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FRACTURE RESISTANCE OF RESTORED MAXILLARY PREMOLARS

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Abstract: Extensively damaged teeth can be restored by different core build-up materials. The aim of this study was to examine the fracture resistance of restored maxillary premolars with composite resin, dental amalgam and glass ionomer cement (GIC) using compressive strength test. Also, to analyse the influence of bond strength of restorative materials on intact and carious dentin. Eighty extracted human maxillary premolars with intact and carious dentin were used in the study. The control group consisted of ten unrestored teeth with intact dentin. Artificial defect in dentin was prepared using diamond bur up to the half of the anatomic crown of the tooth. After core build-up procedure, each specimen was mounted in auto polymerizing acrylic resin blocks 2mm below cement enamel junction and they were kept in distilled water at 37 ^{o}C one day before testing. Then, they were placed in specially adapted devices at an angle of 183^{o} to the longitudinal axis and subjected to a controlled load of 1mm per minute. There were significant differences among control group and restored teeth with composite resin, amalgam and GIC. Results showed that the best fracture values were obtained in control group (749,4N , then intact teeth restored with composite resin (492,5N) and amalgam (341,2N). In the group with carious dentin, values were lower, for composite resin 345,5 N and for amalgam 474,5N. There were no significant differences among restored groups with intact and carious dentin ($p<0.05$). The fracture force corresponding to the teeth restored with GIC were significantly lower compared to the control group and the group with composite resin and amalgam. Satisfactory mechanical properties of restored premolars were obtained using composite resin and dental amalgam as a core build-up material. The carious-affected dentin led to lower bond strength of restored teeth.

Keywords*:* compressive strength, composite resin, core build-up, dental amalgam, glass ionomer cements.

1. INTRODUCTION

It often happens that the coronal tooth structure which meant to serve as abutments in fixed prostheses is extensively destroyed as a result of caries, trauma, previous restoration or endodontic access preparation. Core build-ups are used to repair tooth structure defects prior to crown preparation and stabilize weakened parts of the tooth [1-5]. In the case of large core build-ups, the strength of the build-up material and its stable retention in the tooth stump are critical factors for a long-term success of crown restoration [1].

The value of strength of restorative materials should be close to the value of strength of the tooth structure. Compressive strength is only one of the criteria for the selection of core material, but it is a crucial one. Stronger core materials better resist deformation and fracture, provide more equitable stress distributions, and reduce probability of tensile and compressive failure, greater stability and greater probability of clinical success. Compressive strength is considered to be a critical indicator of success because high compressive strength is necessary to resist masticatory and parafunctional forces [6,7].

Restorative materials commonly used as core materials are silver amalgam, glass ionomer cement, glass ionomer cement, autocured titanium containing composite resin, resin-modified glass ionomer cement and light-polymerized hybrid composite resin [7]. Most of these materials were not specifically developed for this purpose, but as a consequence of their properties, have found application in core build-up procedures [2].

Amalgam has traditionally been used as the best build-up material [4,5]. There are some advan-

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tages of dental amalgam as a restorative material such as: amalgam is strong in bulk section, it does not need sensitive technique and it is sealed by corrosion products [4]. The compressive strength of dental amalgam (380 − 540 MPa) develops progressively after trituration but tensile (57 MPa) and flexural (114 MPa) strengths are much lower, making amalgam brittle [5]. The well-known disadvantages of amalgam such as slow setting process and the lack of adhesion to the tooth structure [8], weak in thin section, mercury content [4] and unpleasant color, were the reasons why alternative core build-up materials have been developed [8].

Several properties of glass-ionomer cements such as fluoride release, adhesion to tooth structure, ease of placement and biocompability make these materials attractive for their use in practice [6]. The main problem in using glass-ionomer as a core material arises from inferior compressive (150 MPa) and tensile (15 MPa) strengths and the role of water in the setting reaction [5].

Composite resins are used because of their appearance, convenience of a single visit core placement and preparation [4,5], avoiding mercury controversy [4] and reliable, strong bond strengths (11−28 MPa) [5]. Comparing to glass ionomers, composites proved superior in respect to their mechanical properties [8]. The compressive strength of composite resins (250−350 MPa) is close to enamel and dentin, but the tensile strength of composite resins is much lower (50−90 MPa). However, the tensile strength of composite resin is higher than tensile strength of glass-ionomer cement and dental amalgam. Composite resins also have some disadvantages such as highly technique sensitiveness, difficulties in distinguishing tooth from core during preparation, dentine bond can be ruptured by polymerization contraction. The use of composite cores is contraindicated in every situation when totally effective isolation cannot be achieved, as in many subgingival situations [4].

Several studies were undertaken to measure mechanical properties of direct core build-up materials such as: compressive strength [2,7,9], diametrical tensile strength [2,7], elastic modulus, flexural strength [2], shear bond strength [10]. *Tirado et al.* [6] showed the effect of thermal cycling on the fracture toughness and hardness of five core build-up materials. The clinical performance of two adhesively retained composite resin core materials were evaluated in an in vivo study and compared with metal-added glass ionomer cement [8]. *Burke et al.* [11] examined fracture resistance of core materials with and without crown preparation in an in vitro study.

Most clinical adhesive procedures involve altered forms of dentin, such as sclerotic or caries-affected dentin [12−15]. Micro hardness measurements have been demonstrated to correlate well with mineralization degree. Namely, micro hardness is significantly lower in caries-affected dentin [12]. In the operative treatment of carious lesions in dentin, the morphology and nature of prepared dentin surface influences bonding of adhesive restorative materials [13].

The purpose of this study was to examine mechanical properties of restored maxillary premolars with composite resin, dental amalgam and glass ionomer cements (GIC) using compressive strength tests.

2. MATERIAL AND METHODS

A total of 56 extracted human maxillary premolars had been collected. The teeth belonged to patients aged from 30 to 60 years. The experimental group consisted of 32 teeth with intact dentin and 24 teeth with carious dentin. The extracted teeth were cleaned and stored in distilled water at 4°C [16,17] during the period of 3 months [18]. Each group of core materials (composite resin, dental amalgam and glass-ionomer cements) was used on eight experimental teeth with normal dentin and on eight teeth with caries-affected dentin. Group division of the specimen is shown in the Table 1. The sample was composed of teeth with an average length of 22,5 ± 1 mm.

Table 1. Group division of specimens according to the type of restorative materials and quality of dentin

Incisors	Composite resin	Dental amalgam	Glass-ionomer cements	Control group	Total
Intact dentin	8	8	8	8	32
Carious-affected dentin	8	8	8	0	24
Total	16	16	16	8	56

Artificial defect in dentin was made by tungsten carbide bur (n. H245; Bassler USA, Savannah, Ga) and a water-cooled high-speed hand piece (Midwest 8000i; Dentsply Professional Division, York, Pa). A part of the dentin was removed up to the half of the anatomic crown of the tooth. The size of the artificial defect was in the ocluso-cervical direction 6.5 ± 0.5 mm, in mesio-distal 3 ± 0.3 mm, and in vestibulo-oral direction measured at the floor of the defect 9 mm ± 0.5 mm. The defect was located in the proximal part of the tooth crown (Fig 1). In all situations, two walls of tooth remained preserved. Caries was removed with round burs in a low-speed contra-angle hand piece (40.000). The caries-affected dentin characteristics after preparation are: discolored, harder than removed dentin and stained pink.

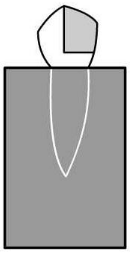


Figure 1. Diagram of tooth preparation and restoration

Core build-up was done following the placement of matrix band around the incisor. The core materials used in this study included reinforced glass-ionomer cements (Argion; VOCO, Cuxhaven, Germany), hybrid light polymerized composite resin (Admira; VOCO, Cuxhaven, Germany) and dental amalgam (Ekstrakap-D III; ICN Galenika, RS). All materials were used precisely according to the manufacturer's instructions as described for core materials.

A parallelometer (Parascop; BEGO, Bremen, Germany) was used to align the restored teeth in the block. The experimental teeth were mounted in autopolymerizing acrylic resin blocks (4 x 2.5 x 2.5 mm) 2 mm below cementoenamel junction and stored in distilled water at 37^{o} C one day before testing. For the purpose of testing each specimen was firstly placed and secured in a specially adapted jig.

The angle of the load for incisors was 183 degrees to the long axis of the tooth which simulated the position of maxillary and mandibular premolars as in dentoalveolar class I [12−14]. The inclination of maxillary premolars in oro-vestibular direction is 6 degrees and the inclination of mandibular maxillary premolars in oro-vestibular direction is 9 degrees, so that we have: 180 – (6 –9) =183 degrees (Fig 2).

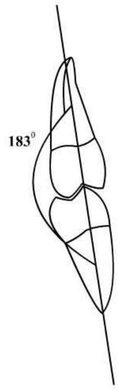


Figure 2. Angle of load for premolars

The loading was directed to the middle part of the occlusal surface of premolars. The contact location was in the middle third of the central fossa and at the point of connection between restorative material and tooth structure (Fig 3). The loading device was of conical shape with an angle of 82 degrees and the tip radius of R=0.8 mm.

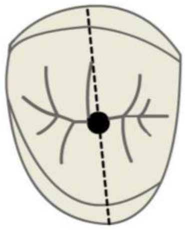


Figure 3. Occlusal view of the contact loading

The experiment was done in the universal testing machine (model 1122; Instron Corp, Norwood, Mass) where controlled loads to the teeth at a crosshead speed of 1 mm per minute until the failure occurred were applied. The failure threshold (ultimate strength) was defined as the maximum load that specimen could withstand. The force at the fracture was noted and registered (Fig 4).

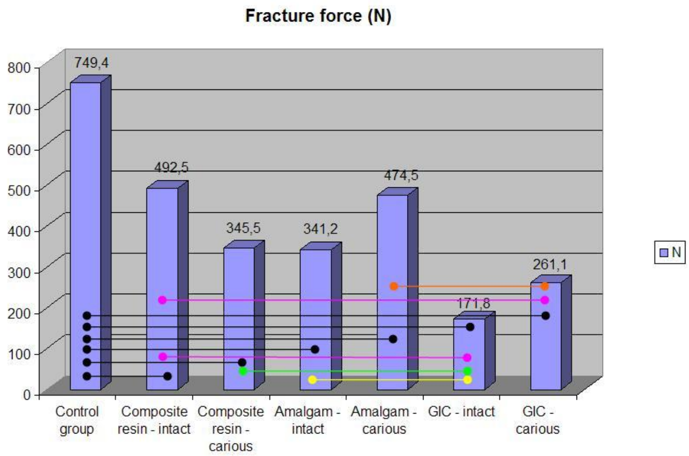
Figure 4. The procedure of loading of experimental tooth

Data were numerically evaluated by using a two-way analysis of variance (ANOVA) and Holm's *t* test. Besides the classical analysis of variance (ANOVA), Kruskal-Wallis test of range was done.

3. RESULTS

Results are shown in the Graph 1. The best fracture values were obtained in control group (749,4±258,8 N), then in the group with intact teeth restored with composite resin (492,5±222,8 N) and amalgam (341,2±136,8 N). In the group with carious dentin, values were lower, for composite resin 345,5± 84,9 N and for amalgam 474,5±59,8 N. There were no significant differences among restored groups with intact and carious dentin ($p<0.05$). The fracture force corresponding to the teeth restored with GIC was significantly lower (for intact 171,8±64,8 N and for caries-affected dentin 263,1±130,8 N) compared to the control group and the group with composite resin and amalgam.

Comparing the mean values of fracture forces between the control group and the group with restored teeth, the following was performed: ANOVA analysis ($F=4.06$, $P=.002$) and Kruskal-Wallis test for ranges. The results reached by those two tests are correspondent. Holm's *t* test is recommended as a first choice test for the analysis of differences between groups within the analysis of variance.



Graph 1. Values of fracture forces (N) and their correlation for whole specimen

The vertical axis in Graph 1 shows the values of fracture forces, while the horizontal lines among the pillars show the score obtained by Holm's t test, where the risk $p<0.05$ is marked by full line and the insignificant values are not marked at all. There were significant differences between the control group and restored teeth with composite resin, dental amalgam and GIC with intact dentin and caries-affected dentin. There were no significant differences between groups with composite resin and dental amalgam. Also, there are no significant differences in values of fracture forces between the restored group with composite resin and amalgam with intact dentin. In the group with the caries-affected dentin, there is no difference between restorative materials, but the values are statistically significantly lower in respect to the control group. The fracture force corresponding to the teeth with intact dentin and caries-affected dentin restored with GIC were significantly lower comparing to the control group.

4. DISCUSSION

In vitro studies require the use of extracted teeth, so the quality of dentin should be unaltered at the time of evaluation [18]. For the purpose of this study, teeth were stored in distilled water at 4°C during 3 months as in other experiments [7,9,19,20,14,18] and maximally recommended time was respected.

Exothermal reaction during the setting acrylic resin block has appeared as a risk factor for the change of the structure of dentin during the experiment. In this study the problem was solved with two phases of fixing teeth in the acrylic blocks in the following way: the site was made in the acrylic resin block, the site corresponded in terms of its dimensions to average root although it was a bit looser, and the site was laid with a thin layer of acrylic resin [21].

Mechanical properties of direct core materials were assessed by many authors [2,6,7,9,10,11]. Clinical trials cannot estimate mechanical properties of restored teeth [8], while *in vitro* tests give possibility to evaluate mechanical properties of restored teeth [9,11], material for restorations [2,6,7,10] and caries-affected restored teeth [21]. The results of this study have shown that the material of choice for premolars with intact dentin includes composite resins and dental amalgams, and they are as strong as the control group. These results are in agreement with the results of other authors [2,5-7,22]. Burke *et al.* [11] have concluded that the teeth restored with amalgam were most fracture resistant [8]. Combe *et al.* [2] measured compressive strength of three composite resin materials, glass-ionomer cement and dental amalgam. Cohen *et al.* [9] have showed that composite resin had statistically significant higher fracture resistance comparing to GIC and dental amalgam.

Results of this study indicate that restored premolars with caries-affected dentin had lower fracture resistance than the control group. The structure of dentin is very important when using the composite resin [15,17,19,20,]. Caries changes the structure of dentin and that is why in this study specimens were divided into two groups. Yoshiyama *et al.* [14] have found that many specimens of resin-bonded caries-affected dentin failed cohesively in dentin, presumably because it was weaker than the bonding resin. This did not occur in normal dentin, where the bonds failed adhesively.

The bonding capability of GICs to dentin were assessed by many authors [23,24,25]. Almost all of these studies were carried out on extracted teeth. All these *in vitro* studies proved the fact that the bonding of GICs to dentin is poor (weak) or nonexistent. These results could be attributed to the conditions of the experiment, that is, to the use of nonvital teeth [23]. The experiment in this study was carried out on extracted teeth, that had to have the same condition for all tested materials. That was a shortcoming of the study. Gateau *et al.* [26] established that silver reinforced GIC had statistically higher degree of inefficiency in comparison with amalgam and composite resin. This is identical with the findings of this work.

It has been proved in practice that there are many premolars damaged by caries. In literature, there is no clear standing whether such teeth should be restored by restorative material or artificial crowns. The aim of this work was to determine which material proved the most suitable for the core build-up of tooth before crown preparation. Kovarik *et al.* [22] state that artificial crowns in experiments fail to determine the forces that separate between dentin and core build- up material; therefore, in this work the loading was applied exactly between tooth and core build-up material without artificial crown.

5. CONCLUSION

Within the limitations of this study, it can be concluded that satisfactory mechanical properties of restored premolars were obtained using composite resin and dental amalgam as a core build-up material. These materials are effective for foundation restorations in premolars teeth intended for crowning. The caries-affected dentin led to lower bond strength of restored teeth.

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ИСПИТИВАЊЕ ОТПОРНОСТИ НА ЛОМ РЕСТАУРИРАНИХ ПРЕМОЛАРА

Сажетак: Велика оштећења крунучног дела зуба захтевају рестаурацију одговарајућим градивним материјалима. Циљ овог истраживања је био да се тестом отпорности на притисак провери отпорност на лом горњих премолара након рестаурације композитима, амалгамима и глас-јономер цементима (ГЈЦ). Анализиран је и утицај квалитета дентина (интактан, кариозан) на јачину везе са рестауративним материјалом. У истраживању је коришћено 40 екстрахованих интактних горњих премолара људског порекла. Код сваког узорка је дијамантским фисурним сврдлом уклањан део зуба до половине анатомске круне зуба. Оштећења су затим помоћу одговарајућих матрица рестаурирани испунима од композита, глас-јономер цемента и амалгама. Након рестаурације коренови зуба су заливани у акрилатне блокове 2 мм испод нивоа глеђно-цементне границе дан пре тестирања и чувани у дестилованој води на 4 °C. Узорци зуба у акрилатним блоковима су потом стављани у посебне алате под углом од 183 степена у односу на уздужну осовину зуба и подвргавани тесту на притисак са брзином оптерећења од 1 мм у минути. Статистички значајна разлика је уочена између контролне групе и зуба рестаурираних композитом, амалгамом и ГЈЦ. Добијени резултати су показали да је највећа отпорност на лом код узорака контролне групе (749,4 N), потом интактних зуба рестаурираних композитним материјалом (492,5 N), и амалгамом (341,2 N). Вредности силе лома зуба са каријесним дентином су биле ниже, и то за композит 345,5 N, а за амалгам 474,5N. Нема статистички значајне разлике између сила лома за интактне и каријесом измењене премоларе код примене истоимених материјала ($p < 0.05$). Вредности силе лома зуба рестаурираних ГЈЦ је била статистички значајно нижа у односу на контролну групу, али и у односу на зубе рестауриране композитом и амалгамом. На основу резултата овог истраживања може да се закључи да се задовољавајућа механичка својства рестаурираних премолара могу остварити применом композита и амалгама. Каријесом измењен дентин доводи до слабије везе са рестауративним материјалом.

Кључне речи: чврстоћа на притисак, композитна смола, дентални амалгам, глас-јономер цементи.