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ORIGINAL RESEARCH

MARGINAL ADAPTION AND NANO LEAKAGE INVESTIGATION OF THREE METAL CERAMIC INLAY DESIGNS - AN INVITRO STUDY

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ABSTRACT

Aims and Objectives: To evaluate the influence of metal framework design on fracture strength, marginal adaptation and nano leakage of three designs of metal ceramic inlays. Materials and Methods: Three designs for metal ceramic inlays with different metal framework extension were studied: Group A - metal extension on all cavity walls, Group B- on all cavity walls but 1.5mm below cavo-surface margin, Group C- on pulpal, axial and ginigival walls. Empress 2 all-ceramic inlays were used as controls (Group D). The fabricated inlays were cemented into standardized resin teeth using adhesive resin cement. Fracture strength was measured by applying an axial load. Marginal adaptation was evaluated using duplicate technique and scanning electron microscopy. Nano leakage was evaluated in terms of silver nitrate penetration after fatigue and thermo cycling artificial aging programs. The data were statistically analyzed using standard one-way ANOVA ($p<0.05$). Results: The marginal adaptation of test groups A and B were significantly lower than the other groups, 70.3 µm and 71.7 µm respectively. Group A had statistically higher fracture strength value (1287 N) compared to the other test groups. Test groups C and D had the lower silver nitrate nano leakage, 115.9 µm and 101.5 µm respectively. There was a weak negative correlation between fracture strength and marginal adaptation and between marginal adaptation and nano leakage. The extension of metallic framework affects the fracture strength, marginal adaptation and nano leakage of the metal ceramic inlays. Conclusion: In conclusion, Group A had statistically higher fracture strength value (1287 N) compared to the other test groups.

Keywords: All-ceramic inlays; Fracture strength; Marginal adaptation; Metal ceramic inlays; Nano leakage.

Introduction

Currently no single restoration type can be considered as ideal for the wide µm modality of dental problems that dentists face every day. Dentists do need diverse treatment options and appropriate treatment planning so the selection of restoration materials and designs become the corner stone for successful dental treatment.[1,2] Metal ceramic inlays (MCI) can be used as individual restoration and as conservative retainers for fixed partial dentures. These inlay-retained fixed partial dentures have become an interesting treatment option because they preserve tooth structure and are better tolerated by the surrounding tissues as compared to full crowns.[3,4] The purpose of this study was to investigate the effect of metal extension of three designs of metal ceramic inlay on fracture strength, marginal adaptation, and nano leakage.

Materials and Methods

A standardized mesio-occlusal-distal preparation for all-ceramic inlay restoration was made on a first mandibular molar. Standardized six occlusal and 12 proximal marks were made on the surface of the preparation and were used as reference points for the measuring marginal adaptation. The preparation was duplicated using clear silicon impression material. The tooth preparation was then duplicated by incrementally filling the mold using a light cured posterior restorative composite material with an elastic modulus resembling that of natural enamel (E=17 GPa). Three MCI test groups were made according to the following metallic framework design variations: **Group A:** Wrap design: the metallic framework extending to all cavo-surface margins of the preparation, **Group B:** Half extension design: the metallic framework extending 1.5mm below the cavo-surface margins, **Group C:** Esthetic design: the metallic substructure extending only on the pulpal, axial and gingival walls, **Group D:** a control all-ceramic inlay fabricated from pressing a luecite reinforced ceramic material (Empress 2 for staining technique, Vivadent Ivoclare, Liechtenstein)

Fabrication of Restorations : For metal ceramic inlays a plaster duplicate was made for each of the prepared resin teeth and coated with die spacer material (30µm thick) and the design of the metallic framework was made by adapting a softened sheet of casting wax (0.5mm thick) on the plaster replica and trimming the wax framework with a sharp scalpel to the required extension. The wax patterns were then processed according to standard lost wax technique. The metallic frameworks were seated on pre-fired refractory replicas of the prepared resin teeth, oxidized, and then opaque ceramic was applied and fired. Dentine and enamel ceramics were subsequently applied and fired.[5] Fabrication of all-ceramic inlays was processed according to manufacturer's recommendation for pressing esthetic ceramic inlays using the equipments recommended by the manufacturer. 15 specimens were fabricated from each test group (n=15).

Cementation Technique: A multipurpose adhesive resin system was selected for cementation. The fitting surface of the metallic frameworks was conditioned using the metallic primer agent (Alloy primer), while any exposed ceramic surface, including the fitting surface was silanated. The surface of the resin teeth was etched for 1 minute (K-Etch), washed and dried then a dual cured resin cement was mixed and coated on the fitting surface of the inlays which were seated under fixed pressure of 30 N. Excess cement was removed and air barrier was then applied for two minutes.

Fracture strength test : The root portion of the resin teeth was secured to a special attachment unit using self cured acrylic resin. The bonded inlays were loaded axially in the center of the occlusal surface with a metallic cusp, with a radius of 4mm, at the rate of 0.5mm/min in a Universal Testing Machine (Comten Industries Inc., Model CL1-4, St. Petersburg, FLA, USA). 100μm thick cupper sheet was used to evenly distribute the load over the surface of loaded inlays. Stress strain diagrams were extracted from computer-generated file.

Marginal adaptation test: The vertical distance between the inlays and the margin of the preparation (cement film thickness) was measured on an epoxy duplicate of each test specimen. The epoxy replicas were gold sputter coated and examined under SEM. The standardized surface markings made on each resin tooth was used as a reference point for measuring marginal adaptation values. The 18 readings measured for each test specimen were averaged.

Nano leakage test: The cemented inlays were subjected to 10000 thermocycles (5-55°C 2 minutes dwell time in air and at each temperature range) isolated with three layers of a varnish solution (except at the cavo-surface margin) and immersed in buffered silver nitrate solution for 24 hours. The restorations were then washed and placed in x-ray film developer solution under intense light for six hours. Finally the restorations were sectioned in bucco-lingual and mesio-distal plans using a diamond coated disc under water cooling (Isomet 1000, Buehler, Lake Bluff, Ill, USA). Each section was then polished with 600 grit silicon-carbide paper, sputter coated and examined under SEM. The distance of silver nitrate penetration was measured on trace lines made on images obtained from each examined section.

Statistical analysis: One-way analysis of variance and Tukey HSD tests were selected for data analysis ($p<0.05$ was considered significant). Pearson correlation test was used to study the correlation between fracture strength and marginal adaptation and between marginal adaptation and nano leakage.

Results

The fracture strength, marginal adaptation and nano leakage of the tested groups are shown in table 1.

Fracture strength test: There was a statistical significant difference in the fracture strength between the tested groups ($F=118$ and $p=0$) as test group A was significantly stronger than the other test groups, which were statistically comparable ($p=0.141$). Test groups 1, 2 and 3 demonstrated a similar fracture pattern in the form of cone cracks beneath the metallic indenter which was considered as the first sign of failure and was recognized on stress strain diagram as sudden drop of stress. These early-detected cone cracks were stable until total destruction and crushing of the samples, which occurred at much higher loads. Test group 4 demonstrated bulk fracture on the inlays.

Groups	Fracture strength (N)	Marginal Adaptation (μm)	Nano leakage (μm)
Group A	1287 (±204)A	70.3 (±13) A	261.3 (±121) A
Group B	565.3 (±33) B	71.7 (±19) A	219.7 (±156) A
Group C	585.9 (±44) B	115.9 (±23) B	74.2 (±44) B
Group D	662 (±125) B	101.5 (±12) B	26.8 (±24) B

Table 1. Fracture strength, marginal adaptation and nano leakage of the tested groups.

Marginal adaptation test: Statistical analysis revealed statistically significant difference between the tested groups ($F=25.92$ and $pP=0$) as test groups A and B had lower marginal adaptation values compared to test groups C and D.

Nano leakage test: Test groups 1 and 2 had statistically higher nano leakage values compared to test groups C and D which demonstrated better seal against silver nitrate particle penetration.The presence of metallic framework under the ceramic veneer did not affect the sealing ability of the resin cement.

Correlation among the tested variables: Two-tailed Pearson correlation test revealed a weak negative correlation between both fracture strength and marginal adaptation (-0.375) and between marginal adaptation and nano leakage (-0.481).

Discussion

As for nano leakage test, the restoration-cement interface was of more concern compared to tooth-cement interface, which was extensively evaluated in many other previous publications. In terms of strength, wrap design inlays demonstrated higher fracture strength compared to the other test groups. That finding can be attributed to the rigid support provided by the metallic framework.[5,6] The half extension design, in which the metallic framework is kept 1mm below the cavo-surface margin of the preparation, had fracture strength comparable to the control all-ceramic inlays.[7] The marginal adaptation of the wrap design, which can technically be considered a cast gold inlay, was significantly better than Empress inlays.[8,9] As the marginal quality of inlay restoration is subject to deterioration during function, this design could be selected in cases where margins extend to functional cusps or areas of high functional stresses.[10] Firing an esthetic veneer over the metallic framework did not result in any noticeable deformation of the underlying framework. Nano leakage is another important parameter that directly affects the survivability of bonded restorations. Various dye penetration tests have been used to evaluate the sealing ability of resin cements.[11] In this study, the length of silver nitrate penetration was statistically higher for test groups A and B, which could be related to the presence of metal on the fitting surface of the restoration. On the other hand inlays with ceramic margins, test group C and D, had the lowest nano leakage values which reflects the effectiveness of hydrofluoric acid etching combined with silanization.[12,13] However, proper selection of the appropriate bonding technique for the restorative material used is a critical factor for achieving a good bond and thus a better marginal seal.[13] Statistical analysis failed to demonstrate a direct relationship between marginal adaptation and fracture strength of the tested inlays nor between marginal adaptation and nano leakage.[14] These

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findings indicate that neither the strength of the inlays nor marginal seal qualities are affected by acceptable variations in marginal adaptation values. Thus, selection of either of the MCI design should be focused on parameters of strength and durability rather than on marginal adaptation.

Conclusions

In conclusion, selection of either metal ceramic inlay designs or all-ceramic inlay restorations should be based on balancing clinical requirements with expected material properties.

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