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Fracture resistance of endodontically treated teeth restored with composite and CAD/CAM resin using different NaOCl concentrations

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Purpose: The aim of this study was to evaluate the fracture resistance of endodontically treated teeth restored by direct and indirect techniques using different concentrations of NaOCl.

Methods: Seventy extracted maxillary premolars were used. Ten teeth were not treated (control group). The remaining 60 teeth were divided into two main groups, according to the type of restoration applied: composite and computer-aided design/computer-aided manufacturing (CAD/CAM) (N=30). Standard MOD cavities and access cavities were prepared, according to the groups. Teeth in each main group were divided into three subgroups according to the irrigation used (distilled water, 2.5% sodium hypochlorite (NaOCl) and 5.25% NaOCl) (n=10). During root canal preparation, each subgroup of composite and CAD/CAM was irrigated with distilled water, NaOCl with 2.5% NaOCl concentration and NaOCl with 5.25% NaOCl concentration. After root canal filling, the specimens were restored with nanohybrid composite resin and CAD/CAM technique using nanohybrid composite block. All teeth were subjected to fracture testing using a universal testing machine.

Results: No significant difference was obtained in terms of fracture strength when irrigation solutions were compared in both composite groups and CAD/CAM groups ($p>0.05$). The fracture strength of the teeth restored with composite resin was statistically significantly higher than the teeth restored with CAD/CAM in each distilled water, 2.5% NaOCl, 5.25% NaOCl solutions ($p<0.05$).

Conclusion: NaOCl irrigation solution used in root canals did not affect the fracture strength of the teeth. The fracture strength of direct composite restorations used in coronal restorations was higher than that of CAD/CAM restorations.

Keywords: CAD/CAM; composite resin; fracture resistance; NaOCl.

Introduction

Effective root canal treatment requires the thorough cleaning of the infe1cted root canal system, removal of necrotic pulp, and obturation of root canal (1). During mechanical root canal preparation, irrigation solutions are used to remove infected dentin chips, eliminate bacteria,

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and lubricate the canal (2,3). NaOCl is widely used as an irrigation solution in clinical practice due to its ability to dissolve infected tissue. However, hypochlorite solutions can affect the mechanical properties of dentin by degrading organic components. The recommended concentration of NaOCl is between 0.5% and 5.25%, although there is no consensus on the ideal concentration. Although a high concentration of NaOCl can enhance the dissolution of organic tissue, it can also negatively affect dentin (4).

Coronal restoration is crucial for the success of endodontically treated teeth. Incomplete or false coronal restoration after successful root canal treatment has been shown to adversely affect tooth survival (5). Therefore, the choice of materials for restoring endodontically treated teeth is of great importance in increasing their resistance to fracture.

Composite resin material is widely used in dental practice because of its acceptable aesthetic properties, sufficient adhesion to enamel and dentin, and support of the remaining tooth structure (6). Despite the high compressive strength and fracture resistance of composite resin, polymerisation shrinkage causes marginal gaps and microleakage, resulting in hyperemia and hypersensitivity (6). Indirect restorative techniques have been developed to reduce the limitations of direct composite restorations in root canal treated teeth.

In recent years, (CAD/CAM) technology has been frequently used in the production of indirect restorations, particularly in the production of aesthetic restorations. The advantages of this technique are many, including the ability to perform the procedure in a single session, the ability to create a restoration which is very similar to the natural tooth, and the ability to reduce the risk of errors in the clinical and dental laboratory process (7).

The objective of this study was to assess the fracture resistance of teeth that have been treated endodontically and restored by direct and indirect techniques using different concentrations of NaOCl. The first null hypothesis of the study is that irrigation with different concentrations of NaOCl solution does not affect the fracture resistance. The second null hypothesis is that different restoration techniques do not affect the fracture resistance of teeth.

Materials and Methods

This study was supported by Zonguldak Bülent Ecevit University Scientific Research Projects (Project No: 2020-13442734-01) and conducted according to Helsinki Declaration. The ethical principles of this in vitro study were approved by the Zonguldak Bülent Ecevit University Ethics Committee with the report numbered 2020/13 (Date: 24/06/2020).

Sample preparation

Seventy maxillary premolar teeth that were extracted due to periodontal problems were used in the present study. Soft and hard tissue residues around the extracted teeth were removed using an ultrasonic device. Teeth with fractures, cracks, open apex, perforation, root canal treatment, or resorption were excluded from the study.

Endodontic procedure

The teeth were divided into two main groups according to the type of restoration applied (n=30). The teeth in each main group were divided into three subgroups according to the irrigation used (distilled water, 2.5% NaOCl and 5.25% NaOCl) (n=10). After working length determination, root canals were instrumented using the ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) file system, with an apical diameter of # 25.06 up to the X2 file. The control and experimental groups of the study are shown in Table 1. Group 1 was accepted as the control group and no cavity preparation or endodontic procedure was performed.

In Group 2 and Group 5, 2.5 ml of distilled water solution was used after each file use. In Group 3 and Group 6, 2.5 ml of 2.5% NaOCl solution was used after each file use. Finally, for the last irrigation, 5 ml of 2.5% NaOCl solution was used in the root canals. In Group 4 and Group 7, a total of 2.5 ml of 5.25% NaOCl solution was used in each canal after each file use. The final rinse used 5 ml of 5.25% NaOCl solution in the root canals. In all test groups, 10 ml of distilled water was applied for 5 minutes to remove the solution and residues from the root canal.

Root canals were obturated with a sealer (AH Plus, Dentsply, Konstanz, Germany) and gutta percha using single-cone technique. Flowable composite resin (Estelite Universal Flow, Tokuyama Dental Corp, Tokyo, Japan) was used to cover the root canal filling. The teeth were stored in humidity (100%) for 48 hour.

Cavity preparation

Following root canal filling, standardized MOD cavity preparations were created using 2 mm diameter round and fissure burs (Diatech Swiss Dental Instruments, Altstätten, Switzerland). The buccal and palatal walls were 2.5 mm ± 0.2 mm thick, and the cavity floor was positioned 1.5 mm above the enamel-cementum junction. To mimic the periodontal ligament, a thin layer of light body impression material (Oran-wash L, Zhermack, Italy) was applied to the roots. The roots were then embedded in acrylic resin blocks in a silicone mold up to 1.5 mm below the enamel-cementum junction.

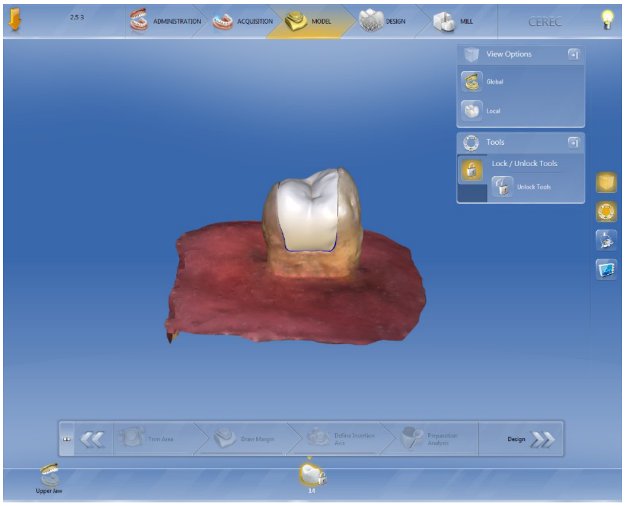

Fig. 1. Restoration design.

Restoration Composite Resin Groups

In group 2, 3 and 4 MOD cavity preparations were restored with nano-hybrid composite (Palfique Estelite, Tokuyama Dental Corp, Tokyo, Japan) by using direct technique. First, enamel tissue etching was performed with phosphoric acid gel (37%, i-Gel, i-Dental, Lithuania) for 30 seconds and washed for 15 seconds. The enamel surfaces of teeth with MOD cavities prepared using the selective etching technique were conditioned with 37% phosphoric acid gel (i-Gel, i-Dental, Lithuania) for 30 seconds. Subsequently, the surfaces were rinsed with water for 15 seconds and gently air-dried. Following the etching procedure, the bonding agents Bond A and Bond B (Tokuyama Universal, Tokuyama Dental, Tokyo, Japan) were mixed in a designated mixing well according to the manufacturer's instructions. The mixed adhesive was applied to the cavity surfaces using an applicator for 20 seconds and gently dispersed with an air syringe for 5 seconds to ensure uniform distribution over the cavity walls. Nano hybrid composite resin was placed in the cavity in 2 mm layers and polymerized with light cure (curing time for each layer: 20 seconds; light intensity: 1200 mW/cm2; Woodpecker, Guilin, China). Restorations were completed with finishing and polishing processes.

Restoration of CAD/CAM Groups

The restoration of the teeth belonging to groups 5, 6 and 7 was performed indirectly with CAD/CAM using nano hybrid block (Voco, Grandio Block, Italy). After opening the software on the computer and identifying the credentials, the "Application" tab was started. In the Indication tab, "Restoration Type" was selected as "Crown" and "Design Type" was selected as "Biogeneric Individual". GC Cerasmart was selected in the "Material" section. In order to standardize the occlusal form and anatomy of the specimens, the upper first premolar from the CEREC database was selected to determine the occlusal surface characteristics of all specimens.

The teeth were measured with an optical impression camera (Cerec Omnicam, Dentsply Sirona, USA). The model tab was switched to and the image was positioned on the maxillary arch. After determining the margin drawing and the entryway, the restoration was designed in the "Design" tab. The design of the restoration was prepared and created in three dimensions in digital environment with CEREC 4.4.1 software (Fig. 1).

After the design of the restoration, the production phase began. Crown restorations were fabricated with nano hybrid composite block (Voco, Grandio Block, Italy) in the milling unit (CEREC MC XL, Sirona, USA). The obtained crowns were removed from the milling unit, the crowns were corrected with a fine-grained diamond bur and the completed restorations were adapted to the teeth.

Cementation was performed using a self-etch adhesive cement (Han, Brussels, Belgium). Residual cement was removed with a probe and polymerization of the cement was achieved with an LED light device (Woodpecker, Guilin, China). The restorations were polished with polishing rubbers (Kenda Polishers).

Fracture Strength Test

The fracture strength of the teeth in the control group, composite and CAD/CAM groups, was measured using an universal test machine (Instron, Canton, MA, USA). A 2 mm diameter metal probe with a rounded tip was inserted into the tester to apply force to the teeth. Specimens embedded in the acryl block were placed on the adjustable metal part. The rounded metal rod was placed in the central groove of the premolars, parallel to the long axis of the tooth, and force was applied to the specimens. The application rate of the load was set to 1 mm/min. The fracture values of the tooth and restoration were recorded in Newton (N) (Fig. 2).

Fracture types

In order to determine the fracture types, the fractured specimens were examined under X25 magnification in a dental operating microscope (Leica DM4000B, Germany). The fracture types were classified as follows (8);

Type I: No fracture

Type II: Fracture limited to the tooth

Type III: Fracture limited to restorative material

Type IV: Fracture observed in the restorative material above the enamel-cement border

Fig. 2. Fracture strength set-up

Type V: Fracture observed in the restorative material is below the enamel cement border

Type II, III and IV fractures were considered as repairable fractures. Type V fractures were considered as non-repairable fractures.

Statistical Analysis

The data were analysed using IBM SPSS V23 software. The normal distribution of the data was assessed using the Shapiro-Wilk test. One-way analysis of variance (ANOVA) was used for normal distribution comparisons and Tukey HSD test was used for multiple comparisons. Chi-square test was used to compare fracture types and repairability according to the groups. The level of significance was $p<0.05$.

Fig. 3. Representative image of the fracture type.

Results

The statistical values for the fracture strength test of all groups are shown in Table 1. Group 1 (Control) showed statistically significantly higher values than all other tested groups ($p<0.05$). When the groups were compared in respect to the irrigation solution used, there was no significant difference between Groups 2, 3 and 4 with composite restoration ($p>0.05$). When the CAD/CAM groups compared in terms of the irrigation solution used; there was no significant difference between Groups 5, 6 and 7 ($p>0.05$).

When both types of restorations were compared in terms of distilled water, 2.5% NaOCl and 5.25% NaOCl irrigation solutions, the composite restoration groups (Groups 2, 3 and 4) showed higher fracture strength values than the CAD/CAM restored groups (Groups 5, 6 and 7) in all solutions ($p<0.05$).

All specimens in the study were found to be fractured. Type II fractures were observed in all specimens in the control group (Fig. 3). In the composite groups (groups 2, 3 and 4), high rates of type IV and V fractures were observed. Evaluation of the CAD/CAM restored groups showed that type II and IV fractures were common in group 5, 40% type II fractures and 30% type IV fractures in group 6. In group 7, type V fractures occurred in 50%, type II fractures in 30% and type IV fractures in 20% (Table 2).

In the composite groups, 60%, 70% and 40% of the fractures were non-repairable in Groups 2, 3 and 4, respec-

Table 1. Fracture resistance values of all groups. (Different superscript letters determines significant difference.)

	N	Mean	St. dev	Median	Minimum	Maximum
Group 1 (control)	10	1806.5562[a]	373.6483	1837.0398	927.61	2286.52
Group 2 (Distilled water Composite)	10	1046.2668[b]	284.66560	994.9159	612.42	1606.54
Group 3 (2.5% NaOCl Composite)	10	1092.3855[b]	216.32544	1083.1568	727.02	1499.21
Group 4 (5.25% NaOCl Composite)	10	1046.2668[b]	284.66560	994.9159	612.42	1606.54
Group 5 (Distilled water CAD/CAM)	10	643.6253[c]	127.49495	687.4905	404.74	831.19
Group 6 (2.5% NaOCl CAD/CAM)	10	645.3140[c]	128.80215	667.5145	452.97	802.88
Group 7 (5.25% NaOCl CAD/CAM)	10	615.8555[c]	147.17863	609.6923	381.58	870.32

CAD/CAM: Computer-aided design/computer-aided manufacturing.

Table 2. Fracture type percentages

	Type II	Type III	Type IV	Type V
Group 1 (control)	10 (100%)	0	0	0
Group 2 (Distilled water Composite)	0	1(10%)	3(30%)	6(60%)
Group 3 (2.5% NaOCl Composite)	0	0	3(%30)	7(%70)
Group 4 (5.25% NaOCl Composite)	0	1(10%)	5(50%)	4(40%)
Group 5 (Distilled water CAD/CAM)	4(40%)	0	4(40%)	2(20%)
Group 6 (%2.5 NaOCl CAD/CAM)	4(40%)	1(10%)	3(30%)	2(20%)
Group 7 (%5.25 NaOCl CAD/CAM)	3(30%)	0	2(20%)	5(50%)

CAD/CAM: Computer-aided design/computer-aided manufacturing.

tively. In CAD/CAM fractures, 80% of repairable fractures occurred in Groups 5 and 6.

Discussion

Irrigation solutions used during root canal treatment may cause structural changes in the inorganic and organic parts of dentin. These changes in the structure of dentin may cause a change in the physical properties of dentin and make the tooth more brittle (9).

Extensive significant loss of tooth structure in the teeth after root canal treatment affects the resistance of the teeth against intraoral forces (10). In addition, with the decrease in the amount of collagen in the dentin, a loss of approximately 14% in the resistance of the tooth was observed (11). The high loss of hard tissue causes vertical root fractures, crown and cusp fractures in root canal treated teeth. Magne et al. (12) reported that stress intensity increased in teeth with endodontic access cavities in which the marginal ridge was removed. It was also observed that fracture resistance decreased by 63% in teeth with MOD cavity preparation (13).

Alveolar bone support and periodontal ligament are important for stress distribution on teeth. In previous studies, elastomeric impression material has been used to mimic the way the load of occlusal forces is distributed to the alveolar bone (14,15). It has been reported that periodontal ligament simulation and embedding method may affect the fracture load and fracture type in fracture strength tests (15). In the present study, silicone impression material was used to simulate the periodontal ligament.

Composite resin is commonly used in dental practice due to its ease of use, good adaptation to the cavity wall, and satisfactory aesthetic properties. The development of resin composites and adhesive systems has enabled the creation of aesthetic restorations for both anterior and posterior teeth. To address the limitations of composite resin restorations, the use of indirect restorations prepared and cemented outside the mouth is recommended (16). The anatomical shape of the teeth and the formation of proximal contacts are facilitated, while the polymerisation shrinkage is limited to thin resin cement (17).

The elastic modulus of composite block materials is close to that of natural teeth. Therefore, composite blocks have higher fracture strength compared to glass ceramic blocks (17). Based on this reason, CAD/CAM nano-hybrid composite blocks were used the present study rather than glass ceramic materials.

According to the results obtained in the present study, there was no significant difference between distilled water, 2.5% NaOCl and 5.25% NaOCl in both composite and CAD/CAM groups. Therefore, the first hypothesis of this study was accepted. Some studies in the literature reported that NaOCl irrigation did not significantly affect the fracture resistance of the teeth in accordance with the results of the present study. Feiz et al. (18) applied different irrigation solutions to the post cavity after root canal treatment and examined the effect of irrigation solutions on the fracture resistance of the teeth and showed no significant effect on the fracture resistance of the tooth. In another study, Küçük et al. (19) reported that NaOCl solution at 1% and 5.25% concentration had no effect on the fracture resistance of root canal treated teeth.

When the results of previous studies were analysed, it was found that dentin dehydration and disorders in collagen structure affect the biomechanical properties of dentin (20). In addition, NaOCl has also been reported to affect the fracture strength of dentin (21,22). However, it is known that the most important factor in the fracture strength of the tooth is the amount of intact tooth structure remaining in the tooth to be restored. The size and the taper of final root canal instrument was selected as 25/.06 in all samples for standardization similar to previous fractture strength study (23).

In the present study, composite groups showed higher fracture resistance than CAD/CAM groups regardless of the irrigation solutions used. Accordingly, the second hypothesis of this study was rejected. In reviewing the literature, there are previous studies that are compatible with the present study in terms of the type of material used. Bajunaid et al. (24) noted that the fracture resistance of the direct composite resin groups was higher than that of the indirect and ceramic CAD/CAM groups in premolar teeth in which direct composite resin, indirect composite resin and ceramic CAD/CAM were used in OM cavity preparation. Liu et al. (25) restored teeth with MOD inlay cavity design using composite resin and CAD/CAM. They found that the fracture resistance of the composite resin group was higher.

The lower fracture strengths in the groups with CAD/CAM composite blocks may be related to the cavity design and the presence of resin cement rather than the material. Previous studies indicated that tubercle-protected restorations should be used in cases of excessive material loss and wall thicknesses of 2 mm or less (8,26). The fracture strength may be affected by the ability of pre-polymerised composite resins to transmit forces directly to the cavity walls and the bonding ability of the cement in between. This conclusion is also supported by fracture types. In the CAD/CAM restored groups, a high incidence of wall fractures was observed, rather than material fractures.

In composite restoration groups type IV and V fracture types were recorded higher compared to CAD/CAM groups. This finding also supported the results of a previous report by Kassis et al. (8). The higher rate of unrepairable fractures in the composite groups with high fracture strength compared to the CAD/CAM groups may be due to the better adhesion of the direct composite restoration application with dentin and the failure of the resin cement used in the CAD/CAM group. Further studies are needed to support the results of the study in terms of both composite-containing CAD/CAM materials and cement types used for the restoration of root canal treated teeth with extensive tissue loss.

Conclusion

The following results were found in the study; the concentration of NaOCl solution does not affect the fracture strength in teeth restored with both direct composite and CAD/CAM blocks. Regardless of the irrigation solution used, direct composite restoration showed higher fracture strength than teeth restored with CAD/CAM. Further studies are needed on different restorative materials, CAD/CAM blocks and cements that can be used in the restoration of root canal treated teeth

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Conflict of Interest: None declared.

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Informed consent: Written informed consent was obtained from patients who participated in this study.

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