

## Effects of threaded post placement on strain and stress distribution of endodontically treated teeth

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**Abstract:** The aim of this study was to evaluate the effect of parallel and tapered threaded post placement on the strain and stress distribution of endodontically treated teeth. Fifteen bovine incisors were sectioned 15 mm from their apices, endodontically treated, and divided into three groups ( $n = 5$ ) according to three different threaded posts: parallel threaded post (Radix-Anker, RA); tapered threaded post (Euro-Post, EP) and tapered threaded post (Reforpost II, RII). A strain-gauge was fixed on the proximal surface perpendicular to the long root axis, 2 mm from the cervical limit. Strain generated during post placement was recorded and compared using one-way ANOVA and Tukey's test ( $\alpha = .05$ ). A scanning electron microscope was used to examine the longitudinal root sections. Stress was evaluated for each group in a two-dimensional finite element analysis. The models were meshed with tetrahedron elements and loaded with 2 N at an angle of  $135^\circ$  to the lingual face. The equivalent Von Mises stress was calculated. The one-way ANOVA showed significant difference among the groups. The RA group ( $150.0 \pm 12.2$  A) produced higher external strain than the RII ( $80.0 \pm 12.2$  B) and the EP ( $70.0 \pm 6.1$  B) groups. The inner strain was approximately five times greater than the external dentin strain. High stress concentrations in each thread of the posts were observed. Scanning electron micrographs showed cracks that started in the threads of the posts. The threaded post placement induced root strain mainly on the parallel side post. Root strain and stress concentration on the post threads tended to create cracks in the inner root canal dentin.

**Descriptors:** Dental Stress Analysis; Dental Pins; Root Canal Therapy.

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### Introduction

Endodontically treated teeth have higher risk of biomechanical failure than vital teeth.<sup>1-5</sup> The likelihood of a pulpless tooth surviving is directly related to the quantity and quality of remaining tissue.<sup>5-8</sup> Posts may interfere with the mechanical resistance of teeth, thus increasing the risk of damage to the residual tooth structure.<sup>9-11</sup> The main purpose of a post is to provide retention for the core foundation, when there is an insufficient remaining clinical crown.<sup>12-14</sup> The retentive ability and the amount of stress generated during post placement are important factors to consider in post selection.

Although fiber post restorations have shown similar properties to

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those of dentin,<sup>15-17</sup> a wide variety of threaded posts continue to be used in restoring endodontically treated teeth. A threaded post system has the advantage of providing greater retention than passive posts, because the threads actively engage the dentin wall. However, increasing stress is exerted on the root structure when a post is threaded into the dentin wall.<sup>18,19</sup> As a result, there is a potential risk of vertical root fracture during the threading procedure or masticatory function, especially in anterior teeth undergoing tangential forces. Therefore, the following question must be asked with regard to clinical protocols: Can threaded posts continue to be considered an adequate option to restore endodontically treated teeth? The aim of this *in vitro* study was to access the stress distribution and the root strain during placement of different threaded posts. The research hypothesis tested was that different threaded posts exert different stress concentration and root strain on endodontically treated teeth.

## Methodology

### Sample preparation

Fifteen bovine incisors with similar root size and shape were selected by measuring the buccolingual and mesiodistal root widths in millimeters, allowing a maximum deviation of 10% from the determined mean.<sup>20</sup> The coronal portion of each tooth was sectioned 15 mm coronally from the root apex, using a diamond double-faced disk # 7020 (KG Sorensen, Barueri, Brazil).

After endodontic treatment, the gutta-percha was removed with hot pluggers to a depth of 10 mm. The roots were covered with a 0.3 mm layer of Impregum F (3M ESPE, St. Paul, USA) polyether impression material to simulate the periodontal ligament, and embedded in a polystyrene resin (Cristal, Piracicaba, Brazil) up to 2 mm below the cervical limit to simulate the alveolar bone.<sup>20</sup> The roots were divided randomly into 3 groups (n = 5) as follows:

- RA - Radix-Anker (Dentsply Mailleffer, Ballaigues, Switzerland) parallel threaded post,
- EP - Euro-Post (Anthogyr S.A., Sallanches, France) tapered threaded post, and
- RII- Reforpost II (Ângelus, Londrina, Brazil) tapered threaded post.

Post space was created in each root according to the manufacturer's instructions.

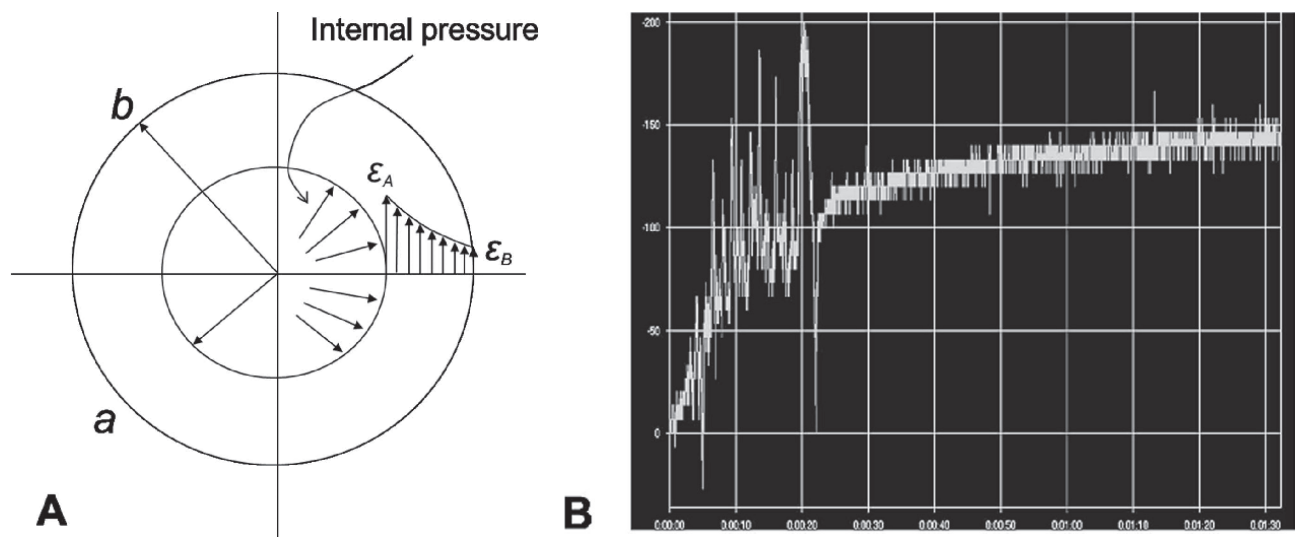
### Strain gauge test

A strain gauge PA-06-060BG-350LEN (Excel Sensores, São Paulo, Brazil) was attached to each specimen with cyanoacrylate glue (Super Bonder Loctite, USA) on the proximal surface, placed perpendicular to the long root axis, 3 mm below the coronal limit. The strain gauge wires were connected to the data acquisition device (ADS0500IP Lynx, São Paulo, Brazil). Each specimen was placed in a custom apparatus that enabled specimen stabilization. The root canals were etched with 37% phosphoric acid (Scotchbond Etchant, 3M-ESPE, St. Paul, USA) for 15 seconds, rinsed with water and dried with paper points. An etch-and-rinse 2-step adhesive (Single Bond Plus, 3M-ESPE) was applied to the root canal walls and polymerized for 20 seconds with a LED-curing unit (Rádii Cal; SDI, Victoria, Australia). Self-curing resin cement (Cement Post - Ângelus, Londrina, Brazil) was manipulated according to the manufacturer's instructions, introduced into the canal with a lentulo spiral drill (Dentsply Mailleffer), and placed on the post. Post threading was carried out manually and the induced strain was recorded. Data was evaluated statistically by one-way ANOVA ( $\alpha = .05$ ) and Tukey's post hoc test (SPSS IBM corporation, New York, USA). The strain variation that occurs across a thick cylinder with an internal and an external radius is described in Figure 1A. The strain in a thick cylinder that has internal pressure is higher in the interior of the canal and decreases the closer it comes to the external surface. The equation used to calculate the relation between the internal and external strain is:

$$\epsilon_{A/B} = (b^2 + a^2) / 2a^2,$$

where  $\epsilon_{A/B}$  = the relation between internal strain and external strain;  $a$  = internal canal radius; and  $b$  = external canal radius.<sup>21</sup>

The value of the residual strain is shown in Figure 1B.



**Figure 1 - A:** Thick cylinder diagram; **B:** External root strain induced by the Radix threaded post.

### Scanning electron microscopy (SEM)

For the purpose of scanning electron microscope analysis, the roots were sectioned longitudinally and submitted to dowel-dentin interface analysis by SEM (LEO Electron Microscopy Ltd., Cambridge, UK) with standardized magnification.

### Finite element method

Three two-dimensional finite element models were created, representing each experimental group. The models were constructed from a scanned longitudinal section of a root, with a post from each group restored with a ceramic crown. The geometry and contours were determined and established using the Mechanical Desktop AutoCAD V6 program (Autodesk, San Rafael, USA). The contours were exported to Ansys 9.0 finite element analysis software (Ansys Inc., Houston, USA). Areas with different material properties were identified and meshed (Figure 2A) with eight-noded isoparametric plane elements (PLANE183), totaling 37,698 elements per model, assuming plane strain conditions. All materials were considered elastic, isotropic, and homogeneous. The applied mechanical properties, namely the elastic modulus (GPa) and Poisson's ratio, were as follows, respectively:

- trabecular bone: 13.7/0.3;
- cortical bone: 13.7/0.3;
- periodontal ligament: 0.06/0.45;

**Table 1 -** Mean strains values (SDs) and statistical categories defined by the Tukey test ( $n = 5$ ;  $\mu\text{S}$ ).

Threaded post	External strain	Calculated internal strain
RA – Radix-Anker	150.3 (12.2) <sup>A</sup>	750 (61.2) <sup>A</sup>
RII – Reforpost II	80.6 (12.2) <sup>B</sup>	400 (61.2) <sup>B</sup>
EP – Euro-Post	70.2 (6.1) <sup>B</sup>	350 (30.6) <sup>B</sup>

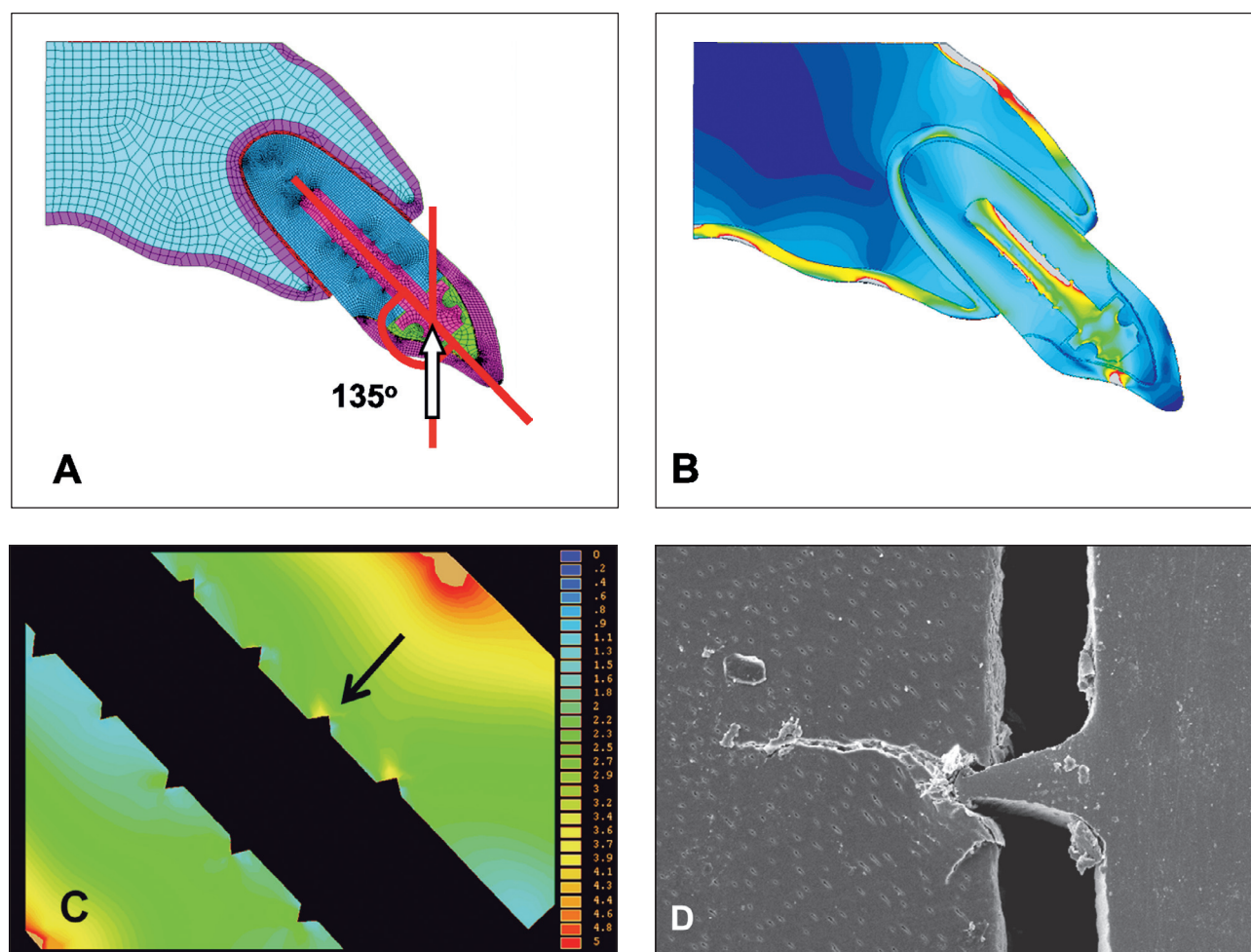
\*Different letters represent significant differences ( $p < 0.05$ ).

- dentin: 13.7/0.3;
- gutta-percha: 0.006/0.45;
- resin cement: 5.1/0.27;
- threaded metallic post: 210.0/0.3;
- composite resin core: 16.6/0.24;
- feldspathic ceramic: 69.0/0.3.

A total load of 2 N was applied on two adjacent nodes (1 N each) at the palatine surface, at a 135° angle to the longitudinal axis of the tooth (Figure 2A). Von Mises equivalent stresses were determined for stress assessment (Figure 2B).

### Results

Root strain means and standard deviations during the post placement are shown in Table 1. One-way ANOVA showed that there was a significant difference in root strain induced by threading of the different posts. Tukey tests revealed that the RA group resulted in significantly higher strain values



**Figure 2 - A:** External and internal contour; meshed model; load application on palatine face; **B:** Equivalent Von Mises stress distribution; **C:** High stress concentration at the post thread end in the Radix-Anker model; **D:** Crack formed by Euro-Post threading.

than the RII and EP groups. High stress concentration in the dentin wall at the thread ends of all posts tested was observed for all models (Figure 2C). The scanning electron micrographs showed cracks in the dentin walls caused by threading of the posts (Figure 2D). The SEM image represents important information on the presence of cracks in the dentin walls, confirming previous studies.

## Discussion

The tested hypothesis was accepted. Different threaded posts indeed increased the stress concentration and root dentin strain of endodontically treated teeth at different levels. The biomechanical analysis of tooth structures and restorative materials showed that the destructive mechanical tests

used to determine fracture resistance are an important means of analyzing tooth behavior in situations of punctual and high intensity load application.<sup>6</sup> They do, however, present limitations with regard to obtaining information on the internal behavior of the tooth-restoration complex.<sup>21</sup> Therefore, it is important to associate non-destructive methodologies, such as strain gauge measurement, and computational analysis, such as finite element analysis, to provide a clearer understanding of the biomechanical behavior of a restorative procedure.<sup>3</sup>

Strain gauges were fixed on the proximal surface, placed perpendicular to the long root axis, and used to measure the tensile strain of the proximal surface induced by the placement of the posts. This tensile strain starts inside the root canal and can spread

through the cracks leading to a catastrophic fracture of the structure. It is important to remember that the strain values shown are the residual strains resulting from post placement, after the root is at rest. Because residual strain did not dissipate with time (Figure 1B), it increased the risk of the root fracture.

Strain variation occurs across a thick cylinder, like root dentin. The strain in a thick cylinder is higher in the interior of the canal and decreases towards the external surface. In this study, roots with approximately 1 mm of internal radius and 3 mm of external radius were used, and the internal strain was five times higher than the external strain, as shown in Table 1.

Threaded posts with larger diameters resulted in a higher depth of threaded embedment into root dentin. When these posts are turned, strain peaks are generated. A final point relates to the thread embedment of the various posts into dentin. Theoretically, the deeper the embedment created, the deeper the cut into the dentin and the higher the strain generated. The RA is a parallel-side post. Consequently, its threads in the post apex are closer to the external surface, making them responsible for the root strain. This may explain the higher strains observed during RA threading over the EP and RII posts, insofar as they are tapered and have active threads only in the cervical portion.

When a root post is necessary, the choice for a post system should be defined for each one that generates the least amount of stress, which may provide more longevity for the restoration.<sup>22</sup> The post material should have an elasticity modulus similar to root dentin in order to distribute the applied forces evenly along the length of the post and the root.<sup>17,23</sup> The threaded posts tested in this study have a high elasticity modulus, resulting in stress concentration at the root canal walls at the post thread end (Figures 2B and 2C). Stress concentration accounted for crack formation and propagation to the external surface of the root, resulting in root fracture.<sup>24</sup> SEM analysis showed cracks formed by post threading (Figure 2D). These cracks started at the post thread end and coincided with stress concentration areas observed in the finite element analysis. We

could clearly observe a correlation among strain, stress, and cracks in the biomechanical behavior of the endodontically treated teeth analyzed in this study. The residual strain inside the root canal may increase crack propagation under fatigue, leading to root fracture.

This study had the advantage of using nondestructive tests, like strain gauge measurement, and numerical analysis as a finite element associated with SEM analysis. However, it also had some limitations, such as using two-dimensional analysis. Generally, three-dimensional numerical models are preferred because these models show greater anatomic detail.

The correct root posts should be chosen based on scientific findings and professional good sense, seeking to obtain the best biomechanical characteristics. When considering the restoration of endodontically treated teeth, it is not enough to think only about the high retentive values without analyzing the potentially irreparable consequence to the dental structure. This study corroborates the principle that metallic threaded posts should be avoided as inserts into the root canal.

## Conclusion

- Within the limitations of this *in vitro* study, the following conclusions were drawn:
- The placement of threaded posts induced high root strain values.
- Root strain values are higher in parallel-side posts than in tapered posts.
- Stress concentration was observed at the post thread end in the inner dentin of the root canal.
- The threading of the post generated cracks in the root canal, irrespective of post configuration.

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