To evaluate the fracture resistance of proclined endodontically treated teeth with different post and core systems: *In vitro* study

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**Abstract**

**Aim:** This study was aimed to evaluate the fracture resistance of proclined endodontically treated teeth with different post and core systems.

**Settings and Design:** Experimental *in vitro* study.

**Methodology:** Eighty extracted maxillary central incisors were selected and decoronated keeping 2 mm of crown ferrule and were endodontically treated. Postspace was prepared retaining 5 mm apical gp using peeso 3. Samples were divided into two groups. In Group 1, Wax pattern fabricated to accommodate different core angulations to be casted with Ni-Cr alloy. In Group 2, ever stick posts were angulated and cemented followed by porcelain fused to metal crown cementation for both the groups. Samples were thermocycled and subjected to the universal testing machine.

**Statistical Analysis Used:** One-way ANOVA and Tukey’s *post hoc* test were used to compare the mean fracture resistance between different angulations in cast post and ever stick posts. Student’s paired *t*-test was used to compare the mean fracture resistance between cast post and everstick posts for each angulations. *P* value was set at *P* < 0.05.

**Results:** The fracture resistance was the highest at 20° and lowest at 30° core angulations in both the groups.

**Conclusions:** Changing core angulation up to 20° can be carried out safely using any of the post systems tested in the study. Core angulations >20°, should be used with caution, especially in patients with abnormal parafunctional habits and occlusal trauma.

**Keywords:** Custom cast post; everstick; fracture resistance; universal testing machine

**INTRODUCTION**

A prevalence of 14.9% of traumatic injuries to anterior teeth was found in the study population with sports activities being the most common cause. Increased overjet and inadequate lip coverage were significantly associated with the occurrence of trauma.[1] Such trauma may result in injury of the pulp with or without damage to the crown or root.

Spear and Kokich, in their review, stated that if teeth are retroclined or proclined, correction may require performing either orthodontics or extensive restorative dentistry and possibly endodontics to establish a more ideal labiolingual inclination.[2] Custom cast post and everstick posts have been clinically practiced in cases that require angulation change with good success rates, but there is a lack of evidence in literature about the optimal level of core angulation that can be achieved without any detrimental effect on the tooth. Therefore, this study was designed to evaluate and compare the fracture resistance of endodontically treated central incisors restored with cast posts and everstick posts.

[1] Spear L, Kokich V. Current concepts and management of traumatic injuries to anterior teeth. J Esthet Restor Dent 1995;7:126-39.

[2] Spear L, Kokich V. Management of traumatic injuries to anterior teeth: Part 2. J Esthet Restor Dent 1997;9:131-42.
at varying core angulations of 0°, 10°, 20°, and 30° to the long axis of the tooth and to observe the fracture patterns of the restored teeth on failure and to analyze the correlation between fracture patterns and varying core angulations. The null hypothesis was that there would be no significant difference in the fracture resistance of the tooth with increase in the core angulation and that there would be no difference in the fracture resistance between cast post and everstick post with varied core angulations.

**METHODOLOGY**

**Source of data**
Eighty caries free and restoration free intact human maxillary central incisors were collected from the Department of Oral and Maxillofacial Surgery, Dayananda Sagar College of Dental Sciences.

**Inclusion criteria**
Eighty intact human maxillary central incisors of similar dimensions with straight roots and single canal.

**Exclusion criteria**
- Carious teeth
- Preexisting fractures or cracks
- Previous restorations
- Previous endodontic therapy.

All samples were cleaned of any calculus and soft-tissue deposits using hand scaler (Gracey curette SG 17/18; Hu-Friedy, Chicago, IL, USA) and were carefully examined under the light microscope for any existing enamel crack or fracture. Teeth were stored in 0.05% chloramine solution for 48 h, and then, transferred to distilled water until the preparation time. The crowns were severed using diamond disc to ensure a standard length of 15 ± 0.5 mm of root length and 3 mm of coronal tooth structure above cementoenamel junction (CEJ). Working length was determined using 15 k file, radiographically. Gates Glidden drills of sizes 1, 2, and 3 were used for coronal flaring. Cleaning and shaping were done in a step-back technique using k files to result in an apical preparation corresponding to 60 k file. During preparation, the canals were irrigated with 3% sodium hypochlorite, alternating with 17% ethylenediaminetetraacetic acid. Final irrigation was done using sterile distilled water and obturated using the International Organization for Standardization 60 size gp with AH plus sealer by lateral compaction technique. Postspace preparation for all teeth was initiated after 24 h of obturation. The gutta-percha was removed using No. 1, 2, and 3 Peeso reamers (Mani) leaving 5 mm of gutta-percha at the apex.

Studies have recommended thicknesses between 0.9 and 1 mm shoulder for the porcelain fused to metal (PFM) crowns. Tooth preparation was done for each specimen to ensure 1 mm of shoulder finish line, 2 mm incisal reduction, and 1.5 mm of labial and lingual reduction.

The prepared 80 samples were then divided into:

**Group 1 – Cast metal post and core (n = 40):**
- Sub-Group 1a – 0° core to the long axis of the root
- Sub-Group 1b – 10° to the long axis of the root
- Sub-Group 1c – 20° to the long axis of the root
- Sub-Group 1d – 30° to the long axis of the root.

**Group 2 – Everstick post (n = 40):**
- Sub-Group 2a – 0° core to the long axis of the root
- Sub-Group 2b – 10° core to the long axis of the root
- Sub-Group 2c – 20° core to the long axis of the root
- Sub-Group 2d – 30° core to the long axis of the root.

**For Group 1**
Post pattern preparation was done using 60 K master apical file. The coronal portion of file was bent at 0°, 10°, 20°, and 30° with respect to the long axis of tooth using an orthodontic plier as seen in Figure 1. Post pattern was made adapting inlay wax to the already angulated endodontic file. After the post pattern was fabricated, the core was waxed and shaped such that the total height of the prepared crown would be 8 mm.

**For Group 2**
Everstick posts were inserted and shaped by condensing to the prepared postspace. The coronal portions of the posts were bent at 10, 20, and 30 for each sub groups with the help of a template and was initially light polymerized inside the root canal for 20 s. The shaped everstick posts were then removed from the root canal and light polymerized for 40 s according to the manufacturer’s instructions. Posts were cemented inside the canals using rely X self-adhesive resin cement and light cured from above the post perpendicular.
Casting of wax pattern for Group 1 and crown fabrication
Wax patterns were sprued and then invested in Novo Cast (Whip Mix Corp., Louisville, KY) according to the manufacturer’s instructions. All the patterns were cast using Ni-Cr alloy. PFM crowns were fabricated for all the samples.

Cast post cementation for Group 1 and crown cementation for Groups 1 and 2
The cast post and core was checked for the fit and cemented in the tooth with Rely X U 200 resin luting cement. The PFM crowns were cemented using glass ionomer luting cement type 1, for both the groups.

Specimen preparation for testing
A thin layer of polyvinyl siloxane was applied on the root surfaces of all the specimens to simulate the periodontal ligament. The teeth were attached to a surveyor (Dentsply Ceramco, York, PA) to align the long axis, and then invested in auto-polymerizing resin at a level of 2 mm to 3 mm below the margin of the preparation to simulate the biologic width. The samples were thermocycled at 5 ± 1 and 55 ± 1 degree centigrade for 1000 thermal cycles with 30 s dwell time to simulate the oral conditions.

All teeth were stored in 100% relative humidity at 37°C for 24 h before being tested.

Fatigue loading
Samples were placed into a jig and screwed to the stationary member of the testing machine and were then loaded at 135° to the long axis of the tooth 3 mm from the incisal edge, simulating the incisal angle, using the universal
testing machine (Mecmesin, ILC-S Load cell 2500N). The samples were subjected to static loading with a crosshead speed of 1 mm/min until fracture occurred. The load at which the teeth fractured was recorded in Newton. After fracture, the samples were assessed for their failure mode. “Favorable fractures” were defined as repairable failures, coronal to the level of CEJ. “Unfavorable fractures” were defined as nonrepairable failures, apical to the level of CEJ.

RESULTS
After testing the samples, the data obtained were tabulated and subjected to the statistical analysis using the one-way ANOVA test followed by Tukey’s post hoc test to compare the mean fracture resistance between different angulations in cast post and everstick posts. Student paired t-test was used to compare the mean fracture resistance between cast post and everstick posts for each angulations. The level of significance (P value) was set at P < 0.05.

According to Tables 1 and 2 and Figure 3, there was a statistically significant difference in the mean fracture resistance between subgroups 1a and 1c, 1a and 1d, 1b and 1d, 1c and 1d at P < 0.001. According to Table 3 and 4 and Figure 4, Group 2a exhibited a mean fracture resistance score of 2072.00, Group 2b with 2299.40, Group 2c with 2477.00, and Group 2d having a mean score of 1641.10. There was a statistically significant difference in the mean fracture resistance between subgroup 2a and 2c, 2a and 2d, 2b and 2d, 2c and 2d at P < 0.001. According to Table 5 and Figure 5, multiple intergroup and intragroup comparisons using the student paired t-test revealed that sub group 1c of cast postgroup exhibited highest score compared to other sub groups of cast post group and sub group 2c of everstick group exhibited highest score compared to other subgroups of everstick group. However, the mean fracture resistance score did not significantly differ between cast post group and everstick group in any subgroups.
DISCUSSION

Restorations of endodontically treated teeth are designed to protect the remaining tooth from fracture, prevent reinfection of the root canal system, and replace the missing tooth structure.

We often come across patients with fractured proclined anterior teeth, seeking aesthetic corrections to improve their smile. Several studies have reported the predominant prevalence of traumatic dental injuries in patients, having such proclined teeth. Children and adolescents presenting inadequate lip closure or an increased overjet >5 mm, are more likely to suffer from such dental traumatic injuries.\(^5\)

The amount of remaining coronal tooth structure is a critical factor in determining the post selection. The bulk of the tooth above the restorative margin should be sufficient enough to achieve the necessary resistance form. The results of in vitro and in vivo studies indicate that cast posts may be used when there is moderate-to-severe tooth loss.
and fiber posts when ample coronal dentin remains and the crown is well supported by remaining tooth structure.8

In vitro studies have to be conducted simulating a clinical situation as close as possible. Many studies that determine the fracture strength of endodontically treated teeth with different postcore options have been carried out without actually placing the crowns.7-12 Therefore, in this study, PFM crown was fabricated for all the specimens, in order to more aptly simulate clinical conditions. PFM was chosen because of its proven strength in addition to being more economical than all ceramic restorations.

Based on the results, the null hypothesis was rejected. Fracture resistance values in everstick group was found to be in the range of 1641–2072 N, and that of the cast postgroup was found to be in the range of 1488N–2023N. While these values seemed well above the range reported by many studies,8-10 it was in accordance with few other studies reported in the literature that used similar methodology.7-12

Fracture resistance of teeth restored with cast posts was lower than that of everstick post at all angulations. Similarly, a study done on premolars comparing the fracture resistance of custom cast post and everstick post, concluded that everstick post group showed the highest fracture resistance, using a loading angle 90° to the long axis of the tooth.9

On analyzing the fracture patterns, it was observed that all the specimens in the cast postgroup showed catastrophic and irreparable fractures (posts did not fracture but the tooth fractured below the CEJ whereas specimens in the everstick group showed favorable and restorable fractures, i.e., at or above the CEJ, as shown in Figure 6.

A material only fractures when the elastic limit is exceeded. Owing to the molecular operating environment MOE of everstick post which is similar to dentin, pliability, and better stress distribution capability, everstick performed marginally better than cast post at every core angulation although the difference was not statistically significant. Cast post being rigid with much higher MOE in comparison to dentine, led to the concentration of the forces along the post, which resulted in uneven stress distribution, and catastrophic fracture of radicular dentin.

The multiphase polymer matrix of everstick posts consists of both linear and cross-linked polymer phases (semi interpenetration polymer network [IPN], semi-IPN). The monomers of the adhesive resins and cements can diffuse into the linear polymer phase, swell it and by polymerization form interdiffusion bonding and a so-called secondary semi-IPN structure. This is said to reduce stress formation at post/dentin and post/cement interfaces.13-15

On comparing the fracture strength values of these specimens at different angulations, in the present study, the fracture resistance was the highest at 20° for both everstick as well as for the cast post group. As the angulation increased from 0° to 20°, the fracture resistance of both everstick and cast postgroup increased, but from 20° to 30°, the fracture resistance decreased. However, there was no statistical difference between the two groups at all core angulations. A study on influence of post angulation between coronal and radicular segment on the fracture resistance of endodontically treated teeth by Haralur et al. concluded that the fracture resistance of 15° angled cast post was highest followed by 10° then 5° respectively. Increased angle between the long axis of facial surface and radicular segment of the post had a positive impact over the fracture resistance of the endodontically treated teeth. They explained that the torque (lateral force) generated from 130° force application is less in 15° angled core in comparison to 10° and 5°, due to altering occlusal impact area and reduction in the perpendicular distance from the center of rotation to the resultant force. Hence, effectively reducing the torque (lateral force) on the root.9

This phenomenon perhaps explains the increase in fracture strength obtained with increase in angulation up to 20° as obtained in the present study, as shown in Figure 7a-c.

Interestingly, when core angulations increased from 20° to 30°, the fracture resistance decreased for both

### Table 5: Comparison of mean fracture resistance (Newtons) between cast post and Everstick posts at different angulations using independent Student’s t-test

| Group (°) Posts | n | Mean  | SD   | Mean difference | t    | P    |
|----------------|---|-------|------|-----------------|------|------|
| 0              | 10| 2023.80| 94.70| –48.20          | –0.829| 0.42 |
| Everstick      | 10| 2072.00| 157.52| –1.604          | –0.09| 0.93 |
| 10             | 10| 2201.10| 141.79| –98.30          | –1.710| 0.10 |
| Everstick      | 10| 2299.40| 113.80| –1.811          | –0.39| 0.70 |
| 20             | 10| 2373.20| 130.66| –13.80          | –0.08| 0.93 |
| Everstick      | 10| 2477.00| 157.54| –1.604          | –0.09| 0.93 |
| 30             | 10| 1488.10| 211.24| –153.00         | –1.811| 0.09 |
| Everstick      | 10| 1641.10| 163.52| –1.604          | –0.09| 0.93 |

SD: Standard deviation

Figure 6: Everstick fracture at cemento enamel junction-favourable fracture

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everstick and cast post groups. It is suggested that, in order to obtain postcore restoration that substitutes tooth strength to its “near” original state, it is important to engineer endodontic postcore restoration that does not induce stress concentrations and high tensile stress for the remaining dentin structure.\textsuperscript{[16]} It is possible that due to the steep incisal guidance angle, the off axial forces seem to outweigh the axial forces, resulting in excessive tensile stress concentration resulting in decreased fracture resistance as obtained in our study.\textsuperscript{[17]}

According to the FE studies, lowest stresses were found when load was applied almost parallel to the long axis of the maxillary incisor without post. The normal maxillary incisor was found to have higher stresses at the larger load angles than the proclined tooth, with or without correction. This is because for the proclined maxillary incisor, the point of contact with the lower incisor is further away from the incisal edge, thus reducing the bending moment about the apex and hence the resulting stresses. However, when the tooth is restored with either a rigid metal post or a flexible fiber post, it may behave differently when a large load is applied.\textsuperscript{[18]}

Moreover, while restoring anterior teeth, occlusal stability is a critical factor to be considered. Thus, the anterior guidance and envelope of function should be maintained in harmony with each other during such angulation changes of restorations to avoid any long term detrimental effects on the teeth.\textsuperscript{[19]}

Helkimo E and Ingervall found that individuals with clenching and grinding habits were found to have higher bite force on the incisors, but not on the molars. This happens because the habits are normally performed in noncentric positions, when the required muscles of these positions are exercised, that occurs when bite force in the anterior regions are measured, and not in a centric position, that occurs when the posterior regions are measured.\textsuperscript{[20]}

However, it may be prudent to point out here that the specimens in this study were subjected to a load far beyond normal occlusal forces. Since it represents a “worst case” scenario, it may be reasonable to presume that even at this extreme angulation change of 30°, the fracture strength values obtained in this study is much more than the anterior bite force encountered under normal clinical loading conditions.

The limitations of this study were that the specimens were subjected to static loading which does not directly replicate forces in the oral cavity with regard to both size of the load and nature of the load. Most pulpless teeth \textit{in vivo}, probably fail as a result of fatigue failure and dynamic loading for which further \textit{in vitro} studies simulating the fatigue stresses that occur in the oral cavity are warranted. Further research is needed to evaluate the clinical implication and long-term success of such angulated restorations.

**CONCLUSIONS**

Under the limitations of this study it can be concluded that:

- Changing core angulation up to 20° can be carried out safely using any of the post systems tested in the study. Core angulations >20°, should be used with caution, especially in patients with abnormal parafunctional habits and occlusal trauma
- Everstick fiber posts are preferred over cast post system for changing core angulations as they provide better fracture resistance with more favorable stress distribution
- Further \textit{in vitro} studies, simulating the fatigue stresses that occur in the oral cavity and long-term \textit{in vivo} studies are essential, to determine the clinical implications and long-term success of such angulated restorations.

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**Conflicts of interest**

There are no conflicts of interest.

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