

9 Summary

The risk of failure of endodontically treated maxillary incisors, restored with posts, direct cores and crowns is particularly high, due to non-axial, perpendicular forces. Regarding fracture strength, elasticity, corrosion and fatigue behaviour fibre-reinforced posts have been discussed as non-metallic alternatives. It has been suggested that the use of endodontic posts bonded to root dentin can improve the distribution of forces along the roots, thereby contributing to a reinforcement of the tooth. The incidence of root fracture may be reduced or occur in a more restorable manner. New tooth-coloured posts have improved the esthetics of teeth restored with posts and all-ceramic crowns. When restoring incisors with all-ceramic crowns, prefabricated tooth-coloured posts should be provided to achieve an optimal esthetic appearance, whereby the fracture resistance should be comparable to that in conventional metallic post restorations.

The evaluation of the load capacity of endodontically treated teeth restored with posts and cores is valuable for the preclinical trials. It is a common *in vitro* method. The applied forces are linear compressive loading or intermittent loading. Fatigue tests have been established for testing adhesive restorations, because they reproduce cyclic loading pattern comparable to the physiological function. More recently various approaches of thermomechanical fatigue loading have been applied and the value of static testing has been questioned. The impact of the different modes of loading (static or dynamic) on the maximum load capacity of postsystems has not been evaluated to date.

The present study aimed to compare the values of load capacity and mode of failure of adhesively restored endodontically treated maxillary incisors with prefabricated posts and all-ceramic crowns, as a function of the post material and the load types. The investigation was performed for one titanium and three glassfibre posts. The maximum load capacity and the mode of failure were recorded. The type of load compared to linear compressive with or without simultaneous thermomechanical loading (chewing simulation) and a new modified gradual cycling loading were evaluated for the same parameters. Another focus was to elucidate the impact of the rigidity of the post materials of an adhesively restored root canal treated tooth regarded as a laminated structure described by its Young's modulus.

Additional two composite resin cements (dual vs chemical curing) were used for post cementation to examine their influence on the maximum load capacity.

132 human maxillary central incisors were selected. The mesial-distal and buccolingual extension at the cemento-enamel junction (CEJ) were measured and the product of these two parameters was calculated. Corresponding to the product the teeth were randomly divided into 11 groups ($n = 12$). All teeth were decoronated perpendicular to the long axis 3 mm coronal from the most incisal point of the approximal CEJ. Endodontic treatment was performed and the roots were obturated by lateral condensation technique. The groups were restored with titanium posts and with the glassfibre posts DentinPost, FibreKor and Luscent Anchor. For the evaluation of the postmaterial all posts were cemented with dual-curing composite cement. For the evaluation of the composite resin cements and the load types, the titanium posts were luted with a chemically polymerized resin cement and the glassfibre posts were luted with dual-curing resin cement. The teeth with extended composite core without posts served as the control group. Immediately after post placement direct composite cores were built up. Teeth were prepared with a 2 mm ferrule height. According to the original dimension of each tooth, all-ceramic crowns (Empress 2) were manufactured and adhesively cemented with dual-curing resin cement.

The comparison of the load types were linear compressive with or without prior chewing simulation and modified gradual cycling loading. The chewing simulation is conducted by 1,2 million cycles of thermo-mechanical (fatigue) loading. Thereby specimens were subjected to 10,000 cycles of simultaneous thermocycling between 5 and 55 °C and the force was applied between 0 and 30 N. loaded the tooth The specimens were loaded in a universal testing machine from the palatal at a crosshead speed of 1 mm/min at an angle of 135 degrees to the long axis of teeth until failure occurred. The gradual cyclic loading was performed with levels of peak force being increased incrementally. Each force level was applied for 100 cycles and force levels were increased in steps of 50 N until fracture occurred. Prior to loading, the specimens encountered 2,000 cycles of thermocycling between 5 and 55 °C. The maximum load capacity and the coronal and apical deflection were recorded. The mode of failure was determined by visual inspection and the Young's modulus was calculated.

Statistical analyses were conducted using Kruskal-Wallis test and Mann-Whitney pairwise test to detect significant differences of the maximum load capacity and Young's modulus between the groups. To evaluate the influence of the factor type of loading, a nonparametric two-factorial ANOVA was applied. A chi-square test was performed to compare the mode of failure. All test were two-sided with a level of significance of 5%.

The comparison of post materials showed no significant difference for maximum load capacity between the four postmaterials and the control group. Mean failure loads vary between 305 N (FibreKor) and 501 N (Titan) [$p > 0,05$]. For the groups with the two resin cements comparable F_{\max} were determined. The comparison of F_{\max} with respect to the three tested loading modes revealed a significant difference only for static loading between the titanium post and the glassfibre post group [$p = 0,04$]. When a chewing simulation or a gradual cyclic loading was performed, no significant differences between F_{\max} values of the two post materials were observed. There was a tendency of increased maximum fracture loads for glassfibre posts in chewing simulation. The median values [GPa] for the Young's modulus were between 2,3 and 2,95.

A significant lower percentage for core fracture was observed for the groups restored with titanium posts, whereas the frequency of root fracture were two times higher compared to the glassfibre post groups. A horizontal fracture line in the middle of the root occurred solely in the titanium post groups. The group with simulated chewing displayed a significant higher frequency of those failure modes assessed as not restorable.

The following conclusions of adhesively restored endodontically treated maxillary central incisors were drawn:

After adhesively luting of the all-ceramic crowns, the maximum load capacity is independent of the post material and the resin cement used for post cementation.

The use of rigid post materials does not stiffen the tooth-post-crown complex.

Linear compressive loading of different post materials can result in unequal load capacities not appearing in either dynamic method. Thus recommendations for clinical use of certain posts based on linear compressive load testing only should be considered with some reservation. The dynamic load testing, gradual cyclic loading or chewing

simulation is to preferre. The introduced procedure of gradual cycling loading is an alternative for the load testing of restored endodontically treated teeth.

The post material and the type of loading had a significant effect on failure modes. Significant more catastrophic failures occurred with prefabricated titanium posts than with glassfibre posts.