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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

# Resistance of endodontically treated roots restored with different fibre post systems with or without post space preparation: in vitro analysis and SEM investigation



*Resistenza di radici trattate endodonticamente e restaurate con sistematiche diverse di perni in fibra con o senza preparazione del post space: analisi in vitro e al SEM*

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## KEYWORDS

Fibre post;  
Fracture resistance;  
Post space preparation;

## Abstract

**Aim:** To compare the mechanical resistance to fracture of two conical post systems placed with no preparation of the root canal with that of double taper fibre posts seated in endodontically treated single roots after standard post space preparation using dedicated drills.

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Preservation of root dentine;  
Self-adhesive cement;  
Taper.

## PAROLE CHIAVE

Perno in fibra;  
Resistenza a frattura;  
Preparazione del post space;  
Risparmio di dentina canalare;  
Cemento autoadesivo;  
Conicità.

**Methodology:** Thirty fibre posts with double (G1,  $n = 10$ , DT Light Post) and single taper (G2,  $n = 10$ , SurgiPost Multiconical; G3,  $n = 10$ , Tech ES Endoshape) were luted with self-adhesive cement in endodontically treated single roots using different post space preparation techniques. The bonded posts were experimentally loaded until failure and the maximum load to fracture was registered. Fracture patterns were qualitatively evaluated and SEM analysis was performed to assess the quality of endodontic treatments and cementation. Data were statistically analysed by means of one-way ANOVA.

**Results:** The mean maximum load to fracture was  $165.05 \pm 23.46$  N in G1,  $151.52 \pm 16.23$  N in G2 and  $129.09 \pm 15.25$  N in G3. Statistically significant differences were pointed out between G1 and G3 ( $p < 0.01$ ) and G2 and G3 ( $p < 0.05$ ). No root fractures were evidenced. SEM analyses showed slightly thicker cement layers at the apical and middle thirds of single taper posts (G2 and G3).

**Conclusions:** DT Light Post and SurgiPost Multiconical fibre posts showed similar properties in terms of mechanical resistance to fracture and higher than those of Tech ES Endoshape. Unrestorable root fractures did not occur with any of the tested posts.

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## Riassunto

**Obiettivi:** Confrontare la resistenza meccanica a frattura di due sistemi di perni conici posizionati senza preparazione del canale con quella di perni in fibra a conicità doppia posizionati in radici trattate endodonticamente dopo preparazione di un post space standard con frese dedicate.

**Materiali e metodi:** Trenta perni a conicità doppia (G1,  $n = 10$ , DT Light Post) e singola (G2,  $n = 10$ , SurgiPost Multiconical; G3,  $n = 10$ , Tech ES Endoshape) sono stati cementati con un cemento autoadesivo in radici singole trattate endodonticamente usando diverse tecniche di preparazione del post space. I perni cementati sono stati sottoposti a test di carico a frattura ed è stato registrato il carico massimo. I pattern di frattura sono stati valutati qualitativamente ed è stata svolta un'analisi SEM per la verifica della qualità dei trattamenti endodontici e della cementazione. I dati sono stati analizzati statisticamente con ANOVA a una via.

**Risultati:** I valori medi di carico massimo a frattura erano i seguenti:  $165,05 \pm 23,46$  N in G1,  $151,52 \pm 16,23$  N in G2 and  $129,09 \pm 15,25$  N in G3. Sono emerse differenze statisticamente significative tra G1 e G3 ( $p < 0,01$ ) e tra G2 e G3 ( $p < 0,05$ ). Non sono state osservate fratture radicolari. L'analisi al SEM ha mostrato strati di cemento leggermente più spessi nei terzi medio e apicale dei perni a conicità singola (G2 e G3).

**Conclusioni:** I perni in fibra DT Light Post e SurgiPost Multiconical hanno fatto riscontrare proprietà simili in termini di resistenza meccanica a frattura, le quali sono risultate superiori a quelle dei Tech ES Endoshape. Non si sono verificate fratture radicolari non restaurabili con alcuno dei sistemi di perni testati.

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## Introduction

Over the last decade, the failure of severely compromised teeth has been reported to be dramatically reduced<sup>1,2</sup> thanks to progress in material engineering and restorative techniques. The most frequent cause of tooth weakening is the loss of dental structure due to decay, trauma and cavity preparation, in particular in cases where the integrity of the roof of the pulp chamber is lost.<sup>3</sup> Furthermore, it is generally accepted that the loss of enamel and dentine is the most critical factor affecting the retention of the restoration.<sup>4,5</sup>

The mechanical resistance of the restored tooth is influenced by the amount of residual tooth structure,<sup>6</sup> the properties of the restorative materials, the presence of a ferrule,<sup>7</sup> the force pattern and distribution, as well as the occlusion of the patient.<sup>4,8</sup> The literature has not clarified yet whether the endodontic treatment by itself could weaken a tooth,<sup>9</sup>

but it certainly does not strengthen the root.<sup>10</sup> The removal of intra-canal dentine could affect the deformability of the root; hence, it is conceivable that the more invasive the endodontic treatment is, as in the case of post space preparation, the less stable and resistant the root will be.<sup>11</sup> Consequently, minimally invasive treatments are recommended in both the preparation of the access cavity and in the shaping of the root canal system,<sup>11</sup> in order to avoid the detrimental removal of sound tooth structure.

To restore a tooth affected by a critical loss of dental structure, the use of one or more posts is useful to improve the retention of the restorative material. The mechanical properties of the posts are paramount for the determination of possible fractures of the restored tooth, and the post system was proved to have a significant influence on fracture resistance.<sup>2,12</sup> Some authors have reported that the presence of a fibre post enhances the mechanical resistance to fracture

**Table 1** Mean values ( $\pm$  standard deviations) in mm of the length and diameters of the specimens divided per group.

	Group 1	Group 2	Group 3
Length	23.3 $\pm$ 1.8	23.1 $\pm$ 2.5	22.9 $\pm$ 1.9
Buccal-palatal diameter	7.0 $\pm$ 0.6	7.1 $\pm$ 1.0	7.3 $\pm$ 0.4
Mesial-distal diameter	5.5 $\pm$ 0.5	5.9 $\pm$ 0.5	5.8 $\pm$ 0.7

of a tooth and reduces the risk of unrestorable failures in comparison with teeth restored without fibre posts.<sup>6,13</sup> The main advantage of fibre posts is represented by their elastic modulus that is very close to that of dentine and allows a stress distribution similar to that of a natural sound tooth; on the contrary, metal posts exert high stress levels at the post-dentine interface.<sup>6,14–16</sup> Further advantages of fibre posts include biocompatibility, resistance to corrosion and fatigue, aesthetic properties and retrievability, since they can easily be removed from the root canal if necessary.<sup>1</sup> Fibre posts are usually luted inside the root canal by means of dentine adhesives and resin cements, allowing for a conservative preparation of the post space.<sup>17</sup> Moreover, the adhesive cementation provides the restorative system with an elastic modulus similar to that of dentine, resulting in a stress distribution pattern comparable to those arising during the occlusal load of a natural sound tooth.<sup>15,18,19</sup>

Ni–Ti rotary instruments are routinely used in endodontics to give a predefined taper to root canals and preserve radicular dentine, thus performing a minimally invasive canal shaping.<sup>11</sup> Consequently, it would be desirable to use a post with the same taper of the last endodontic instrument used to shape the canal, without any further preparation of the coronal and middle canal thirds.

The aim of the present in vitro study was to compare the mechanical resistance to fracture of standard double taper fibre posts luted with self-adhesive cement after dedicated post space preparation with that of two conical post systems placed in endodontically-treated single roots with no preparation of the post space. The null hypothesis was that there was no difference in the resistance to fracture among the three post systems.

## Materials and methods

### Collection of the specimens

Thirty straight single-rooted permanent teeth with complete apex, no decays or previous restorations, extracted for periodontal reasons, were selected from a pool of freshly extracted teeth. Dental plaque, calculus and external debris were removed using manual and ultrasonic scalers. The teeth were stored in 1% thymol solution at 37 °C.

For each tooth, two silicone impressions (Aquasil Putty, Dentsply DeTrey, Konstanz, Germany) were taken, one in buccolingual and one in mesiodistal direction to make the position of each sample repeatable during the radiographic phases. Radiographs were taken with a digital sensor (Kodak RVG 6100, Kodak Dental Systems, Rochester, NY, USA) and a radiographic digital system (2200 Intraoral X Ray System, Kodak Dental Systems) set at 70 kV, 7 mA and 0.12 s. Teeth with more than one canal, with a single oval and/or irregular canal were excluded from the study in order to limit the

anatomical variables affecting the biomechanical behaviour of the restorations.

The length and diameters of the selected teeth were measured with a digital caliper (Absolute Digimatic Caliper, Mitutoyo Digimatic, Sakado, Japan); specifically, the buccolingual and mesiodistal diameters were measured at the level of the cemento-enamel junction (CEJ).

The specimens were randomly divided into 3 groups of 10 teeth each. The similarity among groups in terms of length and diameter was assessed by means of one-way analysis of variance ( $p < 0.05$ ). The mean measurements ( $\pm$  standard deviation) of the specimens included in the study and the outcome of the statistical analysis are shown in Table 1.

### Preparation of the specimens

The crown of each tooth was removed by cutting the tooth 1 mm above the CEJ with a microtome (Micromet, Remet, Casalecchio di Reno, Italy) under constant water irrigation. During all the preparation stages, the specimens were manipulated with wet gauzes in order to avoid dentine dehydration.

A size #10 K file (Dentsply-Maillefer, Ballaigues, Switzerland) was inserted into the canal orifice to scout the canal and check the apical patency, by leading the file in apical direction until its tip was visible at the apical foramen under 4 $\times$  magnifications and marking this length with a rubber stop. The endodontic working length was established 0.5 mm short of this length.<sup>6</sup> The root canals were shaped using Ni–Ti rotary instruments (Mtwo, Sweden & Martina, Due Carrare, Italy) to ISO size 40, 0.06 taper (300 rpm at maximum torque). Once activated, each instrument was progressively taken to working length using a single-length technique without any pressure in apical direction; the instrument was removed once it rotated freely at the working length.<sup>20</sup> During canal instrumentation, constant irrigation was carried out with 2.5 mL 5.25% sodium hypochlorite (Nicolor 5, Ognà, Muggiò, Italy). All canals were finally rinsed with 5 mL 17% EDTA (Pulpdent, Watertown, MA, USA) for 120 s, followed by 5 mL 5.25% sodium hypochlorite and abundant rinsing with saline solution, and dried with paper points (Roeko Paper, Coltene Whaledent, Langenau, Germany). Each set of Ni–Ti instruments was discarded after preparing 10 canals. The canals were filled with the continuous wave of condensation technique (System B, Elements Obturation Unit, Sybron Endo, Orange, CA, USA). An XF or F Buchanan plugger (SybronEndo) was chosen to fit 3 mm short of the working length, avoiding contact with the canal walls. This depth was marked using a rubber stop at the reference point. The System B unit was set at full power at 200 °C with the switch in touch mode. For each specimen, the tug-back of a 40/.06 gutta-percha master point (Mtwo Gutta, Sweden & Martina) was checked 0.5 mm short of the working length and

**Table 2** Post characteristics declared by the manufacturers.

Group	<i>n</i>	Post	Taper	Composition	Tensile strength (MPa)	Elasticity modulus (GPa)
G1	10	DT Light Post	.02–.10	Pretensioned quartz fibres (64% vol.) Epoxy resin Silane	2050	15
G2	10	SurgiPost Multiconical	.10	Glass fibre (80% vol.) Epoxy resin	3100	80
G3	10	Tech ES Endoshape	.10	Silica fibres (60% vol.) Diphenylpropane + methyloxirane Barium sulphate	1426	14

improved, if needed, by trimming the point with a scalpel. The point was then inserted into the canal with its tip covered with resin sealer (AH26, Dentsply-Maillefer). The gutta-percha master point was slowly down-packed driving the activated plugger through the point 1 mm shorter of the depth marked with the rubber stopper; at that level, heat activation was interrupted and the plugger pushed apically for 10 s. A further heat activation of 1 s was performed to detach the compacted apical gutta-percha from the rest of the point and then the plugger was extracted. The back-filling was performed using an Obtura syringe (Obtura Spartan Endodontics, Algonquin, IL, USA) and hand pluggers, leaving a coronal empty space of 9 mm. The quality of the endodontic obturation was verified radiographically. The orifice of the root canal was sealed with glass ionomer cement (Fuji II, GC Corporation, Tokyo, Japan).<sup>21</sup>

The specimens were stored in sterile saline solution at 37 °C. After 24 h, the glass ionomer cement was abraded with #240 silicon carbide discs under constant water irrigation.<sup>21</sup>

The characteristics of the tested posts are described in Table 2. Double taper (.02–.10) quartz fibre posts (DT Light Post #3, RTD, St-Egreve, France) were used in Group 1 (G1) (Fig. 1). The post space was prepared using a #3 calibrated bur mounted on a low speed handpiece under constant water irrigation. The post diameter at 9 mm from the apical tip was measured, resulting in 1.70 mm.

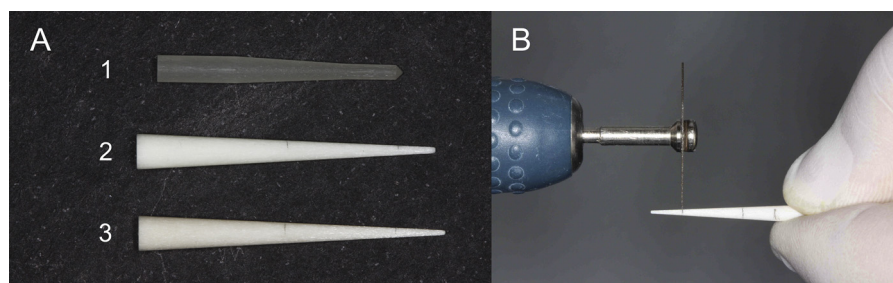
In Group 2 (G2) and Group 3 (G3), single taper (.10) glass (SurgiPost Multiconical, MC Italia, Lainate, Italy) and silica fibre posts (Tech ES Endoshape, ISASAN, Rovello Porro, Italy) were used (Fig. 1). In order to compare the fracture resistance values among groups, the diameter of all the posts at the canal orifice was standardised by marking all single taper

posts at the point where the diameter was 1.70 mm and cutting their tips 9 mm from this reference point with a 0.2 mm thick silicon carbide separating disc (Dedeco International Inc., Long Eddy, NY, USA) (Fig. 1). The fit of each post in the root canal was verified by means of standardised radiographs in both the buccolingual and mesiodistal directions using the positioning silicon templates as described above. Before cementation, all the posts were removed from the root canals and sectioned at 14 mm from the tip using the separating discs, so that each post protruded 5 mm from the canal orifice.

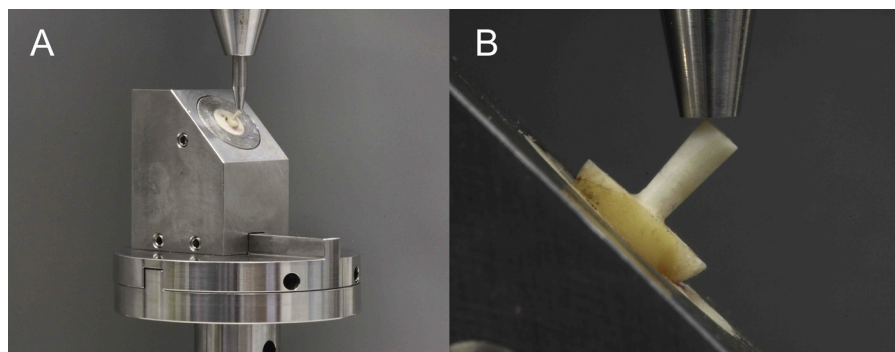
The post space was cleaned with an endodontic rotary brush (Versa Brush, Vista Dental Products, Racine, WI, USA) and then dried with paper points. A self-adhesive luting agent (RelyX Unicem Aplicap, 3M ESPE, St. Paul, MN, USA) was used to cement all the posts using specific intra-canal tips. After extruding the luting cement into the post space, the post was seated with a gentle rotation. The resin cement excess was removed with a manual instrument and the cement was light-cured for 40 s using a halogen unit at 600 mW/cm<sup>2</sup> (Elipar 2500, 3M ESPE). After cementation, the specimens were kept at 37 °C and 100% relative humidity for 24 h.

### Simulation of the supporting periodontal tissues

The external surfaces of the roots were isolated using glycerin gel. Each specimen was embedded in a mass of self-curing acrylic resin (Jet Kit, Lang Dental Manufacturing, Wheeling, IL, USA) and poured into a steel hollow cylinder having a height and diameter of 30 mm and a lumen of 15 mm. The coronal portion of the root protruded 2 mm from



**Figure 1** (A) The tested fibre posts as received by the manufacturers; 1: DT Light Post (Group 1); 2: SurgiPost Multiconical (Group 2); 3: Tech ES Endoshape (Group 3). (B) The cut of the tip of an experimental post.



**Figure 2** (A) The universal testing system used for the loading test. (B) A detail of the flat head stylus of the universal testing machine loading the specimens at 45° to the longitudinal axis of each tooth.

the surface of the acrylic resin. As soon as the resin started to set, each specimen was removed from the block, so as to avoid dehydration caused by the exothermic reaction of polymerisation. In order to simulate the viscoelastic behaviour of the periodontal ligament, a polyvinyl siloxane impression material (Flexitime, Heraeus Kulzer, Hanau, Germany) was injected in the space created by the roots in the resin; then each specimen was inserted again in the same space before the polymerisation of the impression material, allowing the polyvinyl siloxane to set in a thickness of about 200–400  $\mu\text{m}$ . Excess impression material was carefully trimmed after its complete polymerisation.

### Load to failure

A static controlled load was applied on the lingual surface of the head of each post at 45° to the longitudinal axis of the tooth by means of a universal testing machine (Galdabini Sun 500, Cardano al Campo, VA, Italy). A flat head stylus with a diameter of 3 mm and a crosshead speed of 0.75 mm/min was used (Fig. 2). All samples were loaded until fracture and the maximum failure loads were recorded in Newtons. After mechanical failure, the fracture mode was evaluated at 4 $\times$  magnifications.

### Scanning electron microscope analysis

A further evaluation of the quality of endodontic treatment and cementation of the posts was performed by means of a Scanning Electron Microscope (SEM) analysis (Quanta 250, Fei Company, Hillsboro, NE, USA).

Two representative specimens per group were prepared for SEM observation after the mechanical testing. Two grooves were created on the mesial and distal surfaces of the roots with a cutting disc, avoiding contact between the cutting disc and canal walls. The roots were then split into halves with a chisel. Samples were fixed in a 0.2 M buffered solution of 4% glutaraldehyde, dehydrated through multiple steps in alcoholic solutions with increasing concentrations, dried and sputter-coated with gold (Sputter Coater K550X, Fei Company). Images at 11 $\times$  and 250 $\times$  were acquired at the coronal, middle and apical third of each post.

### Statistical analysis

The data obtained from the mechanical tests were statistically analysed by means of dedicated software (Statistical Package for Social Sciences v.15, SPSS Inc., Chicago, IL, USA). All the datasets were analysed for distribution normality and variance equality with Shapiro–Wilk test and Levene test, respectively, to verify the assumptions for the use of parametric tests. A one-way analysis of variance and a Sheffé post hoc test for pairwise comparisons were used to assess the significance of the difference among groups in terms of mean maximum breaking load. In all the analyses, the level of significance was set at  $p < 0.05$ .

### Results

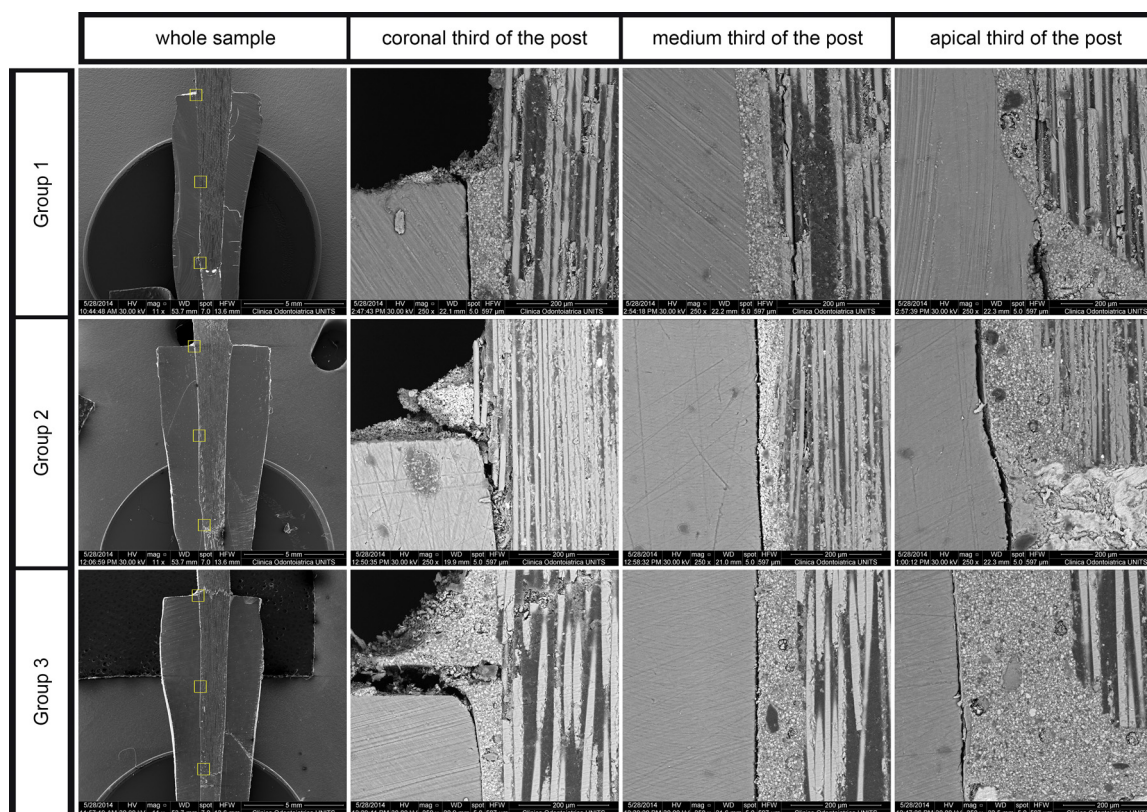
The mean values ( $\pm$  standard deviations) of the fracture loads recorded in N in each experimental group are shown in Table 3. The highest values of fracture resistance were recorded in G1, followed by G2 and G3 respectively. No statistically significant differences were reported between G1 and G2 ( $p > 0.05$ ), while significant differences were evidenced between G1 and G3 ( $p < 0.01$ ) and G2 and G3 ( $p < 0.05$ ). The qualitative analysis of the failure pattern only showed coronal fractures of the posts bending to failure at the canal orifice, while no root fractures were observed.

Comparing the SEM images of the various groups (Fig. 3), differences were noticed in terms of preservation of the original root canal anatomy and cement thickness at the post/dentine interface. Slight discontinuities in the root canal taper in the area of the post tip were observed in G1 and were ascribable to the action of the calibrated drill used to prepare the post space. Furthermore, thicker layers

**Table 3** Mean values ( $\pm$  standard deviations) of the fracture loads (N) recorded in the experimental groups.

Group	Post	Fracture load
G1	DT Light Post	165.05 $\pm$ 23.46
G2	SurgiPost Multiconical	151.52 $\pm$ 16.23
G3	Tech ES Endoshape	129.09 $\pm$ 15.25 <sup>a</sup>

<sup>a</sup> Statistically significant difference compared to G1 and G2 ( $p < 0.05$ ).



**Figure 3** Scanning electron microscope (SEM) microphotographs of Group 1 (DT Light Post), Group 2 (SurgiPost Multiconical) and Group 3 (Tech ES Endoshape). The yellow rectangles marked on the secondary SEM view of the whole sample (11 $\times$ ) highlight the areas of backscattered SEM magnification (250 $\times$ ) of the coronal, middle and apical thirds of the sample posts.

of cement were evident between posts and canal walls both in the apical area and at the middle third of the posts in G2 and G3 rather than in G1.

## Discussion

According to the results of the load-to-failure testing, the null hypothesis was rejected, since statistically significant differences were evidenced among groups in terms of mechanical resistance to fracture. DT Light Post and SurgiPost Multiconical fibre posts showed similar mechanical resistance to fracture and greater than Tech ES Endoshape. As widely demonstrated in literature, the post system has a relevant influence on fracture resistance.<sup>2</sup> With regard to fibre posts, there is a host of factors that act simultaneously and can further affect their mechanical properties, namely the diameter of the post at the canal orifice, the fibre/matrix ratio, dimensions, orientation, density and chemo-physical treatment of the fibres.<sup>22</sup> Our findings suggest that the fibre content alone is not indicative of the fracture resistance of the bonded post, since SurgiPost Multiconical posts have the highest fibre/matrix ratio (80%), followed by the DT Light Post system (64%) and Tech ES Endoshape (60%). The great mechanical resistance found in G1, despite the relatively low fibre content, could be justified by the number of quartz fibres per surface unit and their mechanical treatment; in fact, DT Light Posts have a very high density of pre-tensioned fibres (diameter 12  $\mu\text{m}$ , 32 fibres per  $\text{mm}^2$ ).<sup>23</sup> Furthermore,

this post system is the only one that makes use of a silane to improve the bond strength between the fibres and the resin matrix, and this could also contribute to improve the mechanical performance. According to the knowledge of the authors, to date no data are available in literature about the mechanical performance of SurgiPost Multiconical and Tech ES Endoshape posts, so a comparison of the results is not feasible. It is nonetheless noteworthy that the resistance values we obtained in all groups are considerably greater than those registered in previous studies with similar experimental set-up, testing the fracture resistance of other fibre post systems with comparable or slightly smaller diameters (1.38–1.70 mm).<sup>21,24</sup> In addition, during the mechanical tests performed in the present investigation, no root fractures were noticed in any of the experimental groups; such an occurrence could be explained considering that the elastic modulus of fibre posts is lower than metallic or zirconia posts and can be close to that of dentine. Fibre posts are known to cause significantly less catastrophic failures than other kinds of posts.<sup>25</sup> In light of these considerations, all the tested post systems exhibited a performance that supports their use in the clinical setting.

Changes in the experimental set-up can considerably affect the findings of the *in vitro* fracture resistance tests. An insertion depth of 9 mm was chosen in order to achieve the best post retention avoiding to weaken the root, as reported in recent investigations that showed no differences in fracture resistance seating fibre posts at depths of 5, 7 and 9 mm.<sup>26,27</sup> Posts with main taper of .10 were selected

because the single canal of single-rooted teeth is generally wide enough to receive such posts. Also, according to the instructions of the manufacturer, Mtwo files were used with a brushing motion against canal walls, thus causing a slight widening of the canal that increased the final taper of the coronal and middle canal thirds, exceeding that of the last rotary file.

The worst scenario was obtained by applying the experimental load directly on the post, in order to eliminate any interference of other variables involving the restorative materials and/or the residual tooth structure.<sup>21,24</sup> The simulation of the periodontal ligament was performed as it had already been demonstrated that it could influence both fracture resistance and the failure pattern of endodontically treated teeth.<sup>28</sup> Moreover, several three-dimensional anisotropic Finite Element Analysis (FEA) investigations have proved the paramount role of the periodontal ligament in distributing strains and dissipating stresses in post and core restored teeth.<sup>15,18</sup> In an FEA study<sup>29</sup> it was evidenced that the occurrence of root fractures was reduced in the presence of the periodontal ligament, due to the fact that its elastic modulus is much lower than that of the alveolar bone and ensures a more uniform stress distribution on both the tooth and the surrounding tissues.

The mean cement thickness around the post mainly depends on the congruence achieved between the shape of the post and the root canal walls. The preparation of a circular post space in tight, oval or irregular root canals with the aim of achieving the best fit for a post necessitates the removal of a significant amount of dentine, weakening the root and increasing the risk of perforations.<sup>30</sup> For this reason, the post space preparation should be minimally invasive, with minimum or no widening of the shaped root canal. The dimensions of the posts used in the experimental groups with single taper posts were standardised in length and diameter in order to compare the fracture values among different post systems: mechanical comparability was achieved by standardising the diameter at the canal orifice and the taper of the main portion of the post. Therefore, while the coronal fit of the single taper posts was optimal, the SEM observation revealed that the layer of cement around the post was moderately thicker at the middle and apical thirds of the posts in G2 and G3. Considering the optimal mechanical and adhesive properties of contemporary resin cements, the partially uneven distribution of the luting agent at the middle and apical thirds of the posts does not interfere with the mechanical performance of the restorative system.<sup>1,31,32</sup> It has already been shown that a fitting post is not an essential requirement for the improvement of fracture resistance.<sup>33</sup> In addition, the presence of a thicker layer of cement at the tip of the post would result in an improved passive fit, preventing the negative influence of the well-known "wedge effect".<sup>34,35</sup> Clinically, the post size should be chosen according to the best passive fit and the minimal taper, ideally corresponding to that of the root canal shaping with no further post space preparation. Despite all the operative efforts to prepare the root canal to receive the post and, vice versa, adapt the post to the canal, standardised shapes of prefabricated posts do not fit exactly with the complex anatomy of root canals. Consequently, the thickness of the resin cement around the post could differ significantly.<sup>36</sup> As to the possible loss of retention, some authors

have performed *in vitro* analyses on the influence of different cement thicknesses on the retentive forces of fibre posts to intra-canal dentine; however, no consensus has been reported about the ideal cement thickness to improve post retention.<sup>37</sup>

As a result of the dehydration caused by the preparation of the samples for the SEM analysis, cracks and ostensible gaps appeared at the interface between the dentine and the resin cement, as already observed in previous studies.<sup>38,39</sup> Owing to such a phenomenon, the interface between dentine and cement usually presents microcracks, since the dentine desiccates because of its hydrophilic characteristics while the cement and the post, both hydrophobic, keep the adhesive interface intact.

With regard to the cementation of fibre posts, resin cements have to be preferred to zinc oxide luting agents, since they provide better adhesion and are not affected by significant resorption. Moreover, resin cements present mechanical properties similar to those of fibre posts and dentine.<sup>3,40</sup> In the present study, RelyX Unicem self-adhesive cement was used: no significant differences were reported between its bonding strength and that provided by Panavia F (Kuraray), a dual cure cement with self-etching primer adhesive system.<sup>41</sup> Furthermore, RelyX Unicem showed values of adhesion comparable to those achieved with resin cements using etch-and-rinse adhesive systems.<sup>42</sup> The push-out force recorded for RelyX Unicem resulted to be comparable to that of Panavia F 2.0<sup>43</sup> and Variolink II dual curing cement.<sup>41</sup> According to a recent review that took into consideration the *in vitro* data available in literature, it is possible to state that the bonding strength of the most validated self-adhesive cements is comparable with the adhesion of different multi-step resin cements and satisfactory for clinical use.<sup>44</sup> Moreover, easy handling, repeatability and reduced chair-side time, as well as less operator- and technique-sensitivity, could explain how widespread self-adhesive cements have become in clinical practice.<sup>1,45</sup>

## Conclusion

Within the limitations of the present *in vitro* investigation, DT Light Post and SurgiPost Multiconical fibre posts showed similar mechanical resistance to fracture, which was higher than Tech ES Endoshape. Nevertheless, all the tested posts had high fracture resistance and none of the tested posts caused unrepairable root fractures.

In the same anatomical conditions, the use of single taper conical posts would be preferable than double taper posts, since they allowed for a more conservative post space preparation or no preparation at all. The slightly uneven cement distribution around the middle and apical third of the single taper conical posts can be minimised in the clinical setting by choosing a post with lower taper.

The findings of the present study lay the ground for further investigations to evaluate the clinical performance of the tested post systems.

## Conflict of interest

The authors have no conflicts of interest to declare.

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