III. Mechanical Properties; interaction with tooth

A. Fracture Strength of restored teeth

Aminsalehi, E., **Strength of Incisors Restored by Metallic, Fiber and Ceramic Posts.** ***J Dent. Res 84 (Spec Issue B), African and Middle East Section 2005.***

Objectives: In endodontically treated teeth, because of extensive structural defects, the risk of fracture is increased. For reconstruction of coronal structure posts provide retention. Composite fiber posts were recently introduced to dentistry. This study compared the fracture strength of maxillary central incisors restored by metallic, fiber-reinforced composite and ceramic posts. **Methods:** 30 human maxillary central incisors were used. The crown of each incisor was cut off 1 mm coronally to C.E.J. perpendicular to long axis of the tooth by metal disc. Root canals of teeth were prepared for posts after RCT. Specimens were embedded in autopolymerizing acrylic resin 4 mm below the CEJ and then tested in a universal testing machine (Zwick-Germany). A compressive load was applied at 130 degrees to the long axis until fracture, at a cross-head speed of 0.5 mm/min. Fracture loads were recorded. All data collected were analyzed statistically using the ANOVA and LSD tests. **Results:** The mean and standard deviation (S.D.) of failure loads (in Newtons) were 765 +/- 113/265 N, 790+/- 95/34 N, 614+/- 105/32 N for glass-fiber, ceramic and metallic groups, respectively. ANOVA test detected statistically significant differences between all groups. Teeth restored with fiber and ceramic posts exhibited significantly higher resistance to fracture than with titanium posts. Teeth restored by fiber and ceramic posts were statistically similar by LSD test. The highest proportion of undesirable fractures was seen with titanium posts. **Conclusion:** Usage of fiber and ceramic posts are preferable to titanium posts. Because of more undesirable fractures in the ceramic group than fiber group, use of the latter posts are recommended overall.

Burmann, P, Cardoso, P., Santos, J, Soares, L. **Post Systems: compressive strength of roots prepared at 2/3 and ½ length restored with post systems**. ***J Dent Res.81 IADR Abstract #1933; 2002***

Objectives: Evaluate the mechanical resistance of roots restored with prefabricated posts. **Materials and Methods:** 40 sound upper human central incisors had the crown removed and the roots were endodontically treated. After 24 hours, the root canals were prepared using low rotation, going 2/3 or ½ down the depth of the root, and were divided into 4 groups (n=10). Group A: 10 roots were prepared on 2/3 of the depth for the cementation of the Unimetric Post (Dentsply/Maillifer) (**UNI**) using Clearfil LinerBond 2V and Panavia F (Kuraray Co. Japan), according to manufacturers instructions; Group B: 10 roots were prepared ½ down into the root canal for cementation with the same system as Group A; Group C: 10 roots were prepared on 2/3 of the depth for the cementation of the **AESTHETI-POST** (**AES**: RTD) using ALL-BOND 2 (Bisco) and Post Cement HI-X (Bisco); Group D: 10 roots were prepared ½ down into the root canal for cementation with the same system as Group C. Three mm of the post were left outside of the root canal, on the cervical portion, to allow the fixation of the core restoration with composite resin (Z250-3M/ESPE, USA). Simulating preparation for a crown. The specimens underwent compression at 45^0 on a universal testing machine, at a speed of 0.5 mm/min. until fracture. **Results:** The mean values of load obtained at fracture (Group A=93.4 Kgf, Group B=88.4 Kgf, Group C=95.7 Kgf, Group D=96.3 Kgf) were statistically tested using ANOVA two-way test. All groups showed statistically similar results ($p>0.05$). **Conclusion**: the different preparation depths of the root canals did not influence the results of the strength tests.

Cardoso, P.C., Burmann, P.A., Silveira, B., Albers, A, Soares, L.F. **Fracture Strength of Bovine Pulpless Teeth Restored by Post Systems**. ***J Dent Res. 80; AADR Abstract # 227; 2001***

The development of adhesive cements and prefabricated post system (PPS) provides us a conservative alternative to the traditional cast post –core in the reconstruction of endodontically treated teeth. However, the fracture strength of the core/tooth structures continues to be an object of doubts and discussions. The study aimed at evaluating the “in vitro” fracture strength of roots of restored inferior incisor bovine teeth. Thirty bovine teeth and ten human teeth were selected to constitute 4 groups (n=10); group 1) PPS Cosmopost (Ivoclar) + Syntac + Variolink II (Vivadent);

group 2) PPS C-Post + All Bond 2 + Post Cement HI-X (Bisco, Inc., USA); group 3) PPS ***ÆSTHETI-POST*** +All Bond 2 + Post Cement HI-X (Bisco, Inc., USA); and the group 4) (control group) human incisor teeth prepared for metal ceramic crown. The roots all the same length (15 mm), were embedded into acrylic resin blocks with a film (0.2 mm) of vinyl polysiloxane to simulate the periodontal ligament. The core was build up with composite (7.250 – 3M USA) through a custom transplant matrix. After 24 hours storage ($H_20/37^oC$) the specimens were submitted to the comprehensive test in Richie universal testing machine.

Group	***Average***	***SD***
Cosmopost \ Variolink	87.30 MPa	±13.5814
C-Post – AB2 \ HI-X	67.35 MPa	±18.5305
ÆsthetP + AB2 \ HI-X	80.30 MPa	±19.1038
Human Teeth	97.63 MPa	±37.4461

The statistical analysis of the data (ANOVA) revealed no significant difference ($p>0.05$) among the fracture strength averages of the four groups. The values obtained from the pre-fabricated post systems gave us results are similar to those obtained with natural teeth.

Chuang, S-F, Yaman, P., Dennison, J., et al, **Fracture resistance of devitalized teeth restored with different prefabricated posts. J Dent Res. *Vol 84 (Spec. Iss. A) Abstract #2926, 2005.***

Objectives: To investigate the fracture characteristics of devitalized teeth restored with posts of different materials and length. **Methods:** Sixty intact extracted incisors of similar size were chosen and sectioned 2mm coronal to the CEJ. The root canals were instrumented and obturated. Three different post systems were tested: stainless steel post (SB), glass-fiber post (GF), and carbon-fiber post (CF). The teeth were prepared to post lengths of 5 and 10 mm with the appropriate reamers for each post system. Composite cores of a standardized size were constructed over the cemented posts and Ni-Cr ceramic crowns were fabricated with a 1.5 mm ferrule length. The teeth were stored for 24 hours, thermocycled 1500 times (5-55¢XC). The tooth-crown assembly was mounted with a jig in a universal Instron testing machine and loaded at a crosshead speed of 0.5 mm/minute until failure. The teeth were then inspected under a stereoscope and SEM for fracture patterns. **Results:** The 10 mm/SB group had the lowest failure load (930 N), and was significantly different from the 5 mm/SB (1339 N) and 10 mm/GF group (1271 N). There was no significant difference in the failure loads among the fiber post groups, and in the failure toughness among six groups. Oblique fracture was the dominant pattern in all groups. Teeth restored with posts of the same material demonstrated similar fracture location and directions. Under SEM observation, cracked dentinal tubules were found in the lingual aspects of the SB posts. Over half of the specimens in the metal post groups exhibited fracture planes passing through the apex of the post.. **Conclusions:** Use of a 10 mm metal post did not improve the fracture strength of the restored devitalized teeth. Fiber posts provide more uniform stress distribution, which may prevent fracture at the apical end of the post. The fracture patterns of the teeth were associated with the post materials, while the post length had little influence on either the fracture strength or patterns of the teeth.

Dean, J. P., Jeansonne, B. G., and Sarkar, N. **In Vitro Evaluation of a Carbon Fiber Post. *Journal of Endodontics*. *24: 807-810, 1998.***

Abstract/conclusions: The purpose of this study was to evaluate the influence of endodontic and restorative procedures on fracture resistance of teeth, and to compare the incidence of root fracture in teeth with clinical crowns removed that were restored with three different types of post and a composite core build-up. Seven groups of 10 extracted maxillary canines were used. A control group had only a crown preparation, but no endodontic treatment. Three groups had endodontic treatment, crown preparation, and the access restored. Three groups had endodontic treatment, the crown totally removed, a tapered, parallel, or carbon post (**ComposiPost**) placed, and a composite build-up. All specimens were subjected to a 45-degree load at 0.5 mm/min until failure occurred. The force at failure and the location of fracture were recorded. The groups with post and composite build-ups

failed at significantly lower force than the teeth in which the crowns had not been removed. There were no significant differences in the amount of force required to produce failure among the three groups with different posts and a composite build-up. The group restored with the Composipost had no root fractures, whereas there were five fractures (50%) in each of the parallel and tapered post groups.

Dietschi D, Ardu S, Rossier-Gerber A, Krejci I **Adaptation of adhesive post and cores to dentin after in vitro occlusal loading: evaluation of post material influence.** J Adhes Dent. 2006 Dec;8(6):409-19

PURPOSE: Fatigue resistance of post and cores is critical to the long term behavior of restored nonvital teeth. The purpose of this in vitro trial was to evaluate the influence of the post material's physical properties on the adaptation of adhesive post and core restorations after cyclic mechanical loading. MATERIALS AND METHODS: Composite post and cores were made on endodontically treated deciduous bovine teeth using 3 anisotropic posts (**made of carbon, quartz, or quartz-and-carbon fibers: RTD)** and 3 isotropic posts (zirconium, stainless steel, titanium). Specimens were submitted to 3 successive loading phases--250,000 cycles at 50 N, 250,000 at 75 N, and 500,000 at 100 N--at a rate of 1.5 Hz. Restoration adaptation was evaluated under SEM, before and during loading (margins) and after test completion (margins and internal interfaces). Six additional samples were fabricated for the characterization of interface micromorphology using confocal microscopy. RESULTS: Mechanical loading increased the proportion of marginal gaps in all groups; carbon fiber posts presented the lowest final gap proportion (7.11%) compared to other stiffer metal-ceramic or softer fiber posts (11.0% to 19.1%). For internal adaptation, proportions of debonding between dentin and core or cement varied from 21.69% (carbon post) to 47.37% (stainless steel post). Debonding at the post-cement interface occurred only with isotropic materials. Confocal microscopy observation revealed that gaps were generally associated with an incomplete hybrid layer and reduced resin tags. CONCLUSION: Regardless of their rigidity, metal and ceramic isotropic posts proved less effective than fiber posts at stabilizing the post and core structure in the absence of the ferrule effect, due to the development of more interfacial defects with either composite or dentin.

Fellippe, L. A., Monteiro, S. et al**. Influence of the use and type of endo posts used in the cervical stress level of central incisors submitted to the fatigue test; an in vitro study. *J Dent Res. Vol 81 (Spec. Iss. A) Abstract #0057, 2002*.**

Objectives: The objective of this study was to observe the biomimetic behavior of the fiber resin post and cast post in the cervical stress level of central incisors submitted to the fatigue test. A group of non-posted tooth was also evaluated. **Methods:** Thirty six recently extracted upper central incisors were selected. The teeth were divided in three groups. G1 – Cast post and core. G2 – Fiber resin post and composite core G3 – without post and core. Post was introduced 2/3 of the root. All groups were endodontically treated and received a full cast crown. G1 e G2 were cut 1mm to the cervical limit. G3 was just restored with composite resin. For the fatigue test, the teeth were mounted in epoxy supports with a simulation of the periodontal ligament. The angle of test was 45º . An Instron 4444 (Universal Test Machine) was used for the compressive fatigue test. The maximum load was 60N. After the fatigue test, the groups were thermocycled and immersed in ethylene blue die for 24 hrs. **Results:** were obtained after teeth sectioning. The Kruskal-Wallis test was used. The average for each group was G1-3.0, G2-1.7, G3-4.6. A significant difference was observed (p<0,05) (T=16.25 and p=0,0003.) G2 had the best result. **Conclusion:** the study suggests that teeth with fiber resin post better resists the fatigue test than teeth with cast post or without post, under the specific conditions of the study.

Hayashi, M., Takahashi, Y., Imazato, S., Ebisu, S. **Fracture resistance of pulpless teeth restored with post-cores and crowns**. ***Dent Mater. 2005 Sep 16***

Objectives: The present study was designed to test the null hypothesis that there is no difference in the fracture resistance of pulpless teeth restored with different types of post-core systems and full coverage crowns. **Methods:** Extracted human upper premolars were restored with a fiber post, prefabricated metallic post or cast metallic post-core. Teeth with full crown preparations without post-core restorations served as a control. All teeth were restored with full coverage crowns. A 90-degree vertical or 45-degree oblique load was applied to the restored teeth with a crosshead speed of 0.5mm/min, and the fracture loads and mode of fracture were recorded. **Results:** Under the condition

of vertical loading, the fracture load of teeth restored with the cast metallic post-cores was greatest among the groups (two-factor factorial ANOVA and Scheffe's F test, P<0.05). All fractures in teeth restored with all types of post-core systems propagated in the middle portions of roots, including the apices of the posts. Under the condition of oblique loading, the fracture load of teeth restored with pre-fabricated metallic posts was significantly smaller than that in other groups. Two-thirds of fractures in the fiber post group propagated within the cervical area, while most fractures in other groups extended beyond the middle of the roots. **Significance:** From the results of the present investigations, it was concluded that under the conditions of vertical and oblique loadings, the combination of a fiber post and composite resin core with a full cast crown is most protective of the remaining tooth structure

Isidor, F., Odman, P., and Brondum, K. **Intermittent Loading of Teeth Restored Using Prefabricated Carbon Fiber Posts.** ***International Journal of Prosthodontics***. ***9: 131-136, 1996.***

Abstract/conclusions: This in vitro study evaluated the fracture resistance of bovine teeth with prefabricated carbon fiber posts **(ComposiPost**). Fourteen bovine teeth having similar lengths and dimensions were mounted in an acrylic resin block having a simulated periodontal ligament. The post space was prepared using two calibrated drills that provided an 8.5-mm post length. The prefabricated carbon fiber post was luted with a resin luting agent, and the core was made using the system's autopolymerizing resin core material. A crown was luted to each prepared tooth. Each test specimen was intermittently loaded (250 N) at an angulation of 45 degrees to the long axis of the tooth at a frequency of 2 loads per second. Four of the roots had an incomplete longitudinal fracture after loading. The results of this study were compared to a previous study by the authors that had been conducted under similar conditions. The failure rates of the two types of posts from the previous study (prefabricated parallel-sided posts (Para-Post) and tapered, individually cast posts) were significantly higher (Logrank test; ***P***<.02) than those of the carbon fiber posts.

Jimenez, M. P., Yaman, P., Dennison, J.D., et al **Fracture resistance of endodontically treated teeth restored with composite posts.** ***J Dent Res. Vol 81 (Spec. Iss. A) Abstract #0323, 2002.***

The most recent application of fiber-reinforced composites involves their use as post and core systems to restore endodontically treated teeth. Even though this last application has been advertised and been used clinically by many dentists, there is very little information regarding the physical properties of these posts. **Objectives:** The purpose of this study was to compare the fracture resistance and mode of failure of endodontically treated teeth restored with fiber-reinforced composite posts. **Materials and methods:** Ninety maxillary central incisors were divided into eight experimental groups and one control group of 10 samples each. Teeth from the two experimental groups called "Narrow" and "Flared" canals were restored with Fibre-Kor, Lucent Anchors and Ribbond posts using two different cementation techniques. Specimens were loaded to failure using an Instron machine. **Results:** Statistical analysis using two-way ANOVA revealed no significant difference between flared and narrow canals in mean load to failure between the post systems except for the Ribbond posts. For the narrow canal, the mean load ranged from a low of 4.55 (±1.49) Kg for the Ribbond Standard to a high of 12.9 (±1.64) Kg for the Lucent Anchors while for the flared canal the low mean was 9.04 (±1.76) for Fibre-Kor and the high of 12.87 Kg was equal for both Lucent Anchors and Ribbond Standard. Overall, the ParaPost control group had the highest load value (18.33 ±3.27 Kg). No root fractures occurred in any of the experimental groups. **Conclusions:** Results from the study suggest that the mode of failure or deflection of the fiber reinforced composite posts is protective to the remaining tooth structure**.** Considering the high risk of fracture and the possibility of re-treatment of endodontically treated teeth, the use of these new post systems seems to represent a conservative option when restoring debilitated root canals.

Martinez-Insua, A., DaSilva, L., Rilo, B., and Santana, U. **Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core.** ***Journal of Prosthetic Dentistry***. 80: 527-532, 1998.

Statement of problem. The survival of pulpless teeth restored with a post and core system is a controversial issue. **Purpose.** This study compared the fracture resistance of 2 types of restorations: teeth restored with prefabricated carbon-fiber **(Composipost**) posts and composite cores to cast dowel-core restored teeth. **Material and methods.** A total of 44 recently extracted sound premolars

were randomly distributed into 2 equal groups: group I, restored with prefabricated carbon-fiber post and a composite core; and group II, with custom-cast type III gold alloy post and cores. The size and shape of the posts were identical in the 2 groups. All teeth were fully covered with a nonprecious cast crown. Fracture resistance was measured by applying a point force at 45 degrees to the long angle of the tooth. **Results.** Mean fracture threshold was 103.7 ± 53.1 kg for group I versus 202.7 ± 125.0 kg for group II (differences significant with ***P*** = .003). In group II, however, fracture nearly always affected the tooth itself, whereas in group I, the post-core nearly always failed first. **Conclusions.** Significantly higher fracture thresholds were recorded for the cast post and core group. Teeth restored with cast posts typically showed fracture of the tooth, although at loads rarely occurring clinically.

Osada, T., Warota, S. Hu. K., Kawawa, T. **Determining the Effect of the Post on Corono-Radicular Reconstruction *J Dent Res. 80 IADR Abstract # 1432; 2002***

Adhesion between the resin composite and the radicular dentin structure serves an important role by supporting both the core and the superstructure. The aim of this in-vitro study was to investigate the efficacy of two dentin bonding systems and two resin composites on the fracture resistance of pulpless teeth and to determine the effect of the post. Root canal instrumentation was performed for twenty mandibular first premolars and divided into four groups: 1. experimental dentin bonding system (EXP) self-cured resin composite (Clearfil Fll, Kuraray: Fllk; 2. EXP/dual-cured resin composite (Clearfil DC CORE, Kuraray: DC); 3. commercial dentin bonding system (ED primer and Clearfil Photo Bond, Kuraray: ED)(Fll:4 ED/DC. Slowly increasing forces were applied perpendicular to the longitudinal tooth axis in an Instron testing machine with a crosshead speed of 0.5 mm/min. until the root fractured. Results [mean SD (Kgl)] were compared with those previously obtained for with and without the C-POST) (Osada et al. JDR 79: 628.2000) using two-way ANOVA and Scheffe test.

	EXP/Fll	**EXP/DC (n-5)**	**ED/Fll**	**ED/DC**
No Post	***24.4±2.1***	***25.8±6.6***	***22.6±3.9***	***21.2 ±8.1***
with **ComposiPost**	46.2±21.2	33.6±4.6	26.4±9.6	33.3±13.1
without **ComposiPost**	38.4±12.7	53.2±11.9	47.7±12.9	33.0±13.7

There was no significant difference in the dentin bonding system/resin composite combinations. When the post was present, the fracture resistance was significantly improved ($p<0.01$), probably due to reinforcing and supporting of the resin composite core.

Rosentritt, M., Sikora, M., Behr, M., Handel, G**. In vitro fracture resistance and marginal adaptation of metallic and tooth-colored post systems. *J Oral Rehabil, 2004 Jul;31(7):675-81.***

Summary: The aim of this ***in vitro*** study was to compare the fracture resistance and marginal adaptation of all-ceramic incisor crowns with all-ceramic posts, glass–fibre-reinforced posts and titanium posts as well as a control without any post. Three groups of eight maxillary incisors were restored with an all-ceramic post, a fibre-reinforced composite (FRC) post, a titanium post and a further group was restored without posts. Composite cores were provided and all-ceramic crowns were adhesively luted. After artificial ageing, the fracture resistance of the restored teeth was determined. The marginal adaptation of the restorations at the interfaces between cement-tooth and cement-crown was evaluated with scanning electron microscopy using replica specimen before and after ageing. The restored teeth without posts [270N (235/335)] showed no significantly different fracture strength compared with teeth with the titanium system [340N (310/445)]. The all-ceramic posts [580N (425/820)] and the FRC posts [505N (500/610)] both provided a significant higher fracture resistance than the teeth without posts. Prior to ageing, all materials showed <5% separation at the margins cement-tooth or cement-crown ('marginal gap'). After ageing, the interfaces of all systems deteriorated to values between 6 and 14% marginal gap. The greatest marginal gap was found with the titanium system (14%) at the interface cement-crown and with the all-ceramic posts (12%) at the transition between cement-tooth. Regarding fracture resistance and the marginal adaptation, the all-ceramic and FRC posts may be considered as an alternative to the commonly used titanium post restorations.

Salameh Z, Sorrentino R, Papacchini F., Ounsi HF, Tashkandi E, Goracci C, Ferrari M**. Fracture resistance and failure patterns of endodontically treated mandibular molars restored using resin composite with or without translucent glass fiber posts. *J Endod. 2006 Aug;32(8):752-5.***

The elastic modulus of the restorative material is important in restoring endodontically treated teeth. This study aimed to compare the fracture resistance and failure patterns of 90 mandibular molars restored using resin composites with or without fiber posts, with respect to the number of residual cavity walls. Five restoration types were performed corresponding to different wall defects (groups 1-5). Groups were divided in two subgroups corresponding to the use or absence of fiber posts. Teeth were loaded and resistance of specimens was measured as the axial compressive load to cause fracture and macroscopic fracture patterns were observed. One way ANOVA revealed a significant difference in fracture resistance ($p < 0.001$). Tukey post hoc test also revealed significant differences between groups as samples restored with fiber posts exhibited mostly restorable fractures. It was concluded that the resistance of endodontically treated mandibular molars restored with composite resins is mainly affected by the number of residual walls. Using fiber-reinforced posts optimized fracture patterns.

Shirani, F., Malekipour, M**. In-vitro study of different reinforcement methods of anterior weakened teeth. *J Dent Res. Vol 84 (Spec. Iss. A) Abstract #1732 2005***

Objectives: The purpose of study was to evaluate the potential of intraradicular reinforcement of layered adhesion technique and two different types of post in structurally compromised roots. **Materials and methods:** Root canal therapies were done on 48 extracted similar maxillary incisors. The samples were divided to 4 groups. In three groups for simulation of specimens to weakened teeth, instrumentation was done 5mm apical to CEJ from access cavity. In positive control group that weakening was not done, restoration of access cavity was done with composite resin (Z100, 3M dental product, USA) and dentin bonding agent (Single bond, 3M dental product, USA). In second group access cavity of the weakened teeth was restored only with composite resin and dentin bonding agent to the level of CEJ. In third group weakened cervical area were reinforced with a dual cure composite (Bis-Core, BISCO, INC, USA) and translucent quartz fiber post (**Light-Post**, RTD, France) In the fourth group, the weakened cervical area was reinforced with dual cure composite and cast post with similar morphologic properties. Access cavity in the last two groups were restored with composite resin, then all specimens were tested in an instron machine. **Results:** The mean fracture load for the 4 groups were 170.12, 71.40, 129.36, and 116.6 kgf respectively. The differences between first group and others (P value=0), second group and others (P value=0) were significant. There was no significant differences between third and forth group (P value =0.103), but the rate of restorable fractures (pattern of fracture) was significantly different between these two groups. **Conclusions:** It is concluded that the use of post, dentin bonding agent and a composite resin in a root with thin walls will reinforce the weakened tooth but the type of the post will influence on the final result.

B. Photoelastic measurements

Yamamoto, M., Miura, H., Okada, D., Masuoka, D., Komada, W. and Suzuki, C. **Photoelastic stress analysis in different types of post and core**, ***Dent Res. Vol 86 (Spec. Iss. A) Abstract #2617, 2007***

Objectives: The aim of this study was to compare three types of post and core systems and analyze the stress magnitude within the root. **Methods:** Two-dimensional photoelastic simulation models of endodontic treated upper central incisors were fabricated with epoxy resin sheets (6 mm of thickness). Models were 10 times the life size. The post and core systems were divided in three different types, build-up method using only composite resin (R), build-up method using composite resin in combination with a **glass fiber post** (R+F), and a cast post and core (C). The equivalent ratio of elastic modulus for composite resin, dentin, glass fiber post, and metal were considered for all the parts (5:1). The models were observed in a transmission polariscope with the same loading force (400 N) on 45 degrees palatal direction. The measured points were the buccal margin area of the root and the surrounding area of the apex of the post, which used to present the higher stress concentration area. The isochromatic fringe patterns and the stress distribution in the tooth simulation models were analyzed. **Results:** In the buccal margin area of the root, R, R+F and C showed 3.1 fringe order, 1.4

fringe order, and 2.4 fringe order, respectively. For the surrounding area of the apex of the post, R, R+F and C showed 0.45 fringe order, 0.80 fringe order, and 1.0 fringe order, respectively. **Conclusion:** The stress concentration in the buccal margin area of the root had a higher distribution, compared with the surrounding area of the apex of the post. Resin +Fiber post model had the lowest stress concentration in the buccal margin area of the root.

W.Y. Zhang, C.X. Shi, et al**. Three-dimensional photoelastic stress analysis of roots restored with FRC posts and Ni-Cr alloy posts. *J Dent Res. Vol 83 (Spec. Iss. B China), 2004***

Objectives: Post-and-core is a perfect restoration method for residual crown or root of pulpless teeth. More and more emphasis has been placed on how to avoid tooth fracture and maintain esthetic appearance without reducing strength and retention. This study shows that the new developed fiber-reinforced composite post (FRC) used successfully for several years, because of their strength and relative flexibility, ease of placement or ease of removal. The purpose of this study was to analyze the effect of two modulus elasticity material posts on root stress distribution by using three-dimensional photoelastic analysis. **Methods:** The photoelastic models were divided into four groups according to posts material and loading. The roots stress distribution, which restored with FRC posts and Ni-Cr alloy posts, was analyzed by three-dimensional photoelastic analysis. **Results**: The material of posts influenced the root stress distribution significantly. The greater stress concentration was found at apex of Ni-Cr alloy posts with high modulus, the stress was evenly in FRC posts groups. **Conclusions:** The study concluded that the modulus of posts material influenced the root stress distribution significantly. The FRC posts which modulus was closed to teeth could protect roots from fracture.

C. Stress Distribution F. E. A.

Albuquerque R C, Polleto LT, Fontana RH, Cimini CA. **Stress analysis of an upper central incisor restored with different posts**. ***J Oral Rehabil. 2003 Sep;30 (9):936-43.***

Summary / conclusions: The effect of different anatomic shapes and materials of posts in the stress distribution on an endodontically treated incisor was evaluated in this work. This study compared three post shapes (tapered, cylindrical and two-stage cylindrical) made of three different materials (stainless steel, titanium and **carbon fibre** on Bisphenol A-Glycidyl Methacrylate (Bis-GMA) matrix).Two-dimensional stress analysis was performed using the Finite Element Method**.** A static load of 100N was applied at 45 degrees inclination with respect to the incisor's edge. The stress concentrations did not significantly affect the region adjacent to the alveolar bone crest at the palatine portion of the tooth,regardless of the post shape or material. However, stress concentrations on the post/dentin interface on the palatine side of the tooth root presented significant variations for different post shapes and materials. Post shapes had relatively small impact on the stress concentrations while post materials introduced higher variations on them. Stainless steel posts presented the highest level of stress concentration, followed by titanium and carbon/Bis-GMA posts.

Bolla, M., Laplanche, O., Leforestier, E., Muller-Bolla, M., **Influence of Elastic Modulus of Posts on Stress Distribution J *Dent Res. Vol 86 (Spec. Iss. A) Abstract #2609, 2007***

Objectives: fractures of restored pulpless teeth can be influenced by many factors, including type or design of the post, or the occlusal load and its direction. The purpose of this study is to use finite element analysis to investigate the effect of different posts used for restoring endodontically treated teeth according to different elastic moduli and direction of the occlusal load. Method: a 3-dimensional finite element model, including the periodontal ligament, was constructed in a mesio-distal cross sectional view of a mandibulary premolar. Tooth was fully restored with a cast crown, as occurs in clinical practice. The standard model was composed of 80000 elements and 130000 nodes. Elastic modulus and Poisson's ratio of different components, along with the coordinate and geometry of each node and element were entred into a computer. Four different posts (length: 14 mm – diameter : 1.2 mm ; 3 metallic : stainless, titanium, gold – 1 non-metallic : **carbon fiber**) were investigated according to three different composite core materials. The effect of a 300 MPa load on vertical, 30 degrees and 45 degrees oblique direction was tested. Analysis program (IDEAS, version n°6) was used to solve the stress analysis problem. **Results:** stress distribution in the root depends on the elastic modulus and on the direction of the occlusal load. Elastic modulus of the core is less significant than elastic modulus of the post. **Conclusion**: the effect of the post on stress distribution varies according to the

direction of the load : in a vertical load, gold and carbon fiber posts generate lower stresses in the root than other metallic posts. In a 30 or 45 degrees oblique load, best results are obtained with a carbon-fiber post.

Bolla, M., Laplanche, O. et al. **Elastic modulus and stress distribution: finite element analysis.** ***J Dent Res. Vol 84 (Spec. Iss. A) Abstract #2933, 2005***

Objective: Fractures of restored pulpless teeth can be influenced by many factors, including type or design of the post, or the occlusal load and its direction. The purpose of this study is to use finite element analysis to investigate the effect of different posts used for restoring endodontically treated teeth, according to different elastic moduli and the direction of occlusal load. **Materials and methods:** a 3-dimensional finite element model, including the periodontal ligament, was constructed in a mesio-distal cross sectional view of a mandibular premolar. The tooth was fully restored with a cast crown, as occurs in clinical practice. The standard model was composed of 80000 elements and 130000 nodes. Elastic modulus and Poisson's ratio of different the components, along with the coordinate and geometry of each node and element were entered into a computer. Four different posts (length: 14mm, diameter: 1.2mm) 3 metallic (stainless, titanium gold) and one non-metallic (**carbon fiber**) were investigated according to three different composite core materials. The effect of a 300MPa load on vertical, 30 degrees and 45 degrees oblique was tested. Analysis program (IDEAS, Version 6) was used to organize the stress analysis data. **Results:** Stress distribution in the root depends on the elastic modulus and the direction of the occlusal load. Elastic modulus of the core is less significant than the elastic modulus of the post. **Conclusions:** The effect of the post on stress distribution varies according to the direction of the load. In a vertical load, gold and carbon fiber posts generate lower stresses in the root than other metallic posts. In a 30 or 45 degree oblique load, the best results are obtained with a Carbon fiber post.

Borcic, J., Catic, A., Smojver, I., Antonic., R., Petricevic, N., and V. Reljic, **Stress Distribution in Glass Fiber Vs Cast Post and Core** Dent Res. Vol 86 (Spec. Iss. A) Abstract #2621, 2007

Objectives: Endodontically treated teeth become brittle as a result of moisture loss and have a greater incidence of fracture than vital and healthy teeth. The difference between the elastic modulus of dentin and the post material may be a source of stress in the root structures. The aim of the study was to analyse the mechanical behaviour of a teeth restored with prefabricated **glass fiber** posts and composite core vs cast post and core through 3D finite element analysis. **Methods:** Models have more than 1,5 million elements and an average loading force of 200 N was used to simulate biting forces in the two different occlusal conditions. First condition represents so called normal occlusion with tripodal occlusal contact. Second condition represents malocclusion with single contact on the palatal cusp. The load vectors were applied in the direction normal to the surface in order to simulate the contact with antagonistic teeth. **Results:** Endodontic posts take some of the stresses on themselves and values are smaller on the surface of the tooth. In the case of normal occlusion stress distribution is the same for sound and restored tooth, dissimilarity exsists in the values od stresses. Significantly higher tensile stress values were recorded for the cast post and core restored tooth. At the root furcation, tensile stress appeared only in the restored tooth. In the case of normal occlusion, tensile stress at root furcation occurs only in the model with cast post and core. **Conclusions:** Cast posts resulted in significantly higher stress values. Tensile stresses are much harmful for the tooth tissue and this type of stress occurs at the root furcation only in the restored tooth, esspecially in the cast post and core.

Borcic, J. et al. **Finite element study of the glass fiber endodontic posts.** ***J Dent Res. Vol 83 (Spec. Iss. A) Abstract #0530, 2004***

Objectives: Post and core applications are generally used in the restoration of endodontically treated teeth. The stress distribution during masticatory function in a tooth restored with a post and core can cause root fracture. The different mechanical behavior of post and dentine is a critical parameter for the load transmission. In order to minimize the rigidity difference between the post and the dentine, a new kind of post was developed. The aim of this study was to analyze the mechanical behavior of a new polymeric composite post reinforced with **glass fibers.** A natural tooth was considered as a reference model. **Materials and methods:** The 3D finite element method (FEM) was selected to perform the stress analysis of the two-rooted first maxillary premolar restored with glass fiber posts.

Composite resin was used as the core material and full porcelain crowns covered the model. Four noded tetrahedral were applied in the description of the tooth morphology, resulting in 1,684,512 elements and 246,510 nodes with 739,539 degrees of freedom. A total force of 200N was applied. **Results:** The greatest stresses were observed in the palatal cervical region (-16.126MPa) and in the intraradicular parts of the post (-23.898MPa). In the cervical region, the mean high-intensity compressive stress areas were more extensive in the natural tooth (-175.222 MPa). **Conclusions:** The glass fiber composite post induces a stress field similar to that of the natural tooth, except in the cervical region, where the tooth has higher compressive stresses.

Chuang, S-F, Chang, C-H, Su, K-C, Yaman, P. **Effect of post length and material on periodontally involved teeth . *J Dent Res. Vol 85 (Spec. Iss. B) Abstract #0006, 2006*.**

Objective: To investigate the stress distribution of periodontally involved teeth restored with different posts using finite element analysis. **Methods:** 2-D models of a maxillary central incisor consisting of a PFM crown, composite core, parallel post, dentin, gutta percha, periodontal ligament, and cortical/trabecular bone were constructed using ANSYS v9.0 software. The posts tested were stainless steel (SS), carbon fiber (CF), and glass fiber (GF) at 10mm and 5mm lengths into the root canals. The alveolar bone level was set either as intact periodontium or with bone loss even with the apical end of short post. All materials were assumed to be linearly elastic and isotropic except CF and GF posts which were orthotropic. Teeth were subjected to two different loads: the first a 70N force on the incisal tip; the second a 100N force on the lingual surface of crown at a 145 degree angulation. **Results:** With the 70N load the stress distribution patterns were similar among the groups. For the 100N load at 145 degrees, the models representing periodontal bone loss showed higher von Mises stress over the middle part of root periphery and around the post ends compared to the intact periodontium groups. In the intact periodontium groups, the stress around the crown margins was higher than the middle of the root. The SS post exhibited higher stress levels than the other posts only around the apical end of the post. The SS/5mm group with periodontal bone loss exhibited the greatest stress (334 MPa) on the dentin around the ends of posts. **Conclusion:** Teeth with posts and periodontal bone loss generate higher stress concentrations with an increased risk of root fracture. The major difference in stress distribution between rigid and non-rigid posts is primarily around the apical ends of the posts.

Duret, B., Duret, F., and Reynaud, M. **Long-Life Physical Property Preservation and Postendodontic Rehabilitation With the Composipost. *Compendium*. *17: S50-S56, 1996.***

Abstract/conclusions: Most coronal radicular reconstructions are made of cast inlay core metals or prefabricated metal posts covered in composite. The differences in the mechanical properties of these elements create a heterogeneous mass with inconsistent mechanical behavior. Studies using the Finite Element Method have shown the biomechanical disturbances casued by the inclusion of materials with a modulus of elasticity that is superior to that of dentine (ie, nickel, chrome, zircon, etc). The use of materials with a modulus of elasticity close to that of dentine does not disturb the flow of stress inside the root. To our knowledge, only a composite material structured with programmable mechanical properties would be capable of producing both high mechanical performance and a modulus of elasticity adapted to dentine values. The **ComposiPost,** made of carbon epoxy, accommodates the demands of the dentine, as well as the in vitro stress linked to the prosthesis. The internal structure, consisting of long high-performance carbon fibers, unidirectionally and equally stretched, confers a totally original behavior that is adapted to clinical objectives. In addition, the ComposiPost has a fracture resistance superior to most metals.

Lanza, A., Aversa, R., Rengo, S., Davide, Apicella, D., Apicella, A.. **3D FEA of cemented steel, glass and carbon posts in a maxillary incisor *Dent Mater. 2005 Aug; 21(8):709-15***

Objectives. A comparative study on the stress distribution in the dentine and cement layer of an endodontically treated maxillary incisor has been carried out by using Finite Element Analysis (FEA). The role of post and cement rigidity on reliability of endodontic restorations is discussed. **Methods.** A 3D FEM model (13,272 elements and 15,152 nodes) of a central maxillary incisor is presented. A chewing static force of 10 N was applied at 125° angle with the tooth longitudinal axis at the palatal surface of the crown. Steel, **carbon and glass fiber** posts have been considered. The differences in occlusal load transfer ability when steel, carbon and glass posts, fixed to root canal using luting

cements of different elastic moduli (7.0 and 18.7 GPa) are discussed. **Results and significance.** The more stiff systems (steel and carbon posts) have been evaluated to work against the natural function of the tooth. Maximum Von Mises equivalent stress values ranging from 7.5 (steel) to 5.4 and 3.6 MPa (respectively, for carbon posts fixed with high and low cement moduli) and to 2.2 MPa (either for glass posts fixed with high and low cement moduli) have been observed under a static masticatory load of 10 N. A very stiff post works against the natural function of the tooth creating zones of tension and shear both in the dentine and at the interfaces of the luting cement and the post. Stresses in static loading do not reach material (dentine and cement) failure limits, however, they significantly differ leading to different abilities of the restored systems to sustain fatigue loading. The influence of the cement layer elasticity in redistributing the stresses has been observed to be less relevant as the post flexibility is increased.

Nakamura T, Ohyama T, Waki T, Kinuta S, Wakabayashi K, Mutobe Y, Takano N, Yatani H. **Stress analysis of endodontically treated anterior teeth restored with different types of post material**. Dent Mater J. 2006 Mar;25(1):145-50

Finite element analysis was performed to evaluate stress distribution in maxillary central incisors treated endodontically and restored with a post and an all-ceramic crown. Tensile stress at tooth root was analyzed using two-dimensional finite element models with different post diameters and lengths. One post length was 1/3 of the root (short), while the other was 2/3 of the root (long); one post diameter was 1/3 of the root (narrow), while the other was 2/3 of the root (wide). The following combinations were used for posts and cores: gold alloy cast post and core, commercial stainless steel post and resin core, and fiber post and resin core. Results showed that the fiber post produced less stress on the root dentin around the post tip than did the metal posts. This finding thus suggested that to reduce the stresses that cause root fracture, a long, thin fiber post should be used.

Oliviera, L.C.A., Candido, M.S.M., Duarte, S., Oliviera, S.A.G., **Comparative study of stress distribution in upper incisors; biometric behavior of post systems**. ***AADR Abstract #0548, 2003***

Objective: this work proposes a study about the distribution of mechanical stresses in the radicular dentin restored with different post systems, by means of Photoelastic and Finite Element techniques. This analysis is conducted for the following post systems: **carbon fiber, fiberglass**, zirconium, stainless steel, titanium and cast metal (Cu-Al alloy) and the healthy tooth (control). The computer analysis and numerical results were validated by laboratory experimental data (Photoelastic). **Methods:** For this purpose, representative 2-dimensional models were of the upper central incisor were built for both methods. These models were subject to a 100N load applied at the tip of the crown, at 45^0 from the axis along the tooth. These results are expressed in terms of the Von Mises and Sy stresses and the fringe order, for the Finite Element and photoelastic methods, respectively. **Results:** Through the analysis of these results, it can be concluded that significant stress distributions arise between the 6 different post systems tested, so that those made of zirconium, stainless steel, titanium and cast metal produced high stress concentration at the post/dentin interface region. In the cases of carbon fiber and fiberglass, on the other hand, the stress distribution along the radicular surface is uniform, lacking stress concentration areas. **Conclusion:** The zirconium, stainless steel, titanium and cast metal posts present mechanical properties which are different from those of the tooth structure, resulting in significant alterations over the mechanical behavior of the dental structure. The non-metallic posts comply more satisfactorily with the requirements necessary to provide a mechanical behavior more similar to that of the dental structure, the compatibility among the mechanical properties found in these systems and the dentin providing a biometric behavior, reducing the risk of failure or fracture of the root.

Okada, D., Miura, H., Suzuki, C., Komada, W., Yamamoto, M., Masouka, D., Shin, C. **Stress Distribution in Root Restored with Different Post Systems .** ***J Dent Res 85, (Special Issue B) #0011, 2006***

Objective: Composite resin core materials in conjunction with various kinds of prefabricated posts are gaining in popularity. However, it is not yet clear, which kind of material is most suitable for the post. The aim of this study was to evaluate the influence of the prefabricated post on stress distributions in an abutment tooth restored with composite resin by 3-dimensional finite element analysis. **Methods:** Four 3-dimensional finite element models of an endodonticaly treated premolar were made. In these four models, posts and cores were built up with composite resin and four types of prefabricated post;

glass fiber post (GFP), Titanium post (TIP), Zirconia post (ZRP), and Stainless steel post (STP). In all the models, an occlusal force similar to chewing beef jerky, was applied to the center of occlusal surface (lingual direction: 24N,distal direction:29N, apical direction:164N), which was measured with a small 3-dimensional occlusal force meter. Then Von Mises stress distributions within the root were calculated. **Results:** In all models, there were similar distributions of stress concentration at the apical area. However, in the dentin of the root around the end of the prefabricated posts, there were differences in stress concentration. The magnitudes of stress in this area for GFR, TIP, ZRP and STP were 11.5 Mpa, 12.6 MPa, 12.0 MPa, and 14.9 MPa respectively. **Conclusion:** Within the limitations of this experiment, GFR was indicated to be most suitable since this model showed lower stress values, which means less possibility of root fracture.

Pegoretti A, Fambri L, Zappini G, Bianchetti M. **Finite element analysis of a glass fibre reinforced composite endodontic post.** ***Biomaterials. 2002 Jul;23(13):2667-82***

In this work the mechanical response to external applied loads of a new glass fibre reinforced endodontic post is simulated by finite element (FE) analysis of a bidimensional model. The new post has a cylindrical shape with a smooth conical end in order to adequately fit the root cavity, and to avoid edges that could act as undesired stress concentrators. Mechanical data obtained by three-point bending tests on some prototypes fabricated in the laboratory are presented and used in the FE model. Under various loading conditions, the resulting stress component fields are hence compared with those obtained in the case of two commercial endodontic posts (i.e. a cast metal post and a **carbon fibre post**) and with the response of a natural tooth. The gold cast post-and-core produces the greatest stress concentration at the post-dentin interface. On the other hand, fibre-reinforced composite posts do present quite high stresses in the cervical region due to their flexibility and also to the presence of a less stiff core material. The glass fibre composite shows the lowest peak stresses inside the root because its stiffness is much similar to dentin. Except for the force concentration at the cervical margin, the glass fibre composite post induces a stress field quite similar to that of the natural tooth.

Samilee, P., Arunpraditkul, S., Dechaumphai, P. **Finite element analysis of various post and core restorations in teeth with flared root canal.** ***J Dent Res. Vol 82 IADR Abstract #1936, 2003***

Objectives: Endodontically treated teeth with flared root canal are frequently found for many reasons and the prognosis of post and core restoration are also unpredictable. Reinforcing techniques that weaken the tooth had been introduced, however, the suitable methods are still questioning. The aim of this study is to investigate the stress distribution in root dentin and restorative materials. **Methods:** The 2 –dimensional Finite Element models of flared root canals (Maxillary central incisors) with ten restorative techniques were performed, using MSC/Nastran for Windows. Three evaluated parameters: reinforcing or non-reinforcing the flared root canal, reinforcing materials (composite resin and reinforced glass ionomer) and the post materials (gold alloy type III, Ni-Cr alloy, stainless steel, and **carbon fiber)** were investigated. All materials were assumed to be homogeneous, isotropic, linearly elastic. The load (150N) was applied on the lingual surface of metal-ceramic crown; 130 degrees to the tooth axis. **Results:** The results showed that maximal tensile stress in dentin were reduced in the reinforcing models. Reinforcement with composite resin provided less maximum tensile strength than that with reinforced glass ionomer. Higher elastic modulus of posts, such as Ni-Cr alloy showed more maximum tensile stress at post apex, but less stress concentration at flared dentin compared with posts with lower elastic modulus. **Conclusions:** From this FEA study, reinforcement of flared root canal with composite resin and carbon fiber post showed favorable stress distribution in restoring the teeth with flared root canal.

D. Microleakage

Kazemi, R. B., Reid, L.C., Meiers, J. C**., A new test system for measuring concurrently fatigue and microleakage**, ***J Dent Res. 81 (Spec. Iss. A) Abstract # 3130; 2002***

Objectives: The purpose of this study was to develop and evaluate a non-destructive test system that could test concurrently fatigue and microleakage. **Methods:** A new multi-purpose computer-operated impact machine was designed and used in combination with a modified fluid filtration apparatus to evaluate concurrently both core integrity and post microleakage in the same sample. Crowns of single

rooted teeth were removed and the roots were randomly assigned to five groups (n=10) and restored with the following post systems: one metallic group-Titanium ParaPost (TP) cemented with zinc phosphate, and four non-metallic groups- CosmoPost (CO), **ComposiPost** (CP), **Esthetic C-POST** (EC), and FibreKor Posts (FK). All non-metallic posts were cemented with resin cement. Tetric Ceram was used for composite core for all groups. Samples were imbedded in an acrylic resin mold, connected to the filtration system and the baseline/control microleakage was measured. Samples were then placed in a positioning jig in the fatigue testing machine and subjected to 100,000 impacts at 45 degrees to the long axis of the root with a force of 55N at a frequency of 3HZ. After 60,000 impacts, the samples were subjected to 1,000 thermocycles (60KT) between 5^0C and 55^0C. Microleakage of the post systems was measured at 30K, 60K, 60KT and 100K cycles. **Results:** All samples showed no detectable displacement of any core. Mean +/-SD microleakage in microliters significantly increased in all groups as samples were subjected to increased impacts and thermocycling. The metallic group (TP) showed a statistically significant increase in microleakage ($p<0.05$) when compared to the non-metallic groups (CO, CP, EC and FK) at the conclusion of the study. **Conclusions:** The test design was successful in performing both fatigue loadings and microleakage measurements in the same sample using core integrity and prefabricated post microleakage as test parameters.

Reid LC, Kazemi RB, Meiers JC **Effect of fatigue testing on core integrity and post microleakage of teeth restored with different post systems.** ***J Endod. 2003 Feb;29(2):125-31***.

The purpose of this study was to evaluate a new nondestructive test system, which could test concurrently fatigue and microleakage. Fifty, single-rooted teeth were restored with one of the following posts systems and a composite core: titanium ParaPost cemented with zinc phosphate cement; CosmoPost; **ComposiPost; Esthetic C-Post**; and FibreKor post, all cemented with resin cement. Samples were embedded and placed in a positioning jig. They were impacted at 45 degrees to the long axis of the tooth with a force of 55 N at a frequency of 3 Hz for a total of 100,000 impacts. After 60,000 impacts, samples were thermocycled. Core integrity and post microleakage were evaluated periodically throughout the 100,000 impacts. Samples showed no detectable displacement of any of the cores, but the metallic group showed a statistically significant increase in microleakage ($p < 0.05$) at the conclusion of the study compared with the nonmetallic groups.

Usumez A, Cobankara FK, Ozturk N, Eskitascioglu G, Belli S**. Microleakage of endodontically treated teeth with different dowel systems.** ***J Prosthet Dent. 2004 Aug;92(2):163-9***

Statement of problem: Several new esthetic dowel systems are available for the restoration of endodontically treated teeth, but little is known about how effectively these dowels seal the restored teeth. **Purpose**: The purpose of this in vitro study was to compare microleakage of 3 esthetic, adhesively luted dowel systems with a conventional dowel system. **Methods:** The root canals of 41 human intact single-rooted extracted teeth were prepared using a step-back technique. The teeth were randomly divided into 4 experimental groups (n=10), and 1 tooth served as a positive control. The decoronated roots were obturated with gutta-percha using lateral condensation. Roots were restored with 1 of the following dowel systems according to the manufacturer's instructions: (1) stainless steel dowels (ParaPost), (2) glass fiber dowels (Snowpost), (3) resin-supported polyethylene fiber (Ribbond) dowels, or (4) zirconia dowels (Cosmopost). Using a fluid filtration method, coronal leakage of the specimens along the dowel space and root canal restorative material was measured. Fluid movement measurements were made at 2-minute intervals for 8 minutes to measure the presence of voids existing in the obturated canals, at 1 week, 3 months, and 6 months following dowel insertion. A repeated-measures analysis of variance (ANOVA) was used to analyze logarithmic transformations of data (time and dowel material) for significant differences. The Tukey HSD test and paired 2-tailed tests were used to perform multiple comparisons (alpha=.05). **Results**: The data indicated that the leakage values varied according to the dowel system used (P<.01). There was significant interaction between dowel systems and time of testing (P<.01). The sealing ability of zirconia dowels decreased over time (P<.01), but sealing abilities of stainless steel and resin-supported polyethylene fiber dowels remained constant (P>.05). The sealing ability of glass fiber dowels increased at 3 months (P=.032) and remained constant over the next 3 months (P=.758). Statistically, resin-supported polyethylene fiber and glass fiber dowels showed the lowest coronal leakage when compared with stainless steel and zirconia dowels at all time periods (P<.01). There were no significant differences between resin-supported polyethylene fiber and glass fiber dowels at any time period. The initial leakage measurement in zirconia dowel and stainless steel dowels were

similar (P=.914), but became significantly different at 3 and 6 months (P<.01). **Conclusions:** Resin-supported polyethylene fiber dowels and glass fiber dowels tested exhibited less microleakage compared to zirconia dowel systems. The latter system should be further evaluated because of its unacceptable level of leakage

Vițalariu A, Comăneci R, Tatarciuc M .**Analysis on the stress induced by non metallic posts in dental and periodontal support by using the finite element method** [Article in Romanian] Rev Med Chir Soc Med Nat Iasi. 2006 Jul-Sep;110(3):705-10

AIM: The determination of the influence of non-metallic posts on the stress distribution to the supporting tissues. METHOD: Two 3D models were created: one intact maxillary incisor and one reconstructed with post (ceramic, carbon fiber and glass fiber). The compressive load (30daN) was applied to an angle of 45 degrees on the palatal surface of the crown. The Algor software computed the stress for each model comparing the maximum registered intensity, localization and concentration into the dento-periodontal complex. RESULTS: The fiber reinforced posts induced lower stress peak inside the root, the von Mises stress in the teeth reconstructed with **carbon and glass fiber post** being similar to that recorded in a tooth without post. The ceramic post produced the greatest stress concentration in the middle third of the root, this behavior supporting the potential risk of the vertical root fractures registered "in vivo". CONCLUSIONS: The fiber reinforced posts are more suitable for the clinical longevity of the tooth, representing the best choice to reconstruct an endodontically treated tooth.

E. Failure mode

Bae, J-M., Park, J-S, Kim, Y-J, et al **Effect of component and shape of posts on fracture aspects.** ***J Dent Res. Vol 83 (Spec. Iss. A) Abstract #3135, 2004***

Objectives: This study was to compare the fracture resistance and failure mode of natural teeth with endodontically treated teeth, with and without post systems that have different shapes and components.

Materials & Methods: Total 45 human mandibular incisors were divided into 9 groups; natural teeth (A), root canal treated teeth without post (B), and teeth with their crowns removed and restored with seven kinds of post systems. Each post was cemented with dual-cured resin cement, DUOLINK™ (Bisco) and core build-up was done with light-cured composite, LIGHT-CORE™ (Bisco), except cast posts. Each specimen was embedded in acrylic resin with periodontal ligament simulation and shear load was applied using universal testing machine (Z020, Zwick) at a crosshead speed of 5 mm/min. After test, the fracture aspects were evaluated by naked eye and SEM. **Results:** The followings are the data of fracture resistance and they were analyzed by Kruskal-Wallis test and Duncan's multiple range test at ***P***=0.01 (unit: N). Standard deviations are in parenthesis.

A	**B**	**Cast post**	**Parapost** (Whaledent)	**Parapost fiber white** (Whaledent)	**Filpost** (Filhol Dental)	**C-Post** (RTD/Bisco)	**FRC Postec** (Ivoclar)	**Cosmo post** (Ivoclar)
		46% Au alloy (parallel)	S-S (parallel)	Glass fiber (parallel)	Titanium (taper)	Carbon fiber (taper)	Glass fiber (taper)	Zirconia (taper)
974.0[a] (80.0)	838.6[b] (80.9)	642.4[c] (102.3)	639.8[c] (44.8)	542.4[d] (40.0)	551.8[d] (58.2)	556.4[d] (31.3)	508.8[d] (59.4)	501.6[d] (39.8)

The highest fracture resistance was recorded for Cast post and Para post (***P***<0.01). In failure mod**e, C-Post** and FRC Postec showed favorable aspects with few cracks around apical third. **Conclusions:** The carbon and glass fiber posts with tapered shape resulted in good failure mode, in spite of their lower strength than metal post, meaning the possibility of re-treatment.

Fokkinga, W**.** A., Creugers, N. H., Kreulen, C. M. **In vitro failure mode of fiber-reinforced post-core systems: A systematic review**. ***J Dent Res. Vol. 82 IADR Abstract #2563, 2003***

Objectives: To compare in vitro failure modes of fiber reinforced post systems with prefab metal and cast post systems. **Methods:** The literature was searched using MEDLINE, with the year limits 1984-2002/6 for dental articles written in English, German or Dutch. Key words: (post or core or build-up or dowel) and (teeth or tooth) not (implant or orthodontic or periodontal or primary teeth). The following steps were conducted: 1) Inclusion of abstracts describing post-core techniques to reconstruct endodontically treated teeth and their mechanical characteristics (strength, fracture, failure, resistance, survival, retention, leakage, seal). Descriptive studies or reviews were excluded. 2) Inclusion if in vitro studies on fracture resistance of single rooted human teeth restored with prefab fiber posts and composite cores. 3) Failure mode categorization. Favorable failures were defined as repairable failures including adhesive failures, and fractures above bone simulation. Unfavorable were non-repairable, vertical root fractures. Steps 2) and 3) were conducted using the Aim, Materials and Methods and Results of the articles. All assessments were done by 2 operators. Consensus was reached in case of disagreement. Kappa's were used for observer agreement. Percentages of favorable failures of the post systems were compared using Wilcoxon Signed Rank Test. **Results:** MEDLINE identified 1237 articles. Results of each step: inclusion of 203 articles (Kappa=0.86) of which 21 dealt with fibers, 2) inclusion of 8 articles (Kappa=0.62) of which 6 dealt with failure mode of carbon fibers, 3) failure mode categorization per system (Kappa=0.99). Favorable failures occurred significantly more with the carbon fiber reinforced posts than with the prefab metal (n=11, p=0.05, z=1.96) and respectively, the cast post groups (n=8, p=0.02, z=2.39). **Conclusions:** These results suggest a more favorable failure mode of the Carbon fiber post systems compared with prefab metal and cast post systems. Comparative studies of the different post systems are scarce

King, PA, Setchell DJ. **An in vitro evaluation of a prototype CFRC prefabricated post developed for the restoration of pulpless teeth.** ***J Oral Rehabil. 1990 Nov;17(6):599-609***

Carbon fibre reinforced carbon (CFRC) in the form of a prefabricated post has recently been developed and is theoretically acceptable for consideration in an endodontic post-retained crown system. This study compared four different types of postcore system cemented into 40 extracted anterior human teeth. The test groups consisted of CFRC posts cemented with a composite resin luting agent, and used with either a cast gold alloy core (Group B) or a composite resin core (Group C). Two existing post-core techniques were used as controls for comparison with the CFRC groups. One control was a prefabricated wrought precious alloy post having a cast gold alloy core, and cemented with zinc phosphate cement (Group A). The other was a prefabricated stainless steel post with a composite resin core, and cemented with a composite resin luting agent (Group D). All specimens were restored with a gold alloy crown and tested to failure with an obliquely applied compressive load at 130 degrees in an Instron using a cross-head speed of 5 cm min-1. The results showed that post-retained crowns using a prefabricated CFRC post exhibited properties comparable with, and in some cases better than, those of existing prefabricated posts. The mode of failure of specimens restored with a CFRC post was more favourable to the remaining tooth tissue than was that of specimens restored with a metallic post.

Lang, H., Raab, W., **Interferometric assessment of teeth restored with different post systems.** ***J Dent Res, Vol 84 (Spec. Iss. A) Abstract #0666, 2005***

Objectives: This study evaluated the deformation of endodontically treated teeth with 3 different post systems at 4 simulated clinical stages. **Materials and methods:** Extracted human anterior maxillary teeth (n=30) were used and randomly assigned to 3 groups (i.e. post systems): fiber-reinforced epoxy resin posts –Group 1 (ER DentinPost), zirconium oxide ceramic posts –Group 2 (ER CeraPost) and titanium posts –Group 3 (ER Titan post) (all from Komet, Brasseler GmbH, Lemgo, Germany). A series of endodontic treatments was applied and after each single procedure the teeth were loaded (3.75N) and the deformation was assessed using Speckle pattern interferometry. The following treatments were applied: a) no treatment (control), b) access preparation and initial root canal instrumentation (Kerr files ISO 40), c) post preparation (Size 110) and d) cementation of the posts (gr. 1+2: resin bonded / Gr. 3: zinc phosphate cement). **Results:** Access preparation (with root canal instrumentation) and post preparation significantly increased the deformation under loading ($p<0.05$ - one-way ANOVA and post-hoc Scheffé test). All posts reduced the deformation of the teeth but the levels were significantly different: titanium posts - 0.38±0.02µm > zirconium oxide ceramic posts -

0.45±0.02µm > fiber-reinforced epoxy resin posts - 0.53±0.03µm ($p<0.05$). **Conclusion:** It can be concluded that a) the increase of stability corresponds to the mechanical properties of the post materials and that b) the fiber-reinforced epoxy resin posts can almost preserve the deformation pattern of teeth without a post. This might be favorable in view of studies showing a high incidence of unrestorable root fractures in case of post materials with mechanical properties significantly different from the properties of root dentine.

J.D. McLaren, P. Yaman, J.B. Dennison, A.A. Herrero, N.J. McDonald, and W.C. Wagner**. Effect of Post Length on Fracture of Endodontically Treated Teeth *J Dent Res. Vol 83 (Spec. Iss. A) Abstract #3097, 2004***

Objectives: The objective of this study was to compare the fracture resistance and mode of failure of endodontically treated teeth restored with three different post systems at two lengths. **Methods**: Seventy human single-rooted premolars were endodontically treated and sectioned at the buccal CEJ. Teeth were randomly distributed into groups of ten and assigned to one of seven treatment groups. Three different pre-fabricated posts, Parapost XP, **Light-Post** and Snowlight, were cemented at either 5 or 10 mm into a post space and standardized composite cores fabricated. A composite core group with no post served as a control. Samples were stored for 24 hours in 100% humidity at 37°C and were subsequently loaded at 90° to the longitudinal axis until ultimate failure occurred. An initial failure load and mode of failure were also recorded and analyzed using two-way ANOVA. Results: The average initial failure loads at 10 mm in Newtons were: Parapost XP 170.05 ± 60.08; Light-Post 123.29 ± 46.64; Snowlight 70.43 ± 32.26. The average initial failure loads at 5 mm were: Parapost 111.08 ± 49.84; Light-Post 64.25 ± 33.83; Snowlight 62.85 ± 18.47. The control group value was 40.24 ± 9.52. Core debonding from the tooth interface was the mode of initial failure for all samples.. **Conclusions:** Parapost XP samples had significantly higher initial and ultimate failure loads than Light-Post or Snowlight samples at each of the two respective post lengths. Results indicate that stainless steel post provides better support for a core than glass or quartz fiber-reinforced post when a 90° load is applied. The glass and quartz fiber-reinforced post were not found to be significantly different for providing fracture resistance at 90° load angle. Root fractures upon ultimate failure occurred in 25% of the Parapost XP samples and no root fractures occurred in any other group.

Mannocci, F., Ferrari, M., and Watson, T. F. **Intermittent Loading of Teeth Restored Using Quartz Fiber, Carbon-Quartz Fiber, and Zirconium Dioxide Ceramic Root Canal Posts**. ***Journal of Adhesive Dentistry*. *1: 153-158, 1999.***

Purpose: The purpose of the investigation was to compare the performances of teeth restored with quartz-fiber, carbon-quartz fiber, and zirconium-dioxide posts covered with all-ceramic crowns when subjected to a cyclic loading tests performed in a wet environment. **Methods**: Forty single-rooted human lower premolars having similar dimensions were endodontically treated and mounted in acrylic resin blocks with a simulated periodontal ligament. The teeth were divided into three experimental groups and one control group. Post holes 8 mm long were prepared in the roots of the experimental groups in which quartz fiber **(Aestheti-Plus**), carbon-quartz fiber **(Aestheti-Post),** and zirconium dioxide (Cerapost) posts were cemented. In the control group, no posts were used. The crown buildup was made with composite resin. The teeth were covered with all-ceramic crowns and intermittently loaded an at angle of 45 degrees to the long axis of the tooth at a frequency of two loads per second. **Results:** Only one failure (root fracture + post fracture), was observed in each of the fiber post groups, while in the zirconium dioxide post group, six failures were observed (one crown fracture and 5 root fracture + post fractures). The Kaplan-Meier analysis of the three experimental groups showed that the survival rate of zirconium dioxide posts was significantly lower than that of both types of fiber post. All the experimental groups showed a survival rate higher than that of the control group. **Conclusion:** Fiber posts reduced to a minimum the risk of root fractures of teeth restored with composite cores and Empress crowns under the present experimental conditions (intermittent loading in a wet environment)

Salameh Z, Sorrentino R, Papacchini F, Ounsi HF, Tashkandi E, Goracci C, Ferrari M. **Fracture resistance and failure patterns of endodontically treated mandibular molars restored using resin composite with or without translucent glass fiber posts**. J Endod. 2006 Aug;32(8):752-5. Epub 2006 Jun 15

The elastic modulus of the restorative material is important in restoring endodontically treated teeth. This study aimed to compare the fracture resistance and failure patterns of 90 mandibular molars

restored using resin composites with or without fiber posts, with respect to the number of residual cavity walls. Five restoration types were performed corresponding to different wall defects (groups 1-5). Groups were divided in two subgroups corresponding to the use or absence of fiber posts. Teeth were loaded and resistance of specimens was measured as the axial compressive load to cause fracture and macroscopic fracture patterns were observed. One way ANOVA revealed a significant difference in fracture resistance ($p < 0.001$). Tukey post hoc test also revealed significant differences between groups as samples restored with fiber posts exhibited mostly restorable fractures. It was concluded that the resistance of endodontically treated mandibular molars restored with composite resins is mainly affected by the number of residual walls. Using fiber-reinforced posts optimized fracture patterns.

Sorrentino R, Salameh Z, Zarone F, Tay FR, Ferrari M. **Effect of post-retained composite restoration of MOD preparations on the fracture resistance of endodontically treated teeth**. J Adhes Dent. 2007 Feb;9(1):49-56

Purpose: The present study aimed to compare the fracture resistance and failure patterns of endodontically treated premolars with MOD preparations restored using different material combinations. The null hypothesis postulated that there was no association between the fracture resistance of endodontically treated premolars and the resin composite materials or the post-and-core system used to build up the restorations. **Methods**: Eighty single-rooted maxillary premolars were used. After endodontic treatment and preparation of MOD preparations, 8 groups of 10 samples each were created, using the following material combinations: group 1 (control), flowable and microhybrid resin composites; group 2, flowable A; group 3, flowable B; group 4, microhybrid resin A; group 5, microhybrid resin B; group 6, flowable B + microhybrid resin B; group 7, flowable A + microhybrid resin A + post A; group 8, flowable B + microhybrid resin B + post B. Mechanical static fracture tests were performed loading the specimens till fracture. **Results:** The mean failure loads (N) were 502 (control), 470 (group 7), 445 (group 8), 441 (group 6), 405 (group 5), 364 (group 4), 317 (group 2), and 302 (group 3). Statistically significant differences were found between groups 1 vs 2, 1 vs 3, and 3 vs 7 ($p < 0.05$). CONCLUSION: The fracture resistance of endodontically treated premolars with MOD preparations was enhanced by the use of the sandwich technique. The samples restored with posts predominantly showed restorable fractures, while teeth restored without posts mostly displayed unrestorable failures.

Vitalariu AM, Comaneci R, Tatarciuc MS **Prevention of root fracture using posts reinforced with fiber glass..**Rev Med Chir Soc Med Nat Iasi. 2005 Apr-Jun;109(2):406-11

(The aim of this study was to evaluate the fracture strength and mode of failure of endodontically treated teeth reconstructed with glass fiber reinforced posts. Twenty maxillary central incisors, extracted for periodontal reasons, were divided in 2 groups: gr. 1 - glass fiber posts, and gr.2 - control (endodontically treated but without posts). All samples were embedded in resin bloks and mounted in stainless steel cylinders for the compressive test. The force was applied on oral surface of the crown, until the failure occurred. The compressive loads at failure were recorded and compared with the statistical method Student t. The mode of failure of the specimens were also evaluated. The statistical analysis of the force values showed no significant difference between the groups. In conclusion, because of their low Young's modulus, the non-metallic posts made of resin composite reinforced with glass fibers have a protective effect on the dental tissues, the recorded mode of failure being very similar with the control group.