Influence of ceramic inlays and composite fillings on fracture resistance of premolars in vitro

Antra Ragauska, Peteris Apse, Vladimirs Kasjanovs, Liga Berzina-Cimdina

SUMMARY

Objective. The aim of this study was to assess the resistance of fracture of mesio-occlusal-distal (MOD) ceramic inlays and composite fillings in premolars and to compare fracture modes between the groups.

Material and methods. Twenty seven extracted intact human premolars were selected and divided into three groups: I – intact teeth (control group), II – MOD cavities restored with indirect ceramic inlays (Finesse, Dentsply Ceramco, USA), III – MOD cavities restored with direct composite fillings (Filtek P60, 3M ESPE, USA). The fracture resistance (N) was assessed under axial compressive loading with a metal cylinder 3.2 mm in diameter at a cross-head speed of 0.5 mm/min in a universal testing machine. The data were analyzed with ANOVA and t-test (pd≤0.05). Fracture modes were recorded based on the degree of tooth structure and restoration damage.

Results. The mean force applied to cause failure for group I was 1.218 kN ±0.223, for group II – 1.407 kN ±0.374 and for group III – 0.941 kN ±0.258. T-test showed significant difference between groups I and III (p=0.027), and groups II and III (p=0.008). The fracture modes observed in all groups tended to involve restoration's and cusp's fracture.

Conclusion. It was observed that ceramic inlays in premolars have higher load to fracture value than composite fillings and similar to intact teeth. Both restorations, ceramic and composite in the premolars, tended to fracture together with palatal cusp of tooth.

Key words: ceramic inlays, direct composite, fracture resistance.

INTRODUCTION

During last decade there is an increasing demand for esthetic restorations in mesio-occlusal-distal (MOD) cavities in posterior dentition [1]. The possible solutions are direct and indirect composite resin fillings or ceramic inlays/onlays. Direct composite resins are popular among clinicians due to its ease of handling, good esthetic and mechanical properties, but they are technically sensitive and have polymerization shrink-

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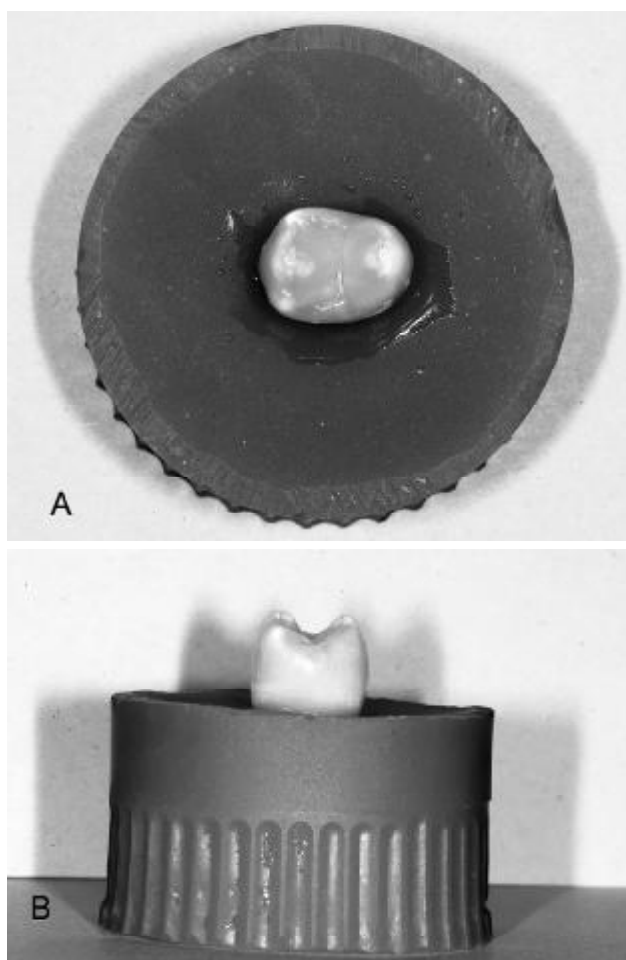E-mail: antraragauska@inbox.lv

age, postoperative sensitivity and low wear resistance. Indirect composite inlays have improved proximal contacts and minimized polymerization shrinkage but still their poor wear resistance, marginal adaptation, fracture toughness and bond strength between restoration and tooth have been published [2, 3, 4]. Ceramic materials have superior esthetics, biocompatibility, resistance to wear, and similar coefficient of thermal expansion as that observed for dental enamel, but ceramic inlays/onlays are brittle and more time consuming than direct composite resins restorations and they are more expensive [5]. Prospective clinical studies have reported fracture of restorations as one of the most frequent reasons for failure [1]. Controversy exists concerning influence of esthetic restorative systems on fracture resistance for posterior teeth [4, 6]. It has been reported that sound molars fractured at a load of approximately 2500 N, and intact maxillary premolars fractured at a load of 1121 N [7, 8]. However, after preparation of MOD cavities, the fracture strength of teeth was reduced to approximately

Fig. 1. Embedded teeth in acrylic resin: A – occlusal view, B – proximal view.

Fig. 2. Cavity preparation design: A – occlusal view, B – proximal view.

54% of their original strength [7, 8]. Conflicting outcomes regarding the strengthening effect of bonded restorations on weakened teeth have been reported. Some studies reported no significant differences in fracture strength between intact and directly or indirectly restored teeth [9, 10, 11], while contrasting findings have been reported in other studies [6, 12, 13, 14]. These conflicting results may be due to differences of materials, tooth preparation variations and testing methods. It is important to evaluate adhesive methods in simulation of oral cavity, avoiding dehydration of samples and impact of chemicals not used in mouth [15, 16, 17]. Many of the studies reported fracture resistance of restorations had not optimized the storage and used materials which are not compatible with oral environment [4, 6, 12, 18]. Although this study is *in vitro* investigation, we have endeavored to include and control as many factors as possible to approximate oral conditions.

The aim of this study was to assess the resistance to fracture of ceramic inlays and composite fillings placed in premolars MOD cavities and to compare fracture modes between groups.
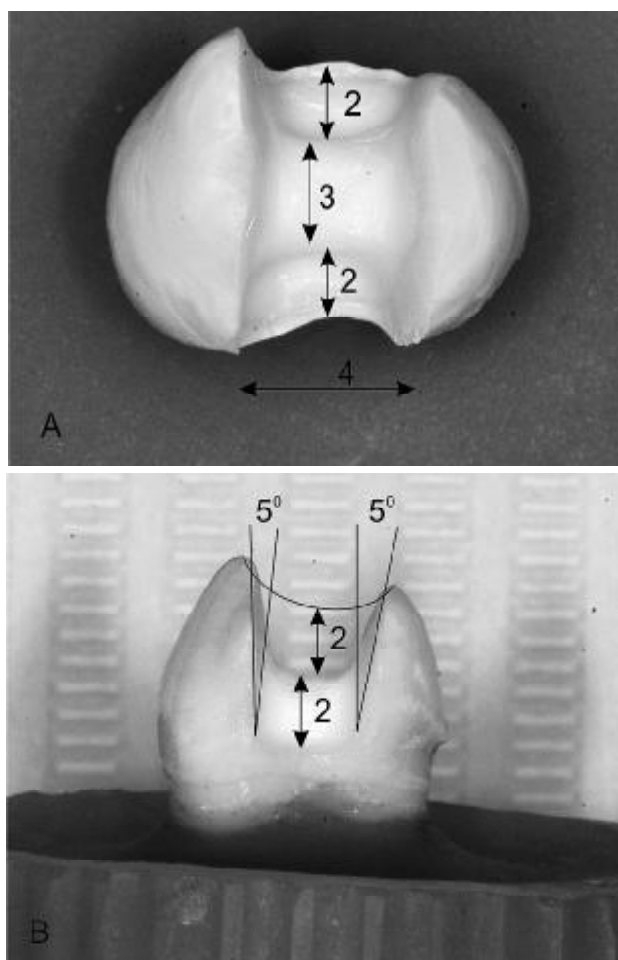
The null hypothesis advanced is that there is no difference between the fracture resistance of ceramic inlays and composite fillings.

MATERIAL AND METHODS

Twenty-seven caries-free sound human upper premolars, freshly extracted for orthodontic reasons, were collected and stored frozen to reduce pulpal cell degeneration that could influence biomechanical changes of dental tissues [15, 16]. After defrosting teeth were stored in 0.9% sodium-chloride solution (Sodium Chloride Fresenius 0.9 %, Fresenius Kabi, Poland), changed every 7 days, in a refrigerator at 4^0 C until completion of the experiment. During all stages of the study, dehydration of the specimens was avoided. Before testing all specimens were stored at room temperature for 24 h [17].

The teeth selected for the study fell in the following measurement criteria: buccolingually 9 mm ±10% mesiodistally 7 mm ±10% and with no visible cracks.

The roots were cleaned with hand scalers and rubber cups with pumice water slurry, covered with
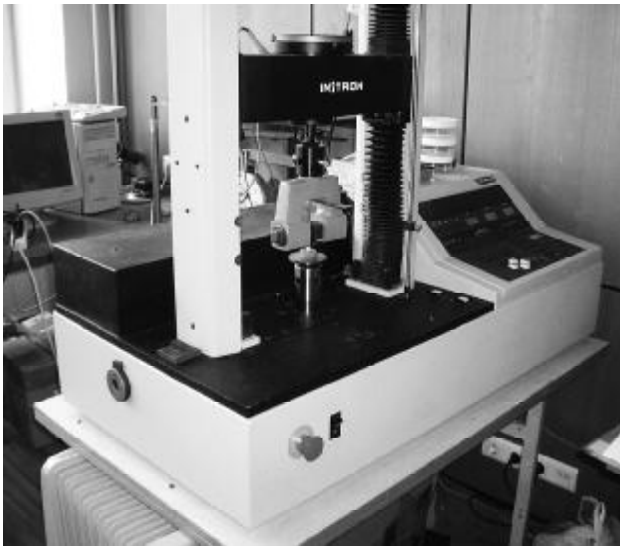
Fig. 3. Axial compressive loading: A – sample positioned in the Instron universal testing device, B – a steel metal cylinder 3.2 mm in diameter is used as plunger.

approximately 0. 3 mm low viscosity vinyl polysiloxane (Flexitime, Heraus Kulzer GmbH, Germany) to simulate the periodontal ligament and vertically embedded in autopolimerizing acrylic resin 2 mm below cement-enamel junction (Figure 1) to simulate alveolar bone [6, 19].

The teeth were randomly divided into three groups of 9 teeth in each group: I – intact teeth (control group), II – MOD cavities restored with indirect leucite reinforced ceramic inlays (Finesse, Dentsply Ceramco, USA), III – MOD cavities restored with direct high viscosity hybrid composite fillings (Filtek P60, 3M ESPE, USA).

MOD cavities were prepared for groups II and III with high speed diamond burs (FG42423, NTI-Kahla GmbH, Germany) and air-water cooling under similar conditions. All internal angles were rounded and the total occlusally divergent angle of vertical walls was 10°. The occlusal isthmus was 4 mm wide buccolingually and with a 2 mm deep pulpal floor. The buccolingual widths on mesial and distal boxes were 4 mm wide, similar to the occlusal isthmus width. Each box had a gingival floor depth of 2 mm mesiodistally and axial wall height of 4 mm. Margins were prepared with 90-degree cavosurface angles (Figure 2).

Group II – ceramic inlays

One-stage impressions of the prepared teeth were taken with light-body viscosity vinyl polysiloxane impression material (Express, 3M ESPE, USA) using custom acrylic trays and the impressions were poured in stone. Restorations were made with vacuum-pressing method according to manufacturer's instructions from leucite reinforced glass ceramic ingots (Finesse, Dentsply Ceramco, USA). The internal sur-

face of each inlay was sandblasted with 50 µm aluminium oxide airbone-particle abrasion at 1 bar pressure and etched with 9. 6% hydrofluoric acid (Mirage, USA) for 4 min. A silane agent (Ceramic Primer RelyX, 3M ESPE, USA) was applied for 60 sec and dried. The cavities were totally etched (enamel and dentin) with 37% phosphoric acid for 15 sec, rinsed, gently dried, avoiding dehydration of dentin. One layer of hydrophilic adhesive resin (Adper Single Bond 2, 3M ESPE, USA) was applied, gently dried and light cured 10 sec (400 mW/cm^2, Astralis 7, Ivoclar Vivadent, Liechtenstein). The resin luting agent (RelyX Adhesive Resin Cement, 3M ESPE, USA) was mixed at 1:1 ratio and applied to the internal surface of the inlay. Inlays were gently pressed into cavities and excess cement was removed with a small brush, light cured 40 sec from each side (800 mW/cm^2, Astralis 7, Ivoclar Vivadent) and polished with silicone cups (3M ESPE, USA).

Group III – composite fillings.

Metal matrices around the teeth were applied and the preparations were totally etched for 15 sec with 37% phosphoric acid, rinsed with water, gently dried and the same hydrophilic adhesive resin as in group II (Adper Single Bond 2, 3M ESPE, USA) was applied in one layer, dried and light cured 10 sec (400 mW/cm^2, Astralis 7, Ivoclar Vivadent, Liechtenstein). High viscosity hybrid composite resin (Filtek P60, 3M ESPE, USA) was layered (not exceeding 2 mm thickness) and light cured for 40 sec each layer (400 mW/cm^2, Astralis 7, Ivoclar Vivadent, Liechtenstein). The first layer was applied at the matrix, the following layers at the buccal or lingual walls of cavities. All restorations were additionally light cured from proxi-
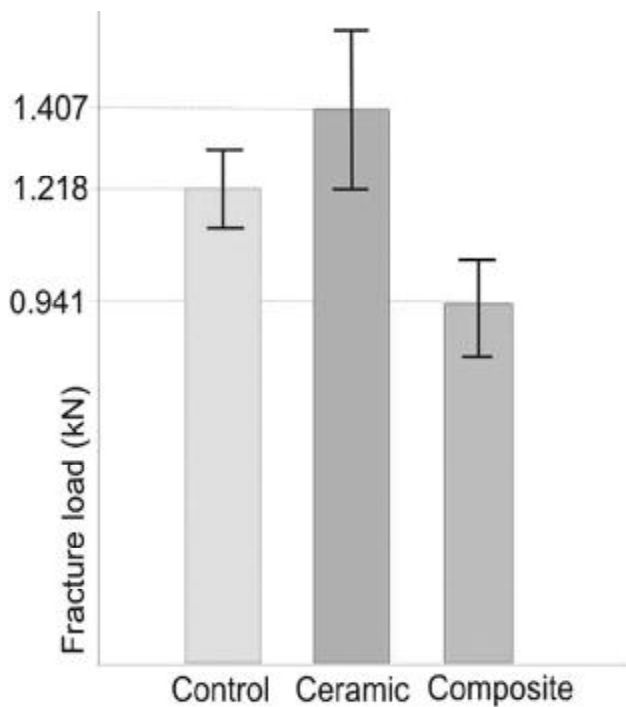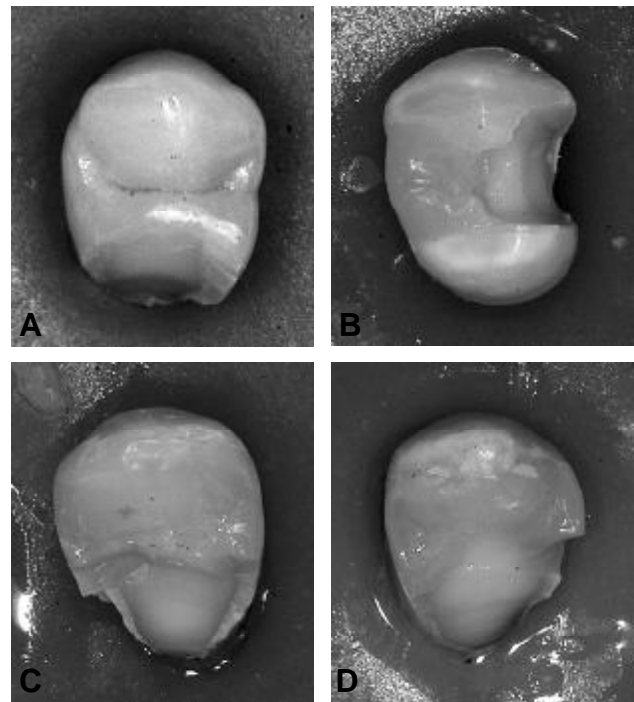
Fig. 4. 4. Mean fracture resistance values and standard deviations

Fig. 5. 5. Fracture modes observed after loading: A – intact tooth; B, C – ceramic inlay; D – composite filling.

mal sides 10 sec (800 mW/cm^2, Astralis 7, Ivoclar Vivadent, Liechtenstein) after removal of matrices and polished with finishing discs (Soft-Lex XT, 3M ESPE, USA) and silicone cups (3M ESPE, USA).

Axial compression test.

The samples were positioned in the testing device to maintain the occlusal surface perpendicular to the loading axis. All specimens were submitted to axial compression in an Instron universal testing machine (model 4301) with a steel cylinder 3.2 mm in diameter at a cross-head speed of 0.5 mm/min until their fracture [20]. The plunger contacted the facial and lingual triangular ridges beyond the margins of the restorations (Figure 3).

Peak load to fracture (N) was measured for each specimen. Means were calculated and analyzed with one-way ANOVA and t-test (SPSS for Windows 14.0, SPSS Inc, USA). The groups were considered statistically different if pd≤0.05.

Fracture modes were recorded, based on the degree of tooth structure and restoration damage,

using a modified classification system proposed by Burke F. J. et al [21]: (I) isolated fracture of restoration; (II) restoration fracture involving a small tooth portion; (III) fracture involving more than half of tooth, without periodontal involvement; and (IV) fracture with periodontal involvement. Fracture modes I-III represented restorable, but mode IV – not restorable situations.

RESULTS

The mean force applied to cause failure for group I was 1.218 kN ±0. 223, for group II – 1. 407 kN ±0. 374 and for group III – 0.941 kN ±0.258, (Figure 4). ANOVA single factor test showed that there was a statistically significant difference between the groups with p=0.009. T-test, assuming unequal variances, showed significant differences between groups I and III (p=0.027), and groups II and III (p=0.008). There was no statistical difference between groups I and II (p=0.216).

The fracture modes (Table) observed in all groups tended to involve restoration's and palatal cusp's fracture (66.7% in ceramic group, but 100% in composite group). Isolated fractures of restorations were observed only in ceramic group while all composites fractured together with tooth structure (Figure 5). In the ceramic group 55.6% of fractures were not restorable but in composite group 66.7 %.

Table. Results according to fracture modes

Fracture mode	Control %	Ceramic %	Composite %
I	0	22.2	0
II	0	11.1	0
III	44.4	11.1	33.3
IV	55.6	55.6	66.7

DISCUSSION

In this *in vitro* study, the control group had a mean fracture resistance value of 1. 218 kN, which was similar to other studies ranged between 882 N and 1. 568 kN [22]. Comparing ceramic and composite groups, the null hypothesis was rejected: ceramic inlays were more fracture resistant than composite fillings. Our results indicated that adhesive ceramic MOD restorations are able to recover strength values similar to those of sound nonrestored teeth, but large direct composite fillings are able to reach only 77 % of the strength of intact tooth. This is in agreement with Camacho G. B. et al, who tested several restoration techniques (including direct composite and indirect ceramic) in MOD cavities in premolars and used spheres 3 mm and 9 mm in diameter [23]. Habekost L. V. et al [12] reported similar results for ceramic group without thermocycling and without endodontical preparations. Stappert C. F. J. et al [18] tested molars and concluded that teeth restored with pressed ceramic inlays have same fracture resistance as intact teeth. Our finding in the composite group showed that MOD direct composite restorations have 23% less fracture strength than intact tooth. This is in agreement with Yamada Y. et al, who reported 18% less resistance than intact tooth and Steele A. and Johnson B. R. , who found 53% less resistance [19,24]. It is also possible that in our study fracture resistance values in composite group are lower than in ceramic group because according to Anusavice K. J. [25] cavity width for direct composite restorations should not exceed one third the buccolingual width of the tooth structure. Our cavities were 4 mm wide occlusally because we compared both materials: ceramic and composite in same conditions.

There are fracture studies in literature with different findings which may be explained because various restorative materials and testing methods were used [4, 12, 14]. When compared with our results, St-Georges A. J. et al reported lower values in all groups (intact teeth, ceramic inlays and indirect composites), which may be due to the differences in root's embedding and type of plunger used. They used a sphere as a plunger with a diameter of 4. 82 mm and did not cover the roots with an elastic membrane [4]. Santos M. J. and Bezerra R. B [14] did not cover the roots with a membrane before embedding either, cavities were prepared into pulp chamber and they used a sphere of 8 mm of diameter as a plunger. Habehost L. V. et al [12] used a 9 mm sphere as a plunger. In these studies the sphere contacted the tooth surface but not the restorations during loading. In our study the roots were covered with elastic membrane to simulate periodontal ligament, providing the lower

concentration of stresses in the cervical region of the tooth [6]. We decided to use a cylinder as a plunger not a sphere, because according Burke F. J. et al and Watts D. C. that is the best method for measuring the resistance of premolars regarding its anatomy [21, 26, 27]. During the experiment our specimens were stored in physiological solution which may have affected the bond strength between restorations and tooth structure similar with oral conditions.

In our study thermocycling was not done before axial loading. Habekost L. V. et al [12] found that maxillar premolars with ceramic MOD inlays without thermocycling reached fracture toughness similar to intact teeth, however, the group that were thermo cycled had decreased fracture resistance. They found that thermocycling affected fracture resistance for ceramic group without endodontical treatment more than for composite by weakening the adhesive bonding. A number of studies did not use thermocycling [4, 14, 22]. In this case we consider that thermocycling may affect adhesive effect of failures.

As the plunger in our study contacted restoration triangular ridges but not cusps of teeth, the geometry of restoration's occlusal surface may has influence on fracture resistance what also mentioned Soares C. J. et al [6] and Soares P. V. et al [22].

Fracture patterns in our study tended to involve restorations and cusps fractures which are in agreement with St-Georges A. J. et al [4] and Soares P. V. et al [22]. However, there were samples in which the restorations fractured but not the tooth that also was reported by Soares C. J. et al [6]. This is due to ceramic's brittle nature: it has high elastic modulus and tends to concentrate stress inside the body of restoration. But we found less isolated ceramic fractures than Soares C. J. et al [6] which may be because they tested molars not premolars with thicker walls and therefore would be expected higher fracture strength. In our study composite group fractured only as type III (fracture involving more than half of tooth, without periodontal involvement) and IV (fracture with periodontal involvement). It can be explained by the elastic modulus of composite being similar to the tooth and having good bond strength. Also Soares P. V. found more not restorable fracture patterns in composite group than in ceramic inlays after axial loading of endodontically treated maxillar premolars [22].

Clinically maximum biting force of approximately 725 N for posterior single tooth is reported in the literature [28, 29]. Our fracture loads exceeded maximal biting forces, but it can represent some overloading situations for example bruxism or traumatic occlusion. All ceramic restorations and 80% of com-

posites survived this force in our results. Stappert C. F. J. et al [18] tested molars with masticatory fatigue loading and no restorations failures noted. Then he proceeded with axial compressive loading and concluded that MOD ceramic restorations have similar strength to natural teeth.

With the limitations of *in vitro* study according to our results we suggest to use ceramic inlays rather than direct composite in large posterior mesio-occlusal-distal cavities, where occlusal forces are directed on restoration.

CONCLUSION

Premolars restored with ceramic MOD inlays may have same fracture strength as intact teeth if axial load is applied on the walls of restorations.

Large direct composite MOD restorations in premolars have lower fracture strength than ceramic inlays and intact teeth.

Both restorations: ceramic and composite in premolars tended to fracture together with palatal cusp of tooth. Only in the ceramic group isolated fracture of restorations were noted.

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