



## **Influence of post materials on the fracture resistance of endodontically treated teeth.**

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### **Abstract**

The bending stiffness of the post should have the ability to transfer and distribute forces and stresses in an endodontically treated tooth to prevent root fracture. The aim of this study was to evaluate the post materials on the fracture resistance of endodontically treated teeth restored with three types of post materials. Thirty extracted human mandibular premolars after root canal preparation and obturation with gutta percha; the roots were divided into three groups according to the type of post material, group Fc restored with fiber post, group Sc restored with stainless steel post and group Tc restored with titanium post. All teeth restored with composite restorative material as core materials. Then all the teeth were subjected to compressive load at 130° angle from the horizontal plan at a 5mm/min crosshead speed until fracture. Results showed that there was a significant difference between groups in terms of fracture loads ( $P= 0.0301$ ). Also the fracture loads of teeth restored with titanium post has highest mean fracture load (830N), whereas teeth restored with Fiber post demonstrated the lowest mean fracture load (701.3N). This study concluded that the teeth restored with metallic post were more fracture resistant than those restored with fiber posts. But the combination of a fiber post and composite core has the favorable mode of fracture that considered repairable, while considered unfavorable when restored with metallic post.

**Keyword: Post, Fracture resistance, Modulus of elasticity**

### **Introduction**

The main goal of endodontic treatment is to create a design in which the tooth is preserved, when restoration fails <sup>(1)</sup>. Endodontically treated teeth present a high risk of biomechanical failure due to the loss of tooth substance resulting from preexisting decay and endodontic therapy. In treating these teeth, intraradicular posts are recommended to aid in the retention of artificial crowns and support the teeth by distributing intraoral forces along the roots. However, structurally compromised teeth are not reinforced by post

insertion <sup>(2, 3)</sup>. The survival of these teeth depends on the condition of the tooth and restoration, and also on the design of the posts <sup>(2)</sup>. Selection of most suitable dowel and core system is challenging, and number of different techniques and materials are used for this purpose in clinical practice <sup>(4, 5)</sup>. A variety of post and core systems are available for the restoration of such teeth but there is no consensus on which systems are best suited for clinical use <sup>(6)</sup>. Several investigators reported that posts do not strengthen teeth but actually weaken them.

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Ideally, a post should minimize the stress on a tooth by distributing occlusal loads evenly and be easy to remove if the root canal should require retreatment<sup>(7)</sup>.

There are two types of posts in use, custom-made and prefabricated. Prefabricated posts are usually made of metals such as stainless steel, titanium and noble metal alloys, or nonmetals, such as ceramic and fiber posts. Cast and prefabricated metal posts have been commonly used for restoring endodontically treated teeth. However, with metal posts, roots are prone to fracture<sup>(8)</sup>. Fiber-reinforced composite (FRC) posts are made of composite in which fibers are embedded in a resin matrix to enhance mechanical properties. Glass, quartz, and carbon fiber can be used to fabricate FRC posts<sup>(9, 10)</sup>. Nevertheless, metal posts and cores are associated with inferior aesthetics, as they do not allow light transmission, might corrode causing gingival and tooth discoloration, and have possible biocompatibility concerns. Some may encounter difficulty in fabrication and fitting, and retrieval is difficult and might lead to tooth and/or root fracture. While nonmetal posts were developed as a result of advances in biomaterials, development in bonding and adhesive systems and enhancement of aesthetic characteristics of dental restorations<sup>(11, 12)</sup>. Nonmetal posts have superior aesthetics, biocompatible, more color stable, corrosion free, and some have similar stiffness to dental tissues thus improving stress distribution<sup>(13)</sup>.

Clinical failure of posts might be attributed to many factors such as caries, periodontal disease, root fracture, post fracture, post distortion, loss of crown retention and loss of post retention. Ready-made or prefabricated metal posts are associated with higher risk of root fracture due to the high stiffness of the metal when compared

to tooth structure, which might lead to increased stress concentration<sup>(14)</sup>. Furthermore, some studies have reported that teeth restored with metal posts had less fracture potential than those restored with carbon fiber posts. Other studies have demonstrated similar levels of fracture potential when metal and carbon fiber posts were compared. While some studies have shown that fracture resistance was not significantly different when ceramic post, carbon fiber post, and prefabricated metal posts were used to restore endodontically treated teeth<sup>(13, 15)</sup>. The aim of this study was to evaluate the effect of post materials on the fracture resistance and mode of failure of teeth restored with prefabricated posts including glass fiber, stainless steel post, and titanium posts, along with use of resin composite core.

## Materials and Methods

Thirty mandibular premolars extracted for orthodontics reason free from caries or previous restoration were selected for this study. Teeth were immersed in 5% sodium hypochloride solution for 24 hours and subsequently restored in normal saline. All teeth were carefully debrided of soft tissue with periodontal curette, followed by cleaning with rubber cup and pumice; teeth were examined by transillumination for presence of cracks. Teeth of similar dimensions and shapes were selected for this study, with as close as possible of the following dimensions: root length 14 mm from cemento-enamel junction (CEJ) to the apex and with width dimension faciolingually and mesiodistally of 6-8 mm and 4-6 mm respectively. The clinical crowns of all teeth were removed at the (CEJ) with a diamond disc rotary instrument (Topdent, Switzerland) under water

coolant. The working length of each canal was calculated to be 1 mm shorter to the root length. Root canals were prepared with nickel-titanium ProTaper hand instrument and Glyde (Dentsply-Maillefer, Ballaigues, Switzerland), for standardization all roots were prepared to file F3, roots were irrigated between instrumentation with 5% sodium hypochloride. The prepare canals were obturated with a single F3 gutta percha cone and AH26 sealer (Dentsply-Maillefer, Ballaigues, Switzerland), then all roots were stored in physiologic saline solution at 37°C for one week.

Each root then was embedded in 2.8 x 2.8 x 2.8 cm<sup>3</sup> individual block of self-curing acrylic resin (Acromed, Modern Medical, UAE) with long axis perpendicular to the base of the block and with acrylic ending at 2mm below the cemento-enamel junction. Before embedding, a thin layer of glycerin was first applied with microbrush on the roots, and after polymerization of acrylic resin the root was carefully removed. Siloxane impression material (Zhermach Oranwash L, Badia Polesin, Italy) was mixed according to the manufacturer instruction and injected into the acrylic resin molds to simulate the periodontal ligament and the root was reinserted again and excess silicone impression material removed.

The roots were randomly distributed into 3 groups (10 for each group) according to the type of post; Group Fc restored with fiber posts (Fiberapost plus, PD, products dentaires Vevey, Switzerland). Group Sc restored with prefabricated stainless steel post (Unimetric stainless steel post, Dentsply-Maillefer, Ballaigues, Switzerland). Group Tc restored with prefabricated nickel titanium posts (Unimetric titanium post, Dentsply-Maillefer, Ballaigues, Switzerland). All posts were shortened to total length of 14mm, so that 10mm of the post could

be placed in the root and the remaining 4mm in to core components<sup>(14, 16)</sup>. For each group the post preparation was started with the removal of root gutta percha with Peeso reamer (Dentsply-Maillefer, Ballaigues, Switzerland) to a point 4mm from root apices to preserve the apical seal. Post spaces were prepared with low-speed drills supplied by each manufacturer. All posts were cemented with self cure resin modified glass ionomer luting cement ( Riva luting plus, SDI, Australia) according to the manufacturer's instruction which include irrigation the post space with saline and dried with cotton paper point (Absorbent paper point, Meta Biomed, South Korea). The walls of the root canal were acid etch for 10 second using 37% phosphoric acid (Super etch, SDI, Australia), then the root canal washed with water spray and dried with paper point. A thin layer of cement was placed in the post space by cotton paper point also cement was placed on the post surface; the post was inserted in the canal. The cement allows to set for 1 hour, and then the access cement was removed with an explorer.

After the cementation procedure was completed, the teeth in each group were prepared for restoration with tetric ceram (ivoclar vivadent, Shaan, Liechtenstein) as a core material. A cellulose mold 6mm height (PD, products dentaires Vevey, Switzerland) was used during core build up for each tooth to ensure standardized core size as well as to exclude voids and deficiencies within the core material. At the fitting surface of each mold a small mark was placed at the middle third of the inner surface of the cellulose mold to provide a standardized point of load application. First, coronal tooth surface was etched for 15 seconds with 37% phosphoric acid (Super etch, SDI, Australia), then rinsed with water for 10 seconds and

dried with air syringe for 5 seconds. A bonding agent (Alpha-dent bonding adhesive. Dental Technologies. 6901. N. Avenue Lincolnwood. Illinois 60712 USA) was applied to the etched dentin surface and the 4mm of exposed post and polymerized with light cure for 20 seconds the tetric ceram was applied in increment of 2 mm and light activated with light cure machine (Halogen light curing unit Dentsply, Switzerland). Finally, in all groups the core materials were covering the prefabricated post.

Each specimen was mounted within an Instron testing machine (computerized instron H5KT Tinius Olsen testing machine, England), which fixed by a specially designed retaining arm of Instron machine, which was used to hold the specimen during testing. Then the load was set at  $130^{\circ}$  from the horizontal plane onto a standard point at the middle of the lingual occlusal line angle of the core, at level of the small indentations. The compressive load was applied on the specimens at a 5mm/min crosshead speed until fracture. The point of fracture was determined by sudden drop of the applied force and an audible crake sound would be heard. The fracture load in kilogram was recorded and later converted to newtons<sup>(1, 6, 11)</sup>. The mode of failure of each specimen was categorized either a core failure (non-catastrophic or favorable) or root fracture only, or core and root fracture (catastrophic or unfavorable).

## Results

The mean failure loads and standard deviations with maximum and minimum loads were calculated for all groups Table (1). Figure (1) shows the bar chart that represents the mean fracture loads for the three groups with titanium post (group Tc) has highest

mean fracture load (830N), whereas teeth restored with Fiber post (group Fc) demonstrated the lowest mean fracture load (701.3N). ANOVA test show that there was significant different between groups in term of fracture loads ( $P= 0.0301$ ) Table (2). Using raw data, a further t-Test show no statistically difference ( $P> 0.05$ ) between group Fc and group Sc, while there were significant differences ( $P< 0.05$ ) found between group Fc and group Tc, and between group Sc and group Tc table (3).

Table (4) shows that the failure mode of group Fc was more favorable type followed by group Tc then group Sc, a magnifying eye lens 10X (China) was used for inspection of these failure modes.

## Discussion

The bending stiffness of the post should have the ability to distribute forces and stresses in endodontically treated teeth to prevent root fracture.

In treating endodontically treated teeth, intraradicular posts are recommended to aid in the retention of artificial crowns and support the teeth by distributing intraoral forces along the roots. However, structurally compromised teeth are not reinforced by post insertion<sup>(2, 3)</sup>. The use of an endodontic post inside the canal transforms the forces from compressive stress (resisted by the dental tissues) to tensile stress (less resisted by the dental tissues). Consequently, the tooth fracture resistance will be reduced<sup>(16)</sup>.

In this study we used investigates the effect of the post materials in fracture resistance of endodontically treed teeth. Like in many studies to simulate clinical conditions, natural teeth of similar dimensions and shapes were used in the study. Thus, the faciolingually and mesiodistally

dimensions of each tooth were recorded at the level of the cervical margin to ensure that each experimental group contained teeth of similar dimension. This method was adopted in many studies<sup>(5, 14, 17-21)</sup>.

Teeth were embedded in acrylic resin block leaving 2mm above the acrylic resin surface to simulate the position of root within the bone in clinical situation and allow good vision to the mode of failure during testing. Using siloxane impression material was to simulate PDL and to provide a cushioning effect that would resemble clinical conditions<sup>(5, 8, 21, 22)</sup>. This material was also selected because its width and modulus of elasticity were similar to those of natural ligament<sup>(23)</sup>.

Composite was the material of choice for core build up because of its good bond strength, controlled and quick setting, good aesthetics, and adequate compressive strength. Moreover, composite core materials have a higher fracture resistance than amalgam and glass ionomer materials<sup>(6, 11)</sup>. In this study, teeth were restored by a post and core without a crown for simplification purposes and to exaggerate the load effect on the tooth<sup>(11, 17)</sup>. Previous research showed that placement of a crown may obscure the effect of different post and core buildup techniques<sup>(11)</sup>.

Loading was applied directly on to the core which was set to 130° angle from the horizontal plane and continuous compressive loading was applied to resemble the mastication procedure, many previous studies has been adopted this angle for load application. A cross head speed of 10 mm/min was used in this study. A wide range of cross head speed was reported in the literature, ranging from 0.5 mm/min to 10 mm/min.<sup>51</sup> However, the use of the continuous loading instead of the more clinically relevant cyclic loading, because the continuous

loading method has been adopted by many studies in this field and is easy to perform in comparison to the cyclic loading method<sup>(1, 6, 8, 11, 17, 22)</sup>.

This results come in agreement with Al-Wahadni et al.,<sup>(11)</sup> they investigate the fracture resistance and mode of failure, they found that teeth restored with Radix-titanium posts were more resistant to fracture than those restored with either glass fiber or carbon post and also agree with Sung-Ho et al.,<sup>(8)</sup> they compared the microleakage and fracture of endodontically treated teeth with different post materials under dynamic loading. They concluded that both glass fiber post and ceramic post showed less microleakage with lowest resistance to fracture than stainless steel posts under dynamic loading. Also agree with Sonthi S. et al.,<sup>(24)</sup> they compared the resistance to vertical root fracture of pulpless teeth restored with six post system. They found that roots restored with titanium posts were more resistance to fracture than stainless steel and fiber post, but disagree with Ayad et al.,<sup>(25)</sup> their result showed that teeth restored with glass fiber post demonstrated high fracture resistance than titanium post, they used intermediate layer of composite resin sandwiched between the root dentin and post, which increased the fracture resistance as a result of complete tag formation for composite resin along the widely opened dentinal tubules.

This could be explained that metal post have high modulus of elasticity, which allow the post to withstand large amounts of stress before bending and transmitting the load to the root, this mechanism makes the tooth more resistance to fracture. However, when a fiber post is used it will bend at lower loads thus allowing transmission of the force to the tooth sooner.

Consequently, the tooth will fail at lower values of stress.

Ferrari M et al.,<sup>(26)</sup> also stated that the difference in the fracture resistance among teeth with different post-core systems can be explained by the modulus of elasticity of the post materials. When a post-core with a high modulus of elasticity, such as a titanium post, is forced against radicular dentin with much lower modulus, the stress is transferred from the rigid post to the less rigid dentin. When a post with a similar modulus of elasticity to that of radicular dentin, such as a fiber post, is used for restoration, less stress is transferred from the post to the dentin would occur. Hayashi et al.,<sup>(27)</sup> suggested that posts with a high elastic modulus such as metallic posts could improve the bending resistance of post-restored teeth by opposing their stiffness to the bending stresses arising from function.

According to manufacturers, fiber endodontic post, were introduced to the dental profession in order to allow homogenous mechanism and chemical bonding between the post and dentin to reinforce the tooth. This could be related to the low elastic modulus of fiber post, which approaches the elastic modulus of dentin<sup>(11)</sup>. Salameh et al.,<sup>(28)</sup> reported that the use of fiber post to restore endodontically treated teeth improved the biomechanical performance loading, implying that the posts significantly contributed to the reinforcement and strengthening of endodontically treated tooth by supporting the remaining tooth structure against compressive stresses.

A finite element study by Chuang et al.,<sup>(2)</sup> reported that the modulus of elasticity of the stainless steel posts is significantly higher than that of dentin, the stiffer posts exhibited a stress-shielding effect by absorbing more of the load. As the force was transmitted apically, greater stress was transferred

to the root dentin around the post end. The fiber posts did not absorb equivalent stress as compared to the stainless steel post due to their lower modulus of elasticity.

The majority of fractures in the stiffer posts were propagated over the middle portion of the roots, while in the fiber post fractures were limited to the cervical portion. This difference in fracture propagation can be explained by the stress distribution in pulpless teeth restored with post-core systems, when load was applied to teeth restored with a metallic post, the stress distributed inside the post all over the interface between the post and root dentin, and in the apex of the post. Reflecting this stress distribution, fractures propagated along the metallic post over the middle portion of the root including the post apex. This indicates that most of the fractured teeth restored with metallic post-cores were not repairable. In contrast, the majority of fractures in the fiber post group were limited to the cervical portion of the root including the core-dentin interface, since the stress was concentrated in the cervical area and the outer root surface. This type of fracture is most easy for repeated repair<sup>(29)</sup>.

## Conclusion

Within the limitation of this study, the following conclusions are drawn: the highest maximum fracture resistance was found by titanium post followed by stainless steel and finally by fiber post. The glass fiber post and composite core show the best combination for maintaining tooth structure with failure modes that considered repairable, while restoration with titanium and stainless steel posts show unfavorable mode of fracture, with higher rate in teeth restored with stainless steel post. That's why the

restoration of endodontically treated had to be done with post material that have elastic modulus similar to that of dentin.

## References

- 1- Vijay Kumar, Harpreet Marjara, Veena Gupta, Hari Parkash. An in vitro study to compare the fracture strength and mode of fracture of endodontically treated maxillary central incisors fractured at cemento-enamel junction and restored with three different post and core system. *Indian J. of dentistry* 2011; 2(3): 61-67.
- 2- Shu-Fen Chuang, Peter Yaman, Alberto Herrero, Joseph B. Dennison, Chih-Han Chang. Influence of post material and length on endodontically treated incisors: An in vitro and finite element study. *J Prosthet Dent* 2010; 104:379-288.
- 3- Torbjørner A, Fransson B. A literature review on the prosthetic treatment of structurally compromised teeth. *Int J Prosthodont* 2004;17:369-76.
- 4- Karina Albino Lencioni, Luiz Ricardo Menani, Ana Paula Macedo, Ricardo Faria Riberio, Rossana Pereira de Almeida. Tensile bond strength of cast commercially pure titanium dowel and cores cemented with three luting agents. *J of Prosthodontic Research* 2010; 54:164-167.
- 5- Bilge Hakan Sen, Senem Yigit Ozer, Sadullah Kaya, Ozkan Adiguzel. Influence of Fiber-reinforced Composites on the Resistance to Fracture of Vertically Fractured and Reattached Fragments. *J Endod* 2011; 37:549–553.
- 6- M. K. AL-Omiri, A. M. AL-Wahadni. An ex vivo study of the effects of retained coronal dentine on the strength of teeth restored with composite core and different post and core systems. *International Endodontic Journal* 2006: 39, 890–899.
- 7- Akkayan B. An in vitro study evaluating the effect of ferrule length on fracture resistance of endodontically treated teeth restored with fiber-reinforced and zirconia dowel systems. *J Prosthet Dent* 2004; 92:155-62.
- 8- Sung-Ho Jung, Kyung-San Min, b Hoon-Sang Chang, Sung-Do Park, Soon-Nyu Kwon, Ji-Myung Bae. Microleakage and fracture pat terns of teeth restored with different posts under dynamic loading. *J Prosthet Dent* 2007; 98:270-276.
- 9- Bae JM, Kim KN, Hattori M, Hasegawa K, Yoshinari M, Kawada E, et al. Fatigue strengths of particulate filler composites reinforced with fibers. *Dent Mater J* 2004; 23:166-74.
- 10- Bell AM, Lassila LV, Kangasniemi I, Vallittu PK. Bonding of fibre-reinforced composite post to root canal dentin. *J Dent* 2005; 33:533-9.
- 11- Ahed M. AL-Wahadni, Sami Hamdan, Mahmoud Al-Omiri, Mohammad M. Hammad, Muhanad M. Hatamleh. Fracture resistance of teeth restored with different post systems: in vitro study. *J of Oral Surg Oral Med Oral pathol Oral Radiol Endod* 2008; 106:e77-e83.
- 12- Stewardson DA. Non-metal post systems. *Dental Update* 2001; 28:326-32., 34, 36.
- 13- Hu YH, Pang LC, Hsu CC, Lau YH. Fracture resistance of endodontically treated anterior teeth restored with four post-andcore systems. *Quintessence Int (Berlin, Germany)* 2003;34: 349-53.
- 14- Ottl P, Hahn L, Lauer H, Fay M. Fracture characteristics of carbon fibre, ceramic and non-palladium endodontic post systems at monotonously increasing loads. *J Oral Rehabil* 2002;29:175-83.
- 15- Pegoretti A, Fambri L, Zappini G, Bianchetti M. Finite element analysis of a glass fibre reinforced composite endodontic post. *J of Biomaterials* 2002;23:2667-82.
- 16- Albuquerque Rde C, Polleto LT, Fontana RH, Cimini CA. Stress analysis of an upper central incisor restored with different posts. *J Oral Rehabil* 2003;30:936-43.
- 17- Al-Wahadni A, Gutteridge DL. An in vitro investigation into the effects of retained coronal dentine on the strength of a tooth restored with a cemented post and partial core restoration. *Int Endod J* 2002; 35:913-8.
- 18- Ziad Salameh, Roberto Sorrentino, Hani F. Ounsi, Walid Sadig, Fadi Atiyeh, Marco Ferrari. The Effect of Different Full-coverage Crown Systems on Fracture Resistance and Failure Pattern of Endodontically Treated Maxillary Incisors Restored with and without Glass Fiber Posts. *J Endod* 2008;34:842– 846.
- 19- Polly S. Ma, Jack I. Nicholls, thomsa Junge, Keith M. Phillips. Load fatigue of with different ferrule length, restored with fiberposts, composite resin-cores, and all ceramic crowns. *J Prosthet Dent* 2009;102:229-234.
- 20- M. I. Reill, M. Rosentritt, M. Naumann, G. Handel. Influence of core material on fracture resistance and marginal adaptation of restored root filled teeth.

- International Endodontic Journal 2008;41, 424–430.
- 21- M. Schmitter, S. Lippenberger, S. Rues, H. Gilde & P. Rammelsberg. Fracture resistance of incisor teeth restored using fibre-reinforced posts and threaded metal posts: effect of post length, location, pretreatment and cementation of the final restoration. International Endodontic Journal 2010; 43:436–442.
- 22- Begum Akkayan. An in vitro study evaluating the effect of ferrule length on fracture resistance of endodontically treated teeth restored with fiber-reinforced and zirconia dowel systems. J Prosthet Dent 2004; 92:155-62
- 23- Mikako Hayashi, Yutaka Takahashi, Satoshi Imazato, Shigeyuki Ebisu. Fracture resistance of pulpless teeth restored with post-cores and crowns. J Dental Materials 2006; 22, 477–485.
- 24- Sonthi Sirimai, Douglas N. Riis, Steven M. Morgano. An in vitro study of the fracture resistance and incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. J Prosthet dent 1999;81:262-9.
- 25- Mohamed F. Ayad, Salma A. Bahannan, Stephen F. Rosenstiel. Influence of irrigant, dowel type, and root-reinforcing material on fracture resistance of thin-walled endodontically treated teeth. J of Prosthodontics 2011;20:180-189.
- 26- Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of clinical performance of fiber post. Am J Dent 2000; 13:9B-13B.
- 27- Hayashi M, Takahashi Y, Imatazato S, Ebisu S. Fracture resistance of pulpless teeth restored with post-cores and crowns. Dent Mater 2006; 22:477– 85.
- 28- Salameh Z, Sorrentino R, Ounsi HF, et al. Effect of different all-ceramic crown system on fracture resistance and failure pattern of endodontically treated maxillary premolars restored with and without glass fiber posts. J Endod 2007; 33:848 –51.
- 29- Plotino G, Grande NM, Bedini R, Pamrijer CH, Somma F. Flexural properties of endodontic posts and human root dentin. Dent Mater 2007;23:1129 –35.

Table (1): Descriptive statistic for the groups

Fracture resistance N			
Groups	Fc	Sc	Tc
Mean	701.3	713.9	830.5
SD	112.55	62.185	113.69
SE	35.597	19.66	35.95
Maximum load	821	788	934
Minimum load	419	598	543

Table (2): ANOVA test for all tested group

	F-test	P-value
4.281	0.014	0.0301

P<0.05 Significant

Table (3): t-Test between groups

Groups	t-test	P-value	Sig
Fc&Sc	0.344	0.79	NS**
Fc&Tc	2.55	0.02	S*
Sc&Tc	2.85	0.011	S*

\*P<0.05 Significant

\*\*P>0.05 Non significant

Table (4): Mode of fracture of the study groups

Fracture mode	Fc	Sc	Tc
Favorable fracture (noncatastrophic)	8	3	6
Unfavorable fracture (catastrophic)	2	7	4
Total teeth No.	10	10	10

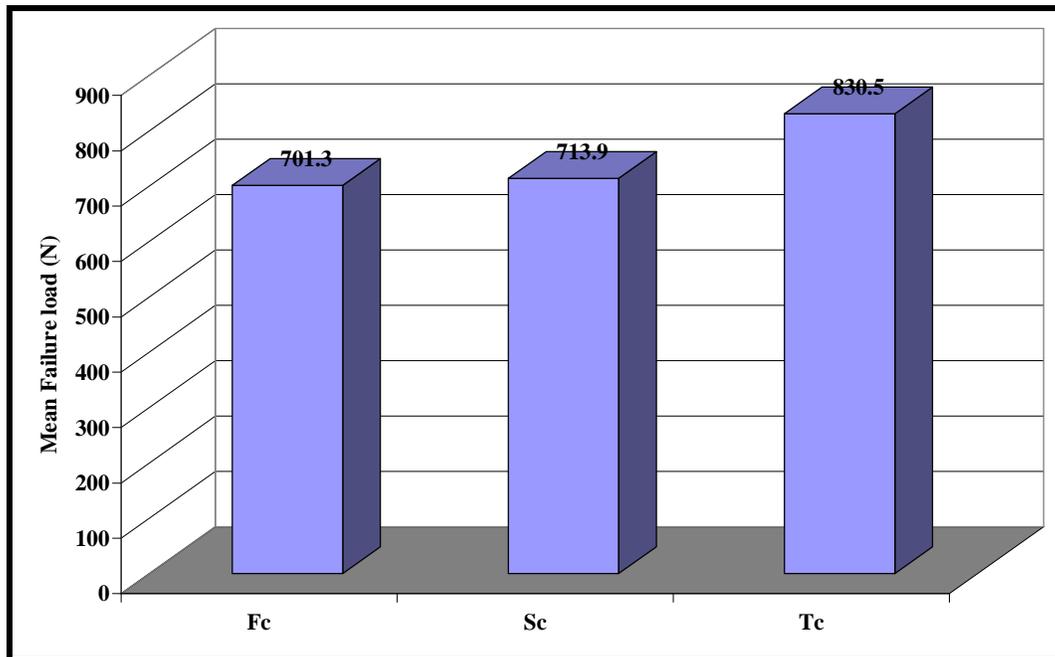


Figure (1): Mean fracture loads of teeth in the three groups