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Original Article

Evaluating the impact of varying post angulations on the fracture resistance of maxillary incisors restored with polyethylene fiber posts

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Abstract *Background/purpose:* Restoring anterior teeth requiring angulation correction remains clinically challenging. Polyethylene fiber posts have been introduced, offering superior adaptability within the root canal and improved aesthetics. However, the effect of varying degrees of post angulation on the fracture resistance of restored teeth has not been thoroughly investigated. This study aimed to evaluate the fracture resistance of maxillary incisors restored using polyethylene fiber posts at varying angulations.
Materials and methods: Thirty-two extracted incisors were selected according to the study criteria. Root canal treatment and gutta-percha removal were performed to prepare for polyethylene fiber posts. All study samples were subsequently divided into four groups of angulations: P1 (5°), P2 (10°), P3 (15°), and a control group (0°). Fracture resistance was tested, and the data were analyzed using one-way ANOVA followed by Post-Hoc comparison with the least

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significant difference (LSD) statistical tests.
Results: A statistically significant difference in fracture resistance was observed among the groups, with group P1 demonstrating the highest fracture resistance (281.29 ± 84.97 N) and the control group exhibiting the lowest (164.75 ± 41.75 N).
Conclusion: There was a difference in the fracture resistance of the maxillary incisors when using polyethylene fiber posts at angulation degrees of 5° and 0°, and angulation degrees of 5° and 15°. Therefore, anterior tooth restoration with angulation correction of 5°—10° can utilize polyethylene fiber posts.

Introduction

The structural integrity and long-term durability of post-endodontic restorations are critical to the clinical success and sustained functionality of endodontically treated teeth. Anterior teeth support facial aesthetics, maintain occlusal integrity, and facilitate clear phonetic articulation. Accordingly, their rehabilitation necessitates careful consideration of both aesthetic and biomechanical factors. The post and core system remains a foundational strategy, particularly for rehabilitating extensively compromised anterior teeth.[1,2] Clinicians face a significant challenge in restoring anterior teeth that require angulation correction to improve aesthetics. Beyond achieving aesthetic improvement, tooth angulation correction must also consider the biomechanical forces received on the tooth, particularly the crown-root angle and facial angle.[3,4]

Maxillary anterior teeth with complex anatomy often require custom post designs with angulation correction, which were previously overcome by custom metal posts.[4] Although custom metal post and core systems capable of accommodating angulations of up to 20° are considered a safe and viable option for post-endodontic restoration rehabilitation.[5] However, the utilization of custom metal posts and core systems necessitates extensive removal of tooth structure within the root canal, is associated with a higher modulus of elasticity, and presents inferior aesthetic outcomes.[6] Therefore, a more conservative post and core system is required, with biomechanical properties similar to the tooth structure and enhanced aesthetic integrity.

Polyethylene fibers, characterized by their aligned polymer chain structure, low modulus of elasticity, and low density, are widely employed in various dental applications, such as splinting materials, tooth replacement, cavity reinforcement, and intracanal posts for endodontically treated teeth. As an intracanal post, polyethylene fiber posts effectively offer the advantages of clinical customization and adaptability.[3,7,8] Additionally, polyethylene fiber exhibits excellent mechanical properties, including a high elastic modulus and tensile strength, combined with superior adaptability, which renders them particularly suitable for the post and core system in anterior teeth requiring angulation correction. Furthermore, their white coloration enhances their applicability in aesthetic restorative procedures.[7,9—11]

A recent study demonstrated that polyethylene fiber posts facilitate uniform stress distribution and provide rigid reinforcement, effectively minimizing fracture propagation and surface deformation.[12] Although widely utilized in various dental applications, their role as intraradicular posts remains relatively underexplored in the current literature. Considering their clinical advantages, the frequent need for angulation correction, and the growing emphasis on minimally invasive dental restoration, this study investigates the fracture resistance of the maxillary incisor teeth restored with polyethylene fiber posts at varying degrees of angulation.

Materials and methods

Sample preparation

A total of 32 extracted human maxillary first incisors have been selected with approval of the Institutional Review Board of the Dentistry Faculty of Hasanuddin University, Makassar, Indonesia (No.0267/PL.09/KEPK FKG-RSGM UNHAS/2023). All teeth used in this study were extracted for periodontal reasons, had straight root canals, and completely developed apices. Teeth with previous endodontic treatment, root fracture, or caries were excluded. Samples were cleaned and stored in saline solution before treatment. The crowns were transversely sectioned using a diamond disc bur (Komet; Henry Schein, Melville, NY, USA), preserving 2 mm of coronal tooth structure above the cementoenamel junction (CEJ). After the access cavity was prepared with an endo access bur (Dentsply Maillefer, Tulsa, OK, USA). A #15 K-file (Dentsply Maillefer) was inserted into the root canal until the tip reached the apical foramen, and the final working length was established 1 mm short of this point. Root canal instrumentation was performed with the crown-down pressureless technique, using Protaper Gold rotary files (Dentsply Maillefer) up to file size #F3, followed by irrigation with 2 mL 2.5 % sodium hypochlorite (NaOCl) (Onemed, Surabaya, Indonesia). Final irrigation was carried out using 1 mL of 17 % ethylenediaminetetraacetic acid (EDTA) (MD-Cleanser; Meta Biomed, Cheongju-si, Republic of Korea), followed by a final rinse with sterile distilled water. The canals were dried using size-matched paper points and obturated with Protaper Gold #F3 gutta-percha (Dentsply Maillefer) and AH Plus resin sealer (Dentsply Maillefer).

Post and core preparation

After 24 hours, gutta-percha was removed using a hot plugger (Fast-Pack; Eighteenth Sifary, Changzhou, China), leaving 4 mm to maintain the apical seal. Ferrule preparation was performed at a coronal level of 2 mm to CEJ. The post and core length was standardized to 14 mm for all samples. Polyethylene fiber tape (Construct, Kerr, Brea, CA, USA), measuring twice the length of the post and core, was folded and adapted to fit accordingly. Post cementation was performed using a self-etch resin cement system. A Single Bond Universal Adhesive (3M ESPE™, St.Paul, MN, USA) was applied to the root canal utilizing a microbrush and left in place for 10 s. The canal was then gently air-dried for 5 s to maintain a moist surface, followed by Noblesse E dual LED curing light for 10 s (Max Dental, Gyeonggi-do, Republic of Korea). To enhance bonding, a wetting resin (PermaSealTM; Ultradent, South Jordan, UT, USA) was applied to the polyethylene fiber tape. A resin cement (Luxacore Z Dual; DMG Dental, Hamburg, Germany) was applied to the root canal walls, after which the polyethylene fiber tape was inserted into the canal using an endodontic plugger. Additional cement was reapplied between the layers of the polyethylene fiber to ensure complete adaptation. Excess cement was removed, and the material was light-cured for 20 s using a light-curing unit.

The core portion of the restoration was then built up using a core build-up composite resin (Luxacore Z Dual; DMG Dental). The degree of angulation of the post and core was assigned according to the treatment protocol: group P1 (5° angulation), group P2 (10° angulation), group P3 (15° angulation), and the control group C (0° angulation). The angle between the long axis of the tooth and the polyethylene fiber post, along with the core build-up, was adjusted according to the specified degree of angulation of each group, and then cured for 20 s (Fig. 1). To replicate the size and shape of the core in the research sample, an impression was made using an elastomer putty consistency impression material. The size and thickness of the core were subsequently standardized using a vernier caliper (Mitutoyo, Kawasaki, Japan).

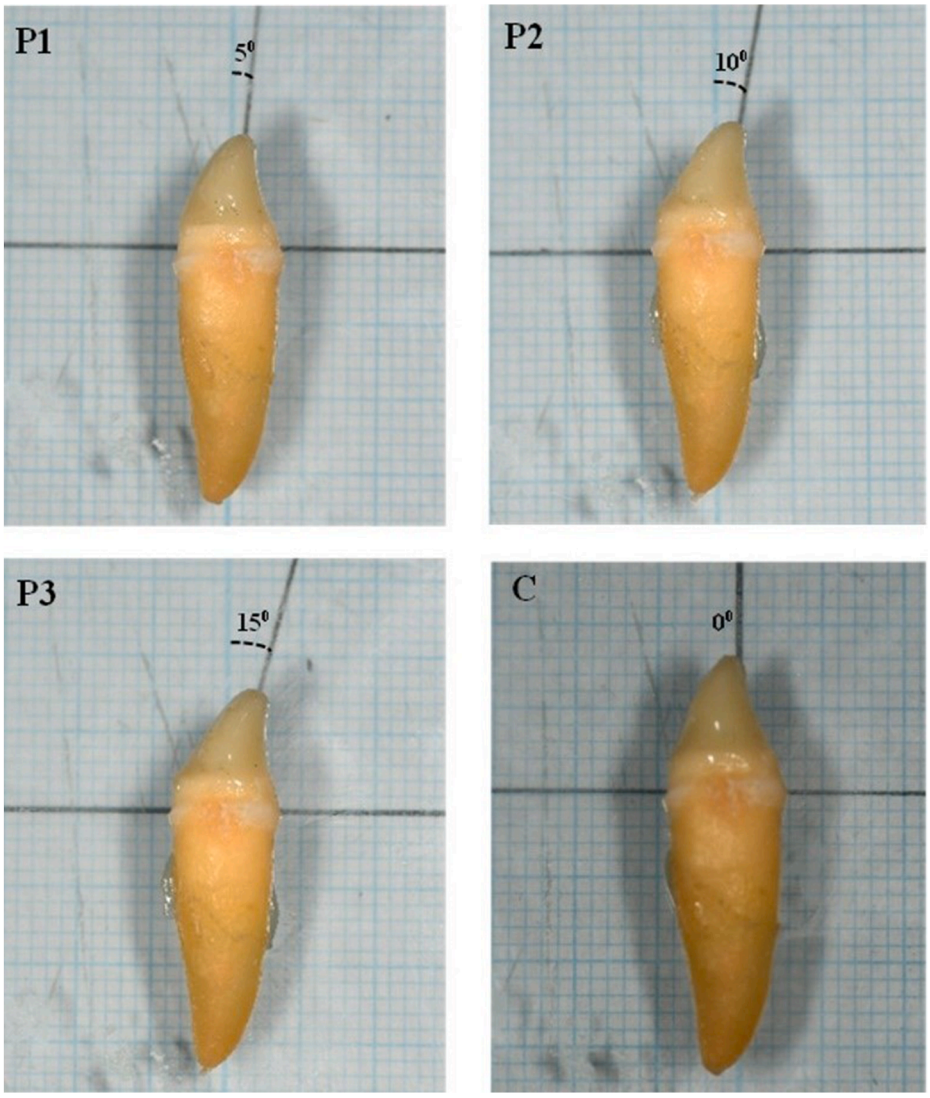

Figure 1 Core build-up with varying angulation degrees was performed as follows: P1 = 5° angulation; P2 = 10° angulation; P3 = 15° angulation; C = 0° angulation.

Figure 2 The samples were embedded up to CEJ on epoxy resin clear, a self-curing acrylic block.

Fracture resistance analysis

All samples were embedded up to the CEJ in self-curing acrylic blocks (Epoxy Resin Clear; Vouch Abadi, Bekasi, Indonesia), measuring 1.5 cm in length, 1.5 cm in width, and 2 cm in height (Fig. 2). The samples were stabilized and maintained in position until the self-curing acrylic had completely polymerized. The fracture resistance test was performed using a Universal Testing Machine (UTM) (Autograph AGSX 50 KN; Shimadzu, Kyoto, Japan) (Fig. 3). The compressive force was applied to the palatal surface of the composite core (3 mm from the incisal) at an angle of 135° to the long axis of the tooth. The tool was activated at a speed of 0.5 mm/min until fracture. The results of the fracture resistance were recorded in Newton (N).

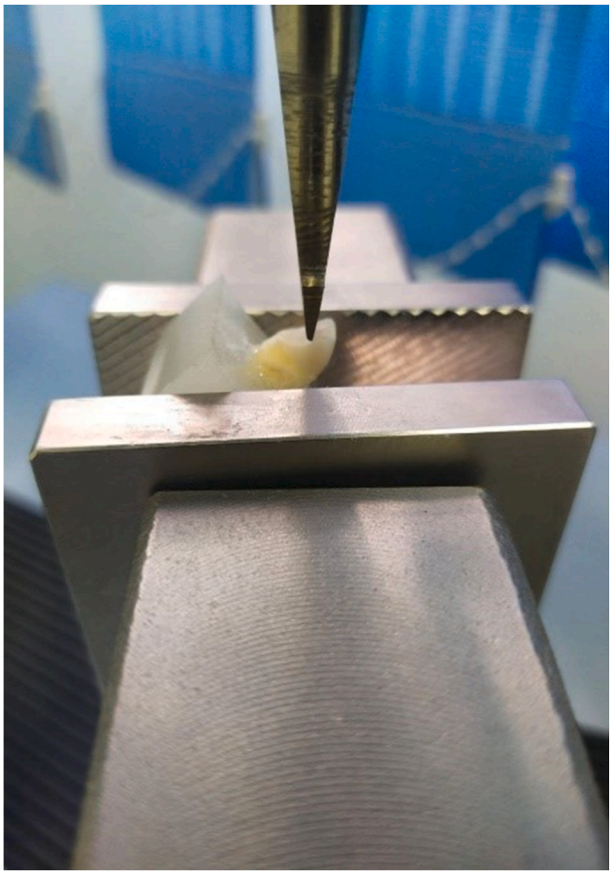

Figure 3 Fracture resistance testing of the samples was evaluated using a universal testing machine.

Statistical analysis

The data analysis was performed using one-way ANOVA, followed by Post-Hoc LSD test with a significance level of $P < 0.05$ applied for all tests. Analyses were performed using SPSS version 26 for Windows and R-studio software (version 2023.06.01).

Result

Fracture resistance values of maxillary incisors restored with polyethylene fiber posts at various angulation degrees

The fracture resistance values of the teeth across the different treatment and control groups were analyzed using one-way ANOVA. The results demonstrated a statistically significant difference in mean fracture resistance among the groups ($P < 0.05$), indicating that variation in the angulation degrees of polyethylene fiber posts significantly affected the fracture resistance of maxillary incisors (Fig. 4).

The mean fracture resistance values of maxillary incisors restored with polyethylene fiber posts at varying angulation exhibited a decreasing trend with increasing angulation. The highest mean fracture resistance was observed in the 5° angulation group (281.29 ± 84.97 N), followed by the 10° group (222.87 ± 104.04 N) and the 15° group (176.85 ± 75.04 N). The control group, with 0° post angulation, showed the lowest mean fracture resistance at 164.75 ± 41.75 N. The lowest mean value was recorded among the treatment groups in the 15° group.

Comparative analysis of fracture resistance in maxillary incisors restored with polyethylene fiber posts at varying angulations

According to the results of the Post-Hoc LSD test, a statistically significant difference in fracture resistance was observed between group 1 and group 3 ($P < 0.05$). Additionally, a significant difference was found between group 1 and the control group ($P < 0.05$) (Table 1).

Significant differences in fracture resistance were observed when comparing group P1 with both group P3 and the control group, suggesting that post angulation substantially affects the mechanical performance of incisor restorations.

Discussion

The success of endodontically treated teeth is influenced by multiple factors, among which the quality of the final restorations is critical. An ideal restorative material must restore form and function, provide a reliable seal, and reinforce the remaining tooth structure.[8,13,14] Both intraradicular and coronal are essential for long-term structural

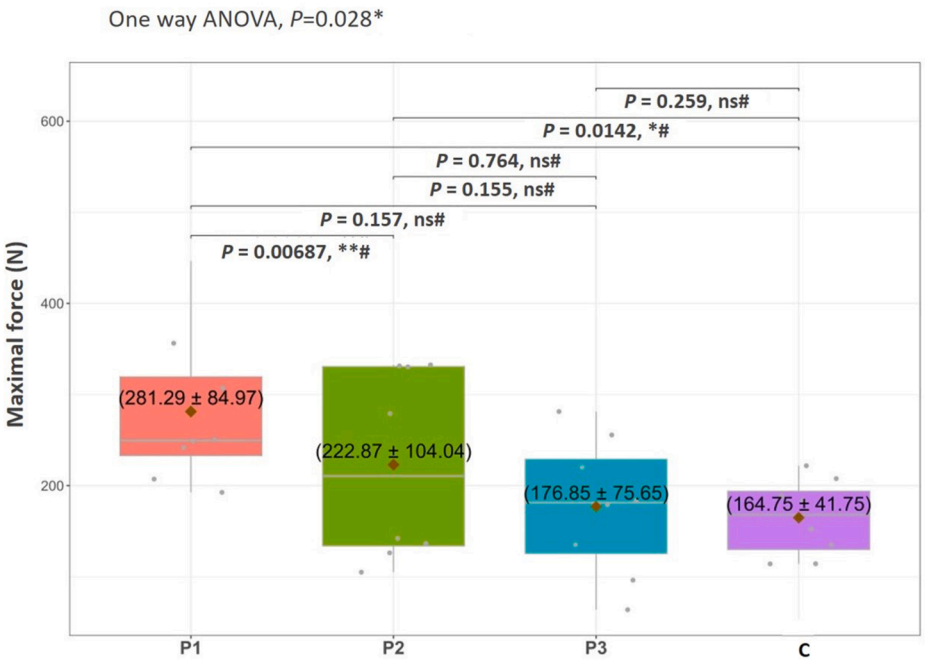

Figure 4 Maximal force (N) measured in four groups (P1, P2, P3, and C), data are shown as mean ± SD. One-way ANOVA revealed a significant difference among groups ($P = 0.028$,*), and post hoc LSD test showed significant differences between P1 and P3 ($P = 0.0069$,**) and P1 and C ($P = 0.0142$,*). Other comparisons were not significant. Significance codes: $P < 0.05$*; $P < 0.01$**; ns not significant; # one-way ANOVA with post hoc LSD test.

Table 1 Comparison of incisor fracture resistance at varying degrees of polyethylene post angulation between research groups.

Group		Mean difference	*P* value	95 % CI	
				Lower bound	Upper bound
P1	P2	58.42	0.155	−23.37	140.21
	P3	104.44	0.014*	22.64	186.23
	C	116.53	0.007*	34.74	198.33
P2	P3	46.02	0.259	−35.77	127.81
	C	58.12	0.157	−23.68	139.91
P3	C	12.10	0.764	−69.69	93.89

*Statistically significant difference ($P < 0.05$).

integrity. In anterior tooth restoration, angulation correction presents a clinical challenge in achieving optimal aesthetics with adequate fracture resistance.[3,4,15] Previous approaches to angulation correction were overcome by using custom metal posts. However, this method presents several drawbacks, including requiring more tooth structure removal, a higher elastic modulus than dentin, and compromised aesthetics.[6] To overcome these limitations, various techniques have been developed, including using polyethylene fiber posts. Polyethylene fiber posts are flexible, ribbon-like composites designed to conform to root canal anatomy without requiring canal enlargement, thereby preserving more of the natural tooth structure. Their pliability before curing allows precise adaptation, supporting conservative and aesthetic restorations.[3,10] The cross-linked fiber threads pattern enhances mechanical interlocking and facilitates angulation correction.[11,16] Moreover, their translucency provides superior aesthetic outcomes compared to metal posts without compromising tooth fracture resistance.[6,7,9]

This study evaluated the fracture resistance of endodontically treated teeth restored with polyethylene fiber posts at varying angulations. Statistically significant differences were observed among groups ($P < 0.05$), likely due to the influence of angulation on stress distribution along the intraradicular post. This finding is consistent with a previous study by Haralur et al. (2017), which demonstrated significant differences in fracture resistance based on varying post angulations.[4] The vertical overlap of the anterior teeth influences occlusal forces during functional activities such as biting or incising. This overlap results in the transmission of forces at an oblique angle rather than along the axis of the teeth.[17] During mastication, occlusal forces applied to the maxillary anterior teeth generate rotational movements around a cervical fulcrum, resulting in compressive stresses on the buccal surface and tensile

stresses on the palatal surface of the intraradicular post. An imbalance favoring excessive compressive forces relative to tensile forces may lead to tooth fracture.[18]

Alterations in post angulation affect occlusal stress distribution, increasing horizontal stress and concentrating stress in the cervical region, thereby impacting fracture resistance.[5,19,20] In this study demonstrated a statistically significant difference in fracture resistance between polyethylene fiber posts at 5° and 15° angulations. Notably, angulations between 5° and 10° demonstrated enhanced fracture resistance, attributed to improved alignment with functional loading and more favourable stress distribution within the tooth structure. Conversely, the 0° angulation group showed the lowest fracture resistance. Aligns with the biomechanics of maxillary incisors, which are predominantly exposed to oblique biting forces. Axial orientation under such loading conditions generates significant bending moments, contributing to lower resistance.[21] This study highlights the critical importance of post angulation in optimizing the biomechanical performance and longevity of endodontically treated teeth. Consistent with a previous study, increased post angulation correlated with decreased fracture resistance, as force transmission shifted toward the cervical-palatal regions, thereby increasing the risk of structural failure.[5]

The load point location on the palatal surface influences the pressure test values. Polyethylene fiber posts angled at 5° distribute stress more evenly along the tooth due to their proximity to the occlusal fulcrum, enhancing pressure resistance. In contrast, posts angled 15° shift the load closer to the cervical fulcrum, concentrating stress at the cervical region, reducing root flexibility, and increasing fracture risk.[22,23] A significant difference in fracture resistance was observed between the 5° post angulation and the control group with posts placed parallel to the long axis of the tooth. This finding aligns with the study by Godla et al. (2019), which demonstrated that endodontically treated teeth restored with intraradicular posts aligned parallel to the tooth's long axis exhibited different stress distribution patterns compared to those with angulated posts. Compressive forces are more effectively distributed along their length when posts are aligned parallel to the long axis. However, angulated posts increase stress concentration due to altered force transmission. Consequently, stress distribution in polyethylene fiber posts is influenced by the degree of angulation, even when load magnitude and direction remain constant.[5]

A study has demonstrated that the circumferential positioning of polyethylene fiber posts can enhance the fracture resistance of teeth compared to other placement techniques.[2] Furthermore, a systematic review reported that fiber posts, including polyethylene types, improve fracture resistance in endodontically treated teeth, with a standardized mean difference favouring their use over non-fiber or conventional post systems.[24] This improvement is primarily attributed to their high elasticity modulus and superior resistance to strain, distortion, and tensile forces, which enable the fibers to adapt well to the contour of the root canal.[6] The isotropic stress distribution of the fiber post further facilitates a monoblock system between the post, core, and surrounding dentin, promoting more uniform force transmission along the root structure.[16] Moreover, polyethylene fiber posts possess an elastic modulus similar to dentin and reinforce the composite resin in all directions, enhancing the fracture resistance of restored teeth.[25]

Fracture resistance in anterior tooth restorations involving angulation correction is influenced not only by the degree of angulation and the type of post used, but also by the adhesive system employed for post cementation.[26,27] Polyethylene fiber posts are custom-formed and cemented with dual-cure resin cement. This study employed a self-etch adhesive technique to enhance post-retention. This method is supported by previous findings, which demonstrated that universal adhesive used in self-etch mode significantly improves bond strength compared to the conventional two-step and rinse technique.[28,29] These results suggest that the self-etch approach offers superior bonding performance and may contribute greater clinical reliability in fiber post restorations. Furthermore, it eliminates the requirement for stringent moisture control within the root canal, facilitating the formation of an effective monoblock between the fiber post and the surrounding tooth structure.[16,30]

In this study, the fracture resistance of teeth restored with polyethylene fiber posts ranged from 164.75 to 281.29 N, aligning with the average human central incisor mastication forces of 93.88—146.17 N.[31,32] These results support the clinical applicability of polyethylene fiber posts for anterior tooth restorations requiring angulation corrections. Furthermore, no significant difference in fracture resistance was observed between 5° and 10° post angulation degrees, indicating that posts within this angulation range can be effectively utilized without compromising structural performance. Complementary to these findings, Ramírez-Gómez et al. (2023) reported that the orientation of polyethylene fiber posts influences the fracture resistance of endodontically treated teeth, particularly when posts are placed at varying angulations. The study highlights that proper fiber alignment improves stress distribution, reducing force concentration and enhancing tooth strength.[33] This suggests that angulation and orientation should be considered together to optimize the structural integrity of restored teeth.

Based on the findings of this study, significant differences in fracture resistance of maxillary incisor teeth were observed when polyethylene fiber posts were placed at an angulation of 5° compared to 0° and 15°. However, within a 5°—10° angulation range, no statistically significant differences in fracture resistance were noted. Therefore, polyethylene fiber posts can be considered a viable option for anterior tooth restoration requiring moderate angulation correction within this range.

Declaration of competing interest

The authors declare no conflict of interest relevant to this study.

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