INVESTIGATION OF FRACTURE RESISTANCE OF DIFFERENT CORE MATERIALS**

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Abstract

The aim of this study was comparatively investigation of in vitro fracture resistance of four different restorative core materials in endodontically-treated mandibulary premolar teeth.

Eighty caries-free human permanent mandibular premolar teeth, freshly extracted because of periodontal or orthodontic reasons were randomly divided into four groups of 20 teeth each. Core restorations were prepared using these core materials: Group 1: Filtek P60 (3M ESPE, USA), Group 2: Clearfil Photo Core (Kuraray Medical Inc., Japan), Group 3: Miracle Mix (GC Corporation, Japan) and Group 4: Vitremer (3M ESPE, USA). Then were subjected to thermocycling 1.000 times with a dwell time of 30 second at 5 ± 2 °C and 55 ± 2 °C. The teeth were loaded in a Universal Testing Machine (TSTM 02500; Elista Ltd. Şti., Türkiye). All the teeth were loaded until fracture was occured. The fracture force (Newton) was recorded for each specimen.

The results obtained were statistically evaluated with ANOVA and Bonferroni corrected Mann Whitney U-tests. Statistically, the mean fracture resistance scores among groups ($p<0.001$) and values of fracture code between Group 1 and Group 4, were significant.

The group of Filtek P60 was found succesfull when the values of fracture resistance were examined.

Experimental article (J Int Dent Med Res 2012; 5: (2), pp. 85-90)

Keywords: Corono-radicular restorations, composite, glass ionomer cement, core materials, fracture resistance.

Received date: 15 December 2012 **Accept date:** 10 feruary 2012

Introduction

The basic aim of endodontic treatment is to prepare a suitable environment for the periapical tissue to heal by allowing the tooth to continue functioning in the mouth following a three-dimensional filling of the root canal with an appropriate material[1-3].

Many different restoration materials and techniques are used on teeth with an excessive loss of material on the coronal structure. Some of the preferred techniques are coronal-radicular build-up technique, packable composites, full crowns, different types and varieties of post-cores, ormocer, cermet cements and amalgam used with metal onlay and inlay. As most of these restorative techniques are not economical and time-consuming for both patient and dentist, it has become a priority for research to be directed to the development of a more economical and practical form of treatment[4].

Two different techniques are used in endodontic treatment for the restoration of teeth which have lost an excessive amount of material. These techniques are coronal-radicular core and post-core restorations[5-7].

Coronal-radicular core is a core structure used in endodontic treatment for teeth with excessive material loss, which is obtained using amalgam, composite resin or glass ionomer filling material 2-4 mm coronal 1/3 in the pulp chamber and root canal space[8, 9].

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**15. Diş Hastalıkları ve Tedavisi Anabilim Dalları Toplantısı'nda poster olarak sunulmuştu. 25-27 Ekim 2010 Trabzon

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Post-core restorations can be obtained using various restorative materials together with cast or prefabricated posts. In both cases the post and core upper structure are inseperable parts of the restoration. The core upper structure supports the crown and communicates the oncoming loads to the tooth. As errors which can be made during placement of the post may weaken the tooth structurally, the post-core system must be used correctly to achieve successful results[10].

Bonilla et al. compared the fracture resistance of different core materials and reported that amalgam and composites were able to withstand the stress of chewing[11].

Glass ionomer cements should not be selected as suitable core material when the stress inside the mouth is taken into consideration. Cho et al. reported that glass ionomer cement materials were clearly less resistant than amalgam and composites[12].

Several post-core systems have been compared in studies up to date. With regard to fracture resistance, no clear difference was seen between amalgam coronal-radicular restorations and cast post and core in studies by Gelfand et al. and Hoag and Dwyer[7,13]. The rate of resistance of glass ionomer materials is lower than amalgam and composite resins. In previous studies comparing amalgam and composites against stres, the least resistant material was determined as glass ionomer[14-16].No cement, including glass ionomer cement strengthened with metal, is suitable for core structure[14]. Amalgam and composite cores are generally chosen as core materials because of their mechanical characteristics[17].

The aim of this in vitro study was to evaluate the suitability of four different core materials which are used in root canal treatment of human mandibulary premolar teeth by measuring the fracture resistance under severe pressure.

Materials and methods

In this study eighty healthy human mandibulary premolar teeth, freshly-extracted for othodontic and periodontal reasons were used. Following the extraction, the roots were removed with a blade from the overlying tissue and the teeth were cleaned with a pumice and rubber brush. The teeth were kept in distilled water until required for the study.

All the teeth were cut under irrigation with the coronal section long axis vertical at 1mm above the cemento-enamel junction using a diamond separator (Horico, Diamond Instruments, Germany). Coronal preparation was started with a Gates-Glidden bur (Gates Drills 32, Mani, Japan). The apical gap was determined with a K-type no 10 reamer (K-Reamer, Medin, Czech Republic). Then the canals were prepared using the step-back technique from 1 mm short of the apical end up to no 35. During the preparation after each reaming 5% NaOCl (sodium hypochloride) irrigation solution was used. When the preparation process was finished the canals were irrigated with 2 ml serum physiologic. The canals were dried with paper points (Absorbent Paper Points, Gapadent, Germany), then gutta-percha (Gutta Percha Points, Aceonedent, Korea) and AH-26 root canal filling material (Root Canal Sealing and Filling Materials, Dentsply, Germany) were used for the filling by using cold lateral condensation technique. The teeth were then randomly divided into 4 groups of 20 teeth in each.

After the endodontic treatment, using a no IV Gates-Glidden bur the gutta-percha in each canal was then extended to a depth of 3 mm from the cemento-enamel junction. To aid core retention, the natural undercuts of the pulp chamber were not touched. The whole teeth were wrapped with stainless steel matrix bands (Roeko GmbH. + Co., Langenau, Germany) and passed to the core restoration stage. All materials were manipulated according to the manufacturers' specifications.

Group 1 (Filtek P60): Enamel and dentine were applied with Scotchbond acid (3M ESPE, USA) and washed with plentiful of water. To leave the cavity slightly damp it was dried with cotton wool, not using an air spray. Two layers of adper single Bond 2 adhesive agent (3M ESPE, USA) were applied to the cavity surface with a brush. Using a light air spray the adhesive was spread in the cavity and was polymerised using a 1000mW/cm^2 strength LED light source for 10 seconds (Light Emitting Diode-Elipar Freelight, 3M ESPE, Germany). Then for the restorative core material, Filtek P60 (3M ESPE, USA), a posterior composite, was placed condensed into the root canal cavity and polymerised with LED light for 20 seconds. The core composite was applied with an incremental technique from the cemento-enamel junction to a height of 4 mm, each time being polymerised for 20 seconds with LED light. Each layer was applied in a manner that the composite did not exceed 2 mm in thickness. Two minutes after polymerisation was completed, the matrix band was removed and the core structure was complete.

Group 2 (Clearfil Photo Core): Clearfil S^3 Bond (Kuraray Medical Inc. Japan) single stage bonding was applied with a brush for 20 seconds to the whole cavity surface. Any excess was removed by pressurised air spray for 5 seconds, the cavity was dried and LED light was applied for 10 seconds. Then for the core material, Clearfil Photo Core (Kuraray Medical Inc., Japan), a hybrid composite was placed condensed in the root canal cavity and polymerised by LED light for 20 seconds. Composite was placed to a height of 4 mm from the cemento-enamel junction and again polymerised for 20 seconds with LED light. According to the manufacturers, 20 seconds of LED light is sufficient for polymerisation of each composite layer of 5.5 mm thickness. Two minutes after polymerisation was completed, the matrix band was removed and the core structure was complete.

Group 3 (Miracle Mix): The cavities were washed and dried with light pressure air. Miracle Mix (GC Corporation, Japan), a glass ionomer strengthened with silver in capsule form, was prepared as the core material. By mixing for 10 seconds with a high speed (+/-4,000 rpm) amalgamator (Silamat S5, Ivoclar Vivadent, Schaan, Liechtenstein) it was activated and placed in the capsule applicator (Capsule Applier, GC Corporation, Japan). The restorative material was firstly placed in the root canal cavity then the application was continued until the core reached a height of 4 mm. As the working time is 1 minute and the hardening time is 5 minutes, all the stages were undertaken quickly and checked. Two minutes after the hardening period finished, the matrix band was removed and the core structure was complete.

Group 4 (Vitremer): Primer (3M ESPE, USA) was applied with a brush for 30 seconds to the whole surface of the cavity, then air-dried for 15 seconds and LED light was applied for 20 seconds. For the core application, 4 measures of powder and 4 drops of liquid (3M ESPE, USA) were mixed on a hard surface for 45 seconds. The prepared core material was then placed in a plastic, glass ionomer application syringe. The glass ionomer material modified with resin was firstly placed condensed with a plugger in the root canal cavity and polymerised by LED light for 40 seconds. The core was applied by incremental technique from the cemento-enamel junction to a height of 4 mm, each stage being polymerised for 40 seconds with LED light. Each layer was applied in a manner not to exceed 2 mm in thickness. Two minutes after polymerisation was completed, the matrix band was removed and the core structure was complete.

24 hours after the restorations were completed, the samples were finished and polished under water with a diamond finishing bur (Diatech Coltene/Whaladent AG, Switzerland) and the restorations were polished with aluminium oxide covered discs (Sof-Lex, 3M ESPE, St. Paul, MN, USA).

The samples were kept in a incubator at 37° C for 24 hours then were subjected to a thermal cycle of between 5 ± 2 ºC and 55 ± 2 ºC 1000 times for 30 seconds.

To replicate the peridontal membrane, the root surfaces of the samples were immersed in molten wax 2 mm below the cemento-enamel junction to obtain 0.2 -0.3 mm thickness of peridontal ligament. Then the samples were embedded in acrylic blocks (Takilon, WP Dental, Germany) up to 2 mm below the cemento-enamel junction. When the the first signs of hardening were seen in the acrylic, the teeth were removed and the wax layer on the root surface was cleaned.

These surfaces were covered in a thin layer of injection type polyvinyl siloxane impression measurement material (Imprint, 3M ESPE, USA), then embedded again in the acrylic blocks. Thus an artificial periodontal membrane 0.2 -0.3 mm thick was formed around the roots.

The fracture test was made using a universal test machine (TSTM 02500; Elista Ltd. Şti., Türkiye) with a 10 mm circumference and 10 cm length stainless steel tip, which was mounted on a stainless steel shaft to the moveable upper part which administers the force of the test machine. The samples were placed upright on a level surface in the test machine.

The test machine was set for the moveable section to apply 0.5 mm per minute fast compresion-cutting type force and this force was continued until breaking point for the samples.

The values at the moment of failure were recorded as Newton (N) on the digital screen of the machine (Table 1).

CODE	FRACTURE FORM	TESTED RESTORATIONS	EXPLANATION
1			Minimum level of fracture on the core restoration
2			Low level of fracture on half the core restoration
3			Fracture of half the core restoration
4			High level of fracture on more than half the core restoration
5			Complete fracture of the core restoration

Table 1. Samples of the types of fractures formed in the core restorations of all the groups.

Results

The mean constant variables were compared by the parametric test, One-way Variance analysis (ANOVA). Paired avarages were compared with the Bonferroni test.

The fracture codes were evaluated by Kruskal Wallis test and where a sigificant difference was found, the Bonferroni corrected Mann Whitney U-test was used as a post-hoc test SPSS 15.0 for Windows software (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. As the hypotheses were two-sided, a value of $p \leq 0.05$ was accepted as significant.

The mean and standard deviation values of the fracture resistance variable of the groups, were calculated and compared by ANOVA test. The values are presented in Table 2.

Groups	$\bar{x} \pm SD$	F	P
Group 1	3020.6 ± 1004.4	28.07	<0.001
Group 2	2297.4 ± 972.3		
Group 3	844.8 ± 419.2		
Group 4	1326.0 ± 761.9		

Table 2. ANOVA test results of the mean fracture values of the four groups.

The Bonferroni test was applied after the ANOVA test to determine which group was different. The results showed a statistically significant differences in these paired comparisons: Group 1 – Group 2 ($p=0.041$), Group 1 – Group 3 ($p<0.001$), Group 1 – Group 4 ($p<0.001$), Group 2 – Group 3 ($p<0.001$), Group 2 – Group 4 ($p=0.002$). Between Group 3 and Group 4, no significant difference was found ($p=0.411$).

The mean values of the breaking code variable of the groups were ordered and the median values calculated, then compared by Kruskal-Wallis test and the breaking code values of the groups were found to be different. To determine in which group the difference originated, the Bonferroni corrected Mann Whitney U-test was applied. The difference was observed to be between Group 1 and Group 4. No statistically significant difference was found between the other groups.

Discussion

Teeth undergoing endodontic treatment are weakened teeth which have lost substance for various reasons such as trauma, abrasions, previous restorations, cavities, and root canal preparation. Up to date, several techniques have been applied and continue to be developed to treat these teeth and enable them to regain their function.

Nyyar stated from his research that the restoration of teeth which have undergone endodontic treatment is important. Because connected to the preparation for endodontic treatment, with the removal of dentine tissue, a loss of resistance is experienced by the tooth relative to the vital teeth and therefore it is necessary to pay great attention to the material used and the manner of restoration of teeth which have undergone endodontic treatment. Nyyar also emphasised that the restoration can be completed as a whole by making use of the root canals (3 mm or less). It was also stated that to achieve the required retention of the core material, the pulp chamber needs to be sufficiently wide and deep[18].The preparation of the teeth and the core restoration applied in this study benefited by a significant amount from previous studies.

To evaluate fracture resistance, groups of 5 -10 teeth have generally been used in previous studies[7,13,19].In this study groups of 20 teeth were used. The reason for using more teeth was to create more potential variation in tooth anatomy, core geometry and surface area.

Root canal filling materials containing Eugenol damage the polymerization of the adhesive system and cause deficiencies in the structure[20].Therefore, AH-26 canal filling paste which does not contain Eugenol was selected for this study.

In this study 80 mandibulary premolar teeth were restored with four different core materials and underwent a thermal cycle of between 5 ± 2 ºC and 55 ± 2 ºC 1000 times with a dwelling time of 30 seconds. The heat variation test was selected to replicate variations in heat and moisture within the mouth.

Previous research has reported that it is necessary to apply the heat test at an average between 5 ºC and 55 ºC and that the cycle being used varying between 1-1.000.000 can be done an average of 500 times[21].

When studies are examined of different core materials showing fracture resistance, composite resins strengthened with silver have been shown to have better qualities of resistance compared to glass ionomer cements[22,23].

Burke and Watts defined the characteristics of ideal core material and from their studies reported that cermet cement has most of these characteristics[24].

Capp and Warren stated that composite and acrylic resins can be used as alternatives to amalgam for core structures and that glass ionomer cement is the weakest core material[25].

The conclusion reached by many previous studies is that when core materials formed of amalgam, resin composite and glass ionomer cement strengthened with silver, are compared under the load stimulated by chewing, core made from amalgam has the highest success rate whereas cermet cement is the least successful[26-28].

Conclusions

The Filtek P60 group was determined as the most successful of the test groups, followed by Clearfil Photo Core, Vitremer and Miracle Mix groups respectively. The Miracle Mix group was determined to be the least successful. When the breaking codes were examined, there was observed to be a statistically significant difference between the Filtek P60 and Vitremer groups, while no statistically significant difference was determined between the other groups.

Arising from the results obtained in this study, Filtek P60 could be recommended for use in posterior teeth as it is a restorative core material of significant resistance. It can be said that glass ionomer materials are not suitable for use in core restorations.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

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