualità. È la storia dell'endodonzia in Italia e nel panorama internazionale, un equilibrio armonico tra tradizione e innovazione. Oggi abbiamo l'opportunità di rafforzare il suo ruolo, rendendola più dinamica e proiettata verso le sfide che ci attendono.
Per realizzare il nostro progetto dobbiamo guardare avanti con coraggio e determinazione, abbracciando le nuove acquisizioni, le nuove tecnologie, i nuovi concetti, promuovendo la multidisciplinarietà e valorizzando i giovani talenti.
Il programma che vi abbiamo presentato nei mesi scorsi non è solo una visione, ma un **impegno concreto** per costruire **una SIE più forte e orientata al futuro.**
Il 2025 sarà un anno cruciale per la SIE, durante il quale ci impegneremo a realizzare i progetti proposti, a partire dalla **redistribuzione delle Macroaree**, un punto cardine del nostro programma, un progetto che mira a rendere la SIE più presente sul territorio, più vicina alle differenti esigenze locali e più rappresentativa a livello nazionale.
La nuova struttura inter-regionale, più capillare e organizzata, garantirà una migliore copertura geografica e una maggiore partecipazione dei Soci alle iniziative della Società.
A supporto di questa riorganizzazione ci saranno due figure chiave: il Segretario di Macroarea e il Coordinatore delle Macroaree, ruolo che sarà ricoperto in primo mandato dal Dott. Mario Mancini. La sua esperienza e dedizione saranno fondamentali per armonizzare le attività regionali, facilitare la comunicazione tra le Macroaree e il Consiglio Direttivo, e garantire che ogni area sia rappresentata in modo efficace e dinamico.
Obiettivi altrettanto cruciali del nostro mandato sono **la valorizzazione dei Soci Attivi** attraverso il progetto **SIE Masterclass** che conferisce visibilità e riconoscimento professionale, la promozione di una cultura di partecipazione e trasparenza con SIE Ascolta e Trasparenza Day, la collaborazione forte e dinamica con le Università Italiane mediante il progetto **UniLab**, la creazione di un network internazionale con SIE Endoworld.
Per la **formazione di giovani professionisti** abbiamo inaugurato il percorso per Consulente Certificato SIE, un iter avanzato di teoria e pratica clinica disponibile in tutta Italia, che offre una certificazione di eccellenza riconosciuta.
É in programma il Cadaver Lab Plus della SIE, corso medio-avanzato per professionisti che desiderano avvicinarsi o approfondire le tecniche di microchirurgia endodontica.
È già operativo il progetto SIE HelpLine che fornisce un supporto clinico immediato per i colleghi giovani e meno giovani che abbiano necessità di confrontarsi con i professionisti esperti della SIE.
Last but not least uno degli obiettivi cardine del mio mandato sarà la **revisione e modernizzazione dello Statuto**, per garantire una maggiore governabilità alla Società, in modo che qualunque futuro direttivo possa operare con efficacia e continuità. Credo fermamente che una struttura più agile, moderna e gestibile sia essenziale per affrontare le sfide future e mantenere la SIE un punto di riferimento nell'endodonzia a livello nazionale e internazionale.
La SIE è stata, è e sarà sempre una eccellenza nell'endodonzia, un punto di riferimento per la formazione, la ricerca e la condivisione di conoscenze e che oggi siamo chiamati a rilanciare con entusiasmo e visione. Per farlo, abbiamo bisogno di voi: della vostra presenza, delle vostre idee, del vostro contributo attivo.
Vi invito quindi a partecipare con passione alle iniziative proposte, a essere presenti al **Closed Meeting di Fiuggi del 20-21 Giugno** e al **Congresso Nazionale di Verona del 21-22 Novembre**, in cui relatori di fama internazionale si confronteranno in un format congressuale totalmente nuovo e coinvolgente. Saranno questi i momenti fondamentali per confrontarci, crescere e rafforzare il senso di appartenenza alla nostra comunità. Ogni vostra proposta costruttiva e innovativa sarà preziosa per costruire una SIE più rappresentativa.
Concludo con un augurio sincero per l'anno che ci attende: che sia un anno di realizzazione, crescita e successi, in cui ogni progetto trovi concretezza e ogni Socio si senta parte attiva di una comunità vibrante e solidale.
Grazie ancora per la vostra fiducia. Resto a disposizione per qualsiasi confronto o suggerimento e vi aspetto numerosi alle prossime iniziative.
Con i migliori saluti,

Il Presidente della Società Italiana di Endodonzia,
Francesco Maggiore

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COME DIVENTARE SOCIO ATTIVO/AGGREGATO

Scaricabile dal sito **www.endodonzia.it**

SOCIO AGGREGATO

Per avere lo status di Socio Aggregato si dovrà presentare la documentazione descritta nel sito www.endodonzia.it che sarà valutata dalla Commissione Accettazione Soci. La documentazione che verrà presentata dovrà mostrare con rigore, attraverso casi clinici, l'interessamento del candidato alla disciplina endodontica.
Un meccanismo a punti è stato introdotto per valutare l'ammissibilità del candidato allo "status" di Socio Aggregato: i punti saranno attribuiti in base al tipo di documentazione presentata. Possono accedere alla qualifica di Socio Aggregato tutti i Soci Ordinari della SIE, in regola con le quote associative degli ultimi tre anni, che completino e forniscano la documentazione alla Segreteria Nazionale (Via Pietro Custodi 3, 20136 Milano) entro i termini che verranno indicati all'indirizzo web: www.endodonzia.it.
La domanda dovrà essere firmata da un Socio Attivo, in regola con la quota associativa per l'anno in corso, il quale è responsabile della correttezza clinica e formale della documentazione presentata.

DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO AGGREGATO

Qualsiasi Socio Ordinario, con i requisiti necessari, può presentare la documentazione per ottenere la qualifica di Socio Aggregato. Un meccanismo a punti è stato introdotto per valutare il candidato: un minimo di 80 punti è richiesto per divenire Socio Aggregato.
La documentazione clinica per ottenere la qualifica di Socio Aggregato dovrà presentare almeno sei casi, di cui non più di tre senza lesione visibile nella radiografia preoperatoria e non più di uno di Endodonzia Chirurgica Retrograda.
Nella domanda non potranno essere presentati casi la cui somma superi i 120 punti per la qualifica di Socio Aggregato.
L'aspirante Socio Aggregato potrà presentare la documentazione clinica in più volte, con un minimo di 40 punti per presentazione, in un arco massimo di tre anni. Il mancato rinnovo della quota associativa, anche per un solo anno, annulla l'iter di presentazione dei casi.

SOCIO ATTIVO

Per avere lo status di Socio Attivo si dovrà presentare la documentazione descritta nel sito www.endodonzia.it che sarà valutata dalla Commissione Accettazione Soci. La documentazione che verrà presentata dovrà mostrare con rigore, attraverso documentazione scientifica e casi clinici, l'interessamento del candidato alla disciplina endodontica.
Un meccanismo a punti è stato introdotto per valutare l'ammissibilità del candidato allo status di Socio Attivo: i punti saranno attribuiti in base al tipo di documentazione clinica e scientifica presentata. Possono accedere alla qualifica di Socio Attivo tutti i Soci Ordinari della SIE, in regola con le quote associative degli ultimi tre anni, che completino e forniscano la documentazione alla Segreteria Nazionale (Via Pietro Custodi 3, 20136 Milano) entro i termini che verranno indicati all'indirizzo web: www.endodonzia.it.
La domanda di ammissione allo status di Socio Attivo rivolta al Presidente della SIE dovrà essere firmata da un Socio Attivo in regola con la quota associativa per l'anno in corso, il quale dovrà aver esaminato e approvato la documentazione. Quest'ultimo è responsabile della correttezza clinica e formale della documentazione presentata.

DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO ATTIVO

Qualsiasi Socio Ordinario, con i requisiti necessari, può presentare la documentazione per ottenere la qualifica di Socio Attivo. Il Socio Aggregato che volesse presentare la documentazione scientifica e clinica a integrazione di quella clinica già approvata dalla CAS per lo status di socio Aggregato, potrà farlo già dall'anno successivo all'ottenimento della sua qualifica.
Un meccanismo a punti è stato introdotto per valutare il candidato a Socio Attivo. Un minimo di 200 punti è richiesto per divenire Socio Attivo.
Nella domanda non potranno essere presentati casi la cui somma superi i 240 punti per la qualifica di Socio Attivo.
La documentazione scientifica potrà essere presentata, a completamento della documentazione clinica, solo per la domanda per divenire Socio Attivo e non potrà superare i 80 punti.
La documentazione clinica dovrà presentare un minimo di sei casi, di cui almeno 4 di molari pluriradicolati con delle precise tipologie: tra questi casi almeno uno deve essere un ritrattamento con lesione visibile nella radiografia preoperatoria e dei restanti tre almeno due devono avere una lesione visibile nella radiografia preoperatoria.
La documentazione clinica non deve presentare più di un caso di Endodonzia Chirurgica Retrograda con immagini e non più di uno senza immagini.
La documentazione scientifica non potrà presentare più di due articoli come coautore.

MODALITÀ DI DOCUMENTAZIONE DEI CASI CLINICI

Criteri e modalità per la valutazione dei casi clinici idonei ad accedere alle qualifiche di Socio Aggregato e di Socio Attivo sono espressi nell'apposita sezione del Regolamento della Società Italiana di Endodonzia (SIE) all'indirizzo web: www.endodonzia.it.

CRITERI DI VALUTAZIONE

I casi clinici verranno valutati nel loro complesso, coerentemente con gli scopi e fini della SIE, e devono essere presentati dai Candidati considerando non solo l'aspetto clinico, ma anche quello formale della documentazione presentata.
La documentazione scientifica verrà valutata considerando la classificazione ANVUR delle Riviste Scientifiche, i documenti scientifici dovranno essere tutti di pertinenza endodontica.

ADEMPIMENTI DEL CANDIDATO

La domanda di ammissione allo status di Socio Aggregato/Attivo, rivolta al Presidente della SIE, dovrà pervenire, insieme alla documentazione di seguito elencata, alla Segretaria della SIE con un anticipo di 20 giorni sulle date di riunione della CAS, sufficiente per poter organizzare il materiale dei candidati. Le date di scadenza saranno rese note sul sito. La domanda dovrà essere firmata da un Socio Attivo in regola con la quota associativa per l'anno in corso, il quale dovrà aver esaminato e approvato la documentazione. Quest'ultimo è responsabile della correttezza clinica e formale della documentazione presentata.

PRESENTAZIONE DEI CASI ALLA COMMISSIONE

La presenza del Candidato è obbligatoria durante la riunione della CAS; è altresì consigliabile la presenza del Socio presentatore.

LA COMMISSIONE ACCETTAZIONE SOCI

La CAS (Commissione Accettazione Soci) è formata cinque Membri di indiscussa esperienza clinica, quattro Soci Attivi con almeno cinque anni di anzianità in questo ruolo eletti a ogni scadenza elettorale dall'Assemblea dei Soci Attivi e Onorari e uno dei Past President della Società incaricato dal CD a ogni riunione. Compito della CAS è quello di esaminare e valutare la documentazione presentata dagli aspiranti Soci Aggregati e Soci Attivi. Per rispetto del lavoro dei Candidati e per omogeneità di giudizio, in ogni riunione CAS verranno valutati non più di 12 candidati a Socio Attivo; resta libero, invece, il numero dei candidati a Socio Aggregato valutabile in una singola riunione. Il Consiglio Direttivo (CD) incaricando la Commissione Accettazione Soci (CAS) la rende responsabile dell'applicazione delle regole descritte nell'articolo 2 del regolamento. Il giudizio della CAS è insindacabile.

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Ceraseal

Obturation is a Fundamental Pillar in Endodontic Success

1 Y

Courtesy of Dr Claudio Farnararo

A tridimensional obturation is one of the key final steps for a successful endodontic therapy. Filling as much as possible of the intricate endodontic anatomy and achieving a stable apical seal are essential for long-term prognosis.

Ceraseal: The Next Generation of Bioceramic Sealers

In modern endodontics, the choice of root canal sealers is crucial for long-term treatment success. Ceraseal, a pre-mixed bioceramic sealer, stands out due to its bioactivity, biocompatibility, and superior sealing properties. Its advanced formulation enhances biological response and long-term stability.

Superior Bioactivity

Ceraseal actively promotes healing and tissue regeneration. Upon contact with moisture, it releases calcium ions, stimulating hydroxyapatite formation. This strengthens the bond with dentinal walls and fosters periapical healing, making it particularly beneficial in apical periodontitis or retreatment cases.

Unmatched Biocompatibility

Unlike traditional sealers that may cause inflammation, Ceraseal is highly biocompatible and does not irritate surrounding tissues. Its calcium-silicate composition enhances tissue tolerance, reducing post-operative complications. In cases of accidental extrusion, it integrates naturally with periapical tissues, minimizing risks and promoting healing.

Hermetic Sealing & Dimensional Stability

Ceraseal's formulation ensures an excellent seal, preventing microleakage and bacterial reinfection. Unlike some conventional sealers that shrink, it maintains dimensional stability for long-term durability. Its flowable consistency allows deep penetration into lateral canals, isthmuses, and dentinal tubules, further enhancing its sealing capabilities.

User-Friendly and Efficient Application

As a pre-mixed, ready-to-use sealer, Ceraseal eliminates complex mixing procedures, reducing errors and ensuring consistent application. It can be delivered with a disposable tip for precision and efficiency while minimizing material waste.

Conclusion

Ceraseal is revolutionizing endodontic sealing materials, offering bioactivity, biocompatibility, ease of use, and superior sealing properties. Its innovative formula enhances treatment predictability and promotes healing while preventing reinfections. For practitioners seeking a high-performance bioceramic sealer, Ceraseal represents a state-of-the-art solution in modern endodontic therapy.

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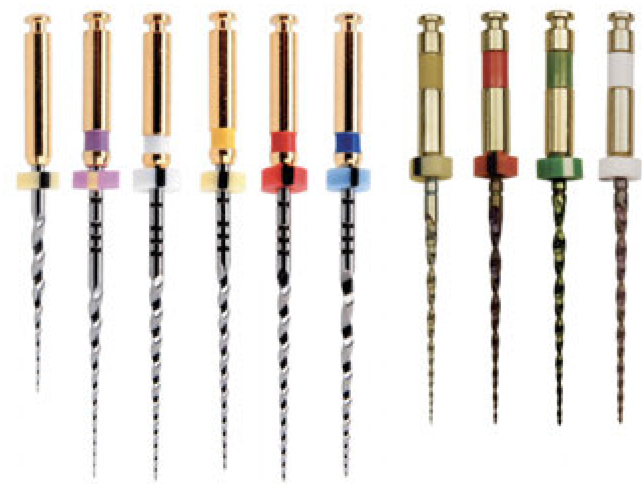
PERFORMANCE. PRICE. TECHNOLOGY.

EdgeEndo offre prodotti e soluzioni endodontiche di altissima qualità con tecnologie all'avanguardia e un ottimo rapporto qualità/prezzo.

Con le linee **EdgeTaper, EdgeTaper Platinum, EdgeOne Fire, EdgeFire X7,** i file EdgeEndo garantiscono velocità e sicurezza nel trattamento endodontico e grandi vantaggi sia per gli operatori che per i pazienti.

L'applicazione alla strumentazione rotante della nuova tecnologia **FireWire™** rende il file più flessibile incrementandone la resistenza alla fatica ciclica, elimina la memoria elastica preservando l'anatomia del canale e la dentina e permette allo strumento di seguire con precisione il percorso canalare in modo semplice ed efficace.

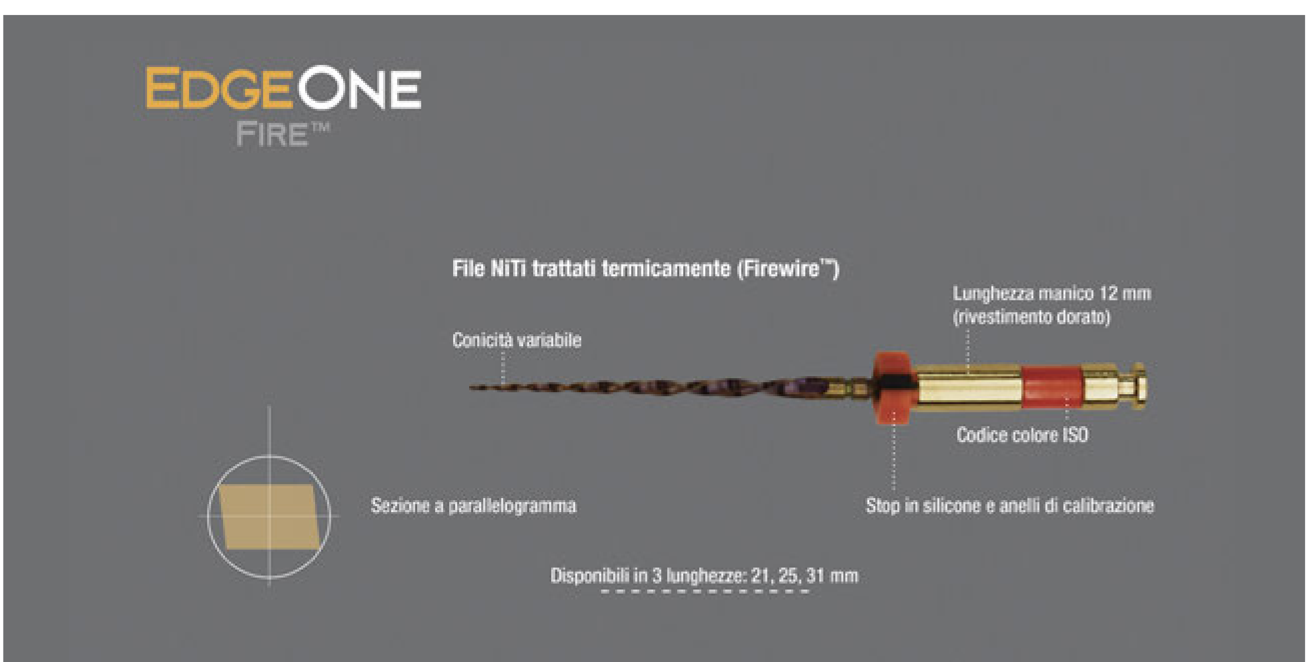
La linea di file reciprocanti EdgeOne Fire riduce il numero di strumenti necessari per la sagomatura, presenta un design conico variabile che riduce il diametro massimo delle spire (MFD) e l'effetto di avvitamento e grazie al nuovo trattamento FireWire™ gli strumenti risultano due volte più resistenti alla fatica ciclica rispetto agli altri.



La parola ai clinici che usano con grande soddisfazione i file EdgeEndo

"Ho recentemente paragonato i file **EdgeEndo NiTi** alla mia sistematica attuale. Sono stato piacevolmente sorpreso dalla loro flessibilità, durevolezza e resilienza alla rottura. Vantaggio più importante per me è stato poter conservare la mia tecnica ottenendo un identico risultato e risparmiando denaro. EdgeEndo è entrato a far parte della quotidianità del mio protocollo clinico."
Prof. Gianluca Gambarini, Università La Sapienza, Roma

"A mio parere X7 è il miglior sistema di file rotanti per la terapia endodontica mininvasiva. L'esclusivo trattamento termico e il diametro ridotto delle spire conferiscono maggiore efficienza e sicurezza nei casi complessi."
Prof. Gianluca Gambarini, Università La Sapienza, Roma



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GUIDELINES FOR AUTHORS

Giornale Italiano di Endodonzia (GIE) was founded in 1987 and is the official journal of Società Italiana di Endodonzia, SIE (Italian Society of Endodontics) https://www.endodonzia.it/

It is a peer-reviewed journal, only available in electonic format and publishes original scientific articles, reviews, clinical articles and case reports in the field of Endodontology. Scientific contributions dealing with health, injuries to and diseases of the pulp and periradicular region, and their relationship with systemic well-being and health. Original scientific articles are published in the areas of biomedical science, applied materials science, bioengineering, epidemiology and social science relevant to endodontic disease and its management, and to the restoration of root-treated teeth. In addition, review articles, reports of clinical cases, book reviews, summaries and abstracts of scientific meetings and news items are accepted. Please read the instructions below carefully for details on the submission of manuscripts, the journal's requirements and standards as well as information concerning the procedure after a manuscript has been accepted for publication in Giornale Italiano di Endodonzia. Giornale Italiano di Endodonzia is indexed in Scopus, Science Direct, Embase and published online by Ariesdue, Milan, Italy and hosted by PAGEPress, Pavia, Italy. All articles are available on www.giornaleitalianoendodonzia.it.

We publish, monthly, new articles in the Early View section while the full Journal is issued twice a year, in June and November.

Authors are encouraged to visit www.giornaleitalianoendodonzia.it for further information on the preparation and submission of articles and figures.

Ethical guidelines

Giornale Italiano di Endodonzia adheres to the below ethical guidelines for publication and research.

Authorship and Acknowledgements

Authors submitting a paper do so on the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the Giornale Italiano di Endodonzia. Giornale Italiano di Endodonzia adheres to the definition of authorship set up by The International Committee of Medical Journal Editors (ICMJE). According to the ICMJE, authorship criteria should be based on 1) substantial contributions to conception and design of, or acquisiation of data or analysis and interpretation of data, 2) drafting the article or revising it critically for important intellectual content and 3) final approval of the version to be published. Authors should meet conditions 1, 2 and 3. It is a requirement that all authors have been accredited as appropriate upon submission of the manuscript. Contributors who do not qualify as authors should be mentioned under Acknowledgements.

Manuscript preparation

Manuscripts should be uploaded as Word (.doc) or Rich Text Format (.rtf) files (not write-protected) plus separate figure files: TIF, EPS, JPEG files are acceptable for submission.

The text file must contain the **abstract, main text, references, tables and figure legends**, but no embedded figures or title page. The title page should be provided as a separate file. In the main text, please reference figures as for instance **figure 1, figure 2** etc to match the tag name you choose for the individual figure files uploaded.

Please note that **manuscripts must be written in English**. Authors whose native language is not English are strongly advised to have their manuscript checked by a language editing service or by a native English speaker prior to submission.

Manuscript Types Accepted

Original Scientific Articles must describe significant and original experimental observations and provide sufficient detail so that the observations can be critically evaluated and, if necessary, repeated. Original Scientific Articles must conform to the highest international standards in the field.

Systematic Review Articles reconsider and bring previously published systematic reviews up to date. This allows authors to present changes to the review while avoiding unwarranted duplication in the literature. A guiding principle for an update is that it is an event that is discrete and distinct from the conduct and reporting of the original systematic review (or previously updated review). This means that at a minimum the search for studies will have been brought up to date and that any changes to the results and conclusions of the original review (or a previously updated review) are described. Systematic review updates will not usually warrant publication of a new full-length article. However, any published update will be an independent publication. It will not be part of the original review publication (or previously updated review).

We encourage authors to be innovative in how they report and present systematic review updates. Systematic review updates are not appropriate for corrections/errata. Authors must clearly acknowledge and reference any previously-published work they are updating.

Review Articles are accepted for their broad general interest; all are refereed by experts in the field who are asked to comment on issues such as timeliness, general interest and balanced treatment of controversies, as well as on scientific accuracy. Reviews should generally include a clearly defined search strategy and take a broad view of the field rather than merely summarizing the authors´ own previous work. Extensive or unbalanced citation of the authors´ own publications is discouraged.

Mini Review Articles are accepted to address current evidence on well-defined clinical, research or methodological topics. All are refereed by experts in the field who are asked to comment on timeliness, general interest, balanced treatment of controversies, and scientific rigor. A clear research question, search strategy and balanced synthesis of the evidence is expected. Manuscripts are limited in terms of word-length and number of figures.

Clinical Articles are suited to describe significant improvements in clinical practice such as the report of a novel technique, a breakthrough in technology or practical approaches to recognised clinical challenges. They should conform to the highest scientific and clinical practice standards.

Case Reports or **Case Series** illustrating unusual and clinically relevant observations are acceptable, but they must be of sufficiently high quality to be considered worthy of publication in the Journal. On rare occasions, completed cases displaying nonobvious solutions to significant clinical challenges will be considered. Illustrative material must be of the highest quality and healing outcomes, if appropriate, should be demonstrated.

Case reports should be written using the **Preferred Reporting Items for Case reports in Endodontics (PRICE) 2020 guidelines.** A PRICE checklist and flowchart (as a Figure) should also be completed and included in the submission material. The PRICE 2020 checklist and flowchart can be downloaded from: http://pride-endodonticguidelines.org/price/. It is recommended that authors consult the following papers, which explains the rationale for the PRICE 2020 guidelines and their importance when writing manuscripts:

- Nagendrababu V, Chong BS, McCabe P, Shah PK, Priya E, Jayaraman J, Pulikkotil SJ, Setzer FC, Sunde PT, Dummer PMH. *PRICE 2020 guidelines for reporting case reports in Endodontics: a consensus-based development.* Int Endod J. 2020 Feb 23. Doi: 10.1111/iej.13285. https://onlinelibrary.wiley.com/doi/10.1111/iej.13285.
- Nagendrababu V, Chong BS, McCabe P, Shah PK, Priya E, Jayaraman J, Pulikkotil SJ, Dummer PMH. *PRICE 2020 guidelines for reporting case reports in Endodontics: Explanation and elaboration.* Int Endod J. 2020 Mar 28. Doi: 10.1111/iej.13300. https://onlinelibrary.wiley.com/doi/abs/10.1111/iej.13300.

Manuscript Format

The **official language** of the publication is **English**. It is preferred that manuscript is professionally edited. All services are paid for and arranged by the author and use of one of these services does not guarantee acceptance or preference for publication.

Authors should pay special attention to the **presentation** of their research findings or clinical reports so that they may be communicated clearly.
Technical **jargon** should be avoided as much as possible and clearly explained where its use is unavoidable. **Abbreviations** should also be kept to a minimum, particularly those that are not standard. Giornale Italiano di Endodonzia adheres to the conventions outlined in *Units, Symbols and Abbreviations: A Guide for Medical and Scientific Editors and Authors.* If abbreviations are used in the text, authors are required to write full name+abbreviation in brackets [e.g. Multiple Myeloma (MM)] the first time they are used, then only abbreviations can be written (apart from titles; in this case authors have to write always the full name). If names of equipments or substances are mentioned in the text, brand, company names and locations (city and state) for equipment and substances should be included in parentheses within the text.
The **background** and **hypotheses** underlying the study, as well as its main conclusions, should be clearly explained.
Titles and abstracts especially should be written in language that will be readily intelligible to any scientist.

Structure
All manuscripts submitted to Giornale Italiano di Endodonzia should include Title Page, Abstract, Main Text, References, Clinical Relevance, Conflict of Interest, Acknowledgements, Tables, Figures and Figure Legends as appropriate.
Title Page should bear:

I. Title, which should be concise as well as descriptive (no more than 150 letters and spaces);
II. Initial(s) and last (family) name of each author;
III. Name and address of department, hospital or institution to which the work should be attributed;
IV. Running title (no more than 30 letters and spaces);
V. Three to five key words (in alphabetical order);
VI. Name, full postal address, telephone, fax number and e-mail address of author responsible for correspondence (Corresponding Author).

Abstracts should be no more than 250 words giving details of what was done.

Abstract for Original Scientific Articles should be no more than 250 words giving details of what was done using the following structure.
Aim: give a clear statement of the main aim of the study and the main hypothesis tested, if any.
Methodology: describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and statistical tests.
Results: give the main results of the study, including the outcome of any statistical analysis.
Conclusions: state the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

Abstract for Systematic Review Articles should be divided into Aim, Methodology, Result, Conclusion.
Aim: Provide an explicit statement of the main objective(s) or question(s) the review addresses.
Methodology: Specify the inclusion and exclusion criteria for the review, the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched. Specify the methods used to assess risk of bias in the included studies and the methods used to present and synthesis of studies.
Results: Give the total number of included studies and participants and summarise relevant characteristics of studies. Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).
Conclusion: Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision) and a general interpretation of the results and important implications.

Abstract for Review Articles should be non-structured, no more than 250 words giving details of what was done including the literature search strategy.

Abstract for Mini Review Articles should be non-structured of no more than 250 words, including a clear research question, details of the literature search strategy and clear conclusions.

Abstract for Case Reports and **Case Series** should be no more than 250 words using the following structure.
Aim: give a clear statement of the main aim of the report and the clinical problem which is addressed.
Summary: describe the methods adopted including, as appropriate, the design of the study, the setting, entry requirements for subjects, use of materials, outcome measures and analysis if any.
Key learning points: provide up to five short, bullet-pointed statements to highlight the key messages of the report. All points must be fully justified by material presented in the report.

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Aim: give a clear statement of the main aim of the report and the clinical problem which is addressed.
Methodology: describe the methods adopted.
Results: give the main results of the study.
Conclusions: state the primary conclusions of the study.

THE STRUCTURE

Main text for Original Scientific Articles should include Introduction, Materials and Methods, Results, Discussion and Conclusion.
Introduction: should be focused, outlining the historical or logical origins of the study and gaps in knowledge. Exhaustive literature reviews are not appropriate. It should close with the explicit statement of the specific aims of the investigation, or hypothesis to be tested.
Material and Methods must contain sufficient detail such that, in combination with the references cited, all clinical trials and experiments reported can be fully reproduced.
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Results should present the observations with minimal reference to earlier literature or to possible interpretations. Data should not be duplicated in Tables and Figures.
Discussion may usefully start with a brief summary of the major findings, but repetition of parts of the abstract or of the results section should be avoided. The Discussion section should progress with a review of the methodology before discussing the results in light of previous work in the field. The Discussion should end with a brief conclusion and a comment on the potential clinical relevance of the findings. Statements and interpretation of the data should be appropriately supported by original references.
Conclusions should contain a summary of the findings.

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In the case of systematic reviews, whether with or without meta-analyses, strict adherence to the PRISMA guidelines (http://www.prisma-statement.org/) is mandatory. Additionally, authors must submit a PRISMA checklist (http://www.prisma-statement.org/PRISMAStatement/Checklist.aspx) and flowchart (http://www.prisma-statement.org/PRISMAStatement/FlowDiagram) along with the manuscript.

Main Text of Review Articles
should be divided into Introduction, Review and Conclusions.
The Introduction section should be focused to place the subject matter in context and to justify the need for the review. The Review section should be divided into logical subsections in order to improve readability and enhance understanding. Search strategies must be described and the use of state-of-the-art evidence-based systematic approaches is expected. The use of tabulated and illustrative material is encouraged. The Conclusion section should reach clear conclusions and/or recommendations on the basis of the evidence presented.

Main Text of Mini Review Articles
should be divided into Introduction, Review and Conclusions; please note that the Conclusions section should present clear statements/recommendations and suggestions for further work. The manuscript, including references and figure legends, should not normally exceed 4,000 words.

Main Text of Case Reports and Case series
should be divided into Introduction, Report, Discussion and Conclusion. They should be well illustrated with clinical images, radiographs, diagrams and, where appropriate, supporting tables and graphs. However, all illustrations must be of the highest quality.

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Standard journal article
(1) Somma F, Cammarota G, Plotino G, Grande NM, Pameijer CH. The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials. J Endod 2008;34:466-9.

Corporate author
British Endodontic Society - Guidelines for root canal treatment. Giornale Italiano di Endodonzia 1979;16:192-5.

Journal supplement
Frumin AM, Nussbaum J, Esposito M. Functional asplenia: demonstration of splenic activity by bone marrow scan (Abstract). Blood 1979;54 (Suppl. 1):26a.

Books and other monographs
Personal author(s)
Gutmann J, Harrison JW. Surgical Endodontics, 1st edn Boston, MA, USA: Blackwell Scientific Publications, 1991.

Chapter in a book
Wesselink P. Conventional rootcanal therapy III: root filling. In: Harty FJ, ed. Endodontics in Clinical Practice, (1990), 3rd edn; pp. 186-223. London, UK: Butterworth.

Published proceedings paper
DuPont B. Bone marrow transplantation in severe combined immunodeficiency with an unrelated MLC compatible donor. In: White HJ, Smith R, eds. Proceedings of the Third Annual Meeting of the International Society for Experimental Rematology; (1974), pp. 44-46. Houston, TX, USA: International Society for Experimental Hematology.

Agency publication
Ranofsky AL Surgical Operations in Short-Stay Hospitals: United States-1975 (1978). DHEW publication no. (PHS) 78-1785 (Vital and Health Statistics; Series 13; no. 34.) Hyattsville, MD, USA: National Centre for Health Statistics.

Dissertation or thesis
Saunders EM. In vitro and in vivo investigations into root-canal obturation using thermally softened gutta-percha techniques (PhD Thesis) (1988). Dundee, UK: University of Dundee.

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