CLINICAL RESEARCH

Porcelain Inlays Cemented with Composite Resin Cement: An In Vivo Investigation of Pulpal Reaction One Year Following Cementation

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Purpose: **This in vivo study was designed to verify the presence of pulpal inflammation on teeth after 1 year of function from cementation of porcelain inlays.**

Materials and Methods: **Thirty-two vital, healthy, caries-free and previously untreated maxillary and mandibular first premolars in eight patients needing extraction for orthodontic reasons were included in this study. For each patient three first premolars were randomly chosen and treated with porcelain MOD inlays. One first premolar served as the control group with no restorations. The porcelain inlays were cemented with dental adhesive and composite resin cement without pulpal protection. The same dentist, following standardized preparation, impression, and cementation techniques, accomplished all clinical phases. The teeth were extracted 1 year later. The condition of the pulp tissues of the 24 teeth with porcelain inlays was compared with the pulpal tissues of the eight teeth of the control group. The data relating to the number of inflammatory cells were evaluated by one-way analysis of variance to assess quantitative differences between the group of teeth with porcelain inlays and the group without porcelain inlays ($p < 0.05$). Means and standard deviations were calculated for each group.**

Results: **The microscopic analysis revealed the absence of pulpal inflammation of the teeth with porcelain inlays when compared with the teeth of the control group. The analysis of variance revealed no statistical differences between the two groups compared.**

Conclusion: **Within the limitations of this study, the cementation of porcelain inlays with dental adhesive and composite cement on healthy premolars did not result in any inflammatory reaction of the pulpal tissues 1 year after placement.**

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INDEX WORDS: porcelain inlays, pulpal reaction

MULTIPLE articles have recorded the increase in esthetic restorative dental procedures.[1-5] This has resulted in the introduction of materials and techniques capable of performing tooth-colored restorations in posterior teeth. Increasing demand for restorations has led to the greater use of all-ceramic materials because of their biocompatibility and optical properties.[6,7] An available option for the esthetic treatment of posterior teeth is represented by porcelain inlay restorations.

Porcelain inlays represent a heterogeneous family of tooth-colored restorations for definitive restorations of posterior teeth. Some in vivo studies have proven that satisfactory clinical results can be achieved with different types of porcelain inlays restorations.[8-11] These clinical results have been closely associated with the marginal quality of the restorations.[12-17] Due to outstanding advances in adhesive dentistry, it is now possible to bond porcelain inlay restorations strongly to enamel and dentin by the use of composite cement interposed between the restoration and the tooth preparations.[18-20] With direct posterior composite resin restorations, the restorative

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material is subject to a high level of polymerization shrinkage.[21-29] The advantage of bonded porcelain inlay (indirect) restorations is that most of the composite resin cement used for cementation is displaced by the definitive porcelain restoration. Thus, the amount of composite polymerized in the oral cavity is minimal; this should reduce the problem of the polymerization shrinkage associated with composite resin restorative materials used for direct posterior restorations.[21-29]

Many researchers have shown that none of the composite resin cements used for inlay cementation were able to completely eliminate interfacial gaps.[30-39] A recent prospective controlled clinical study evaluated the clinical performance of IPS Empress (Ivoclar Vivadent AG, Schaan, Liechtenstein) inlays and onlays with cuspal replacements and proximal margins below cementoenamel junctions over an 8-year period. Eight of the 96 restorations investigated had to be replaced (failure rate 8%; Kaplan-Meier): six inlays suffered cohesive bulk fractures and two teeth required endodontic treatment. After 8 years of clinical service, significant deterioration (Friedman two-way ANOVA; $p < 0.05$) was found for marginal adaptation of the remaining restorations. Of the surviving restorations, 98% exhibited marginal deficiencies, independent of the luting composite.[40]

The presence of interfacial gaps between dental structures and porcelain inlays clinically determines the occurrence of microleakage. Microleakage can be defined as the passage of bacteria, fluids, molecules, or ions between a cavity wall and the restorative material applied to it.[41] Microleakage occurs because of marginal gaps between the restoration and the cavity wall.[41] Bacterial infection due to the presence of these marginal gaps is well known as being, in effect, the main factor responsible for pulpal reaction in case of direct composite resin restorations.[42-49] When the pulpal tissues are irritated by thermal shocks during the cavity preparation procedures or by the action of chemical agents used during the restorative phase (for example, the acid etching procedure), they usually recover.[50-58] It has been observed that if the adhesive procedures have been correctly accomplished, the adhesive systems will impart structural changes to the dentinal substrate by creating this intertwined hybrid zone composed of collagen, residual mineral particles, and resin.[50,51] Many articles related to adhesive procedures used for the cementation of porcelain inlays to tooth structure have shown that the presence of a hybrid layer between adhesive resin and dentin seem to adequately seal the dentinal tubules and allow a cellular reorganization of the pulpal tissues.[59-66] Accurate cementation, following accurate preparation of the tooth and accurate impression procedures, should decrease the presence of marginal gaps between restorations and the cavity walls and minimize the risk of bacterial infection of the pulpal tissues.

The purpose of this in vivo study was to verify the presence of pulpal inflammatory reactions in teeth with cemented MOD porcelain inlays after 1 year of function.

Materials and Methods

Eight patients, each 13 years old, requiring extraction of the four first maxillary and mandibular premolars for orthodontic reasons, were chosen. All teeth were vital, healthy, caries-free, and had never been treated before. Patients who exhibited bruxism, severe malocclusion, serious gingival inflammation, poor oral hygiene, or high caries rates were ineligible for this study. None of the patients dropped out or were dismissed. According to a list of randomization,[67] in each subject three first premolars were chosen to have MOD porcelain inlays prepared and cemented; the remaining first premolar represented the control tooth. The Clinical Medical Ethical Committee approved the study. The consent of patients and of their parents was obtained prior to tooth preparation. One operator, constantly following the same clinical techniques, carried out all procedures.

Dental Substrate Preparation and Impression

Box-shaped cavity preparations with butt-joint cavosurface angles and a taper of approximately 10° were developed. New, slightly conical diamond burs (#6855 314 025, Komet, Gebr. Brasseler Gmbh & Co. KG, Lemgo, Germany) were mounted in a high-speed handpiece under abundant water irrigation at the initial preparation phase. The tooth preparations were approximately 3 mm deep and were extended interproximally, so that interproximal contacts with the adjacent teeth were completely broken. The gingival margin was prepared entirely in enamel at the cementoenamel junction. A periodontal explorer (#23, Hu-Friedy Mfg. Co., Inc., Leimen, Germany) was used for verification of uniformity of cavity dimensions. Finishing diamond burs (#8855 025, Komet, Gebr. Brasseler Gmbh & Co. KG) mounted in a slow-speed handpiece under abundant water irrigation were used to refine the preparations.

Complete arch polyether impressions (Permadyne, 3M ESPE, Seefeld, Germany) were made with a single impression-double mixing technique. Irreversible hydrocolloid impressions (Xantalgin Select fast set, Heraeus Kulzer GmbH & Co, Hanau, Germany) were made of the opposing dentitions, and impressions were poured with an ADA type IV stone (New Fujirock, GC Corp, Tokyo, Japan). Light-cured temporary filling restorations (Fermit, Ivoclar Vivadent AG, Schaan, Liechtenstein) were carefully placed into the preparations, allowing time for the fabrication of the porcelain inlays. No pulpal protection material was placed during the temporary phase. Powdered veneer porcelain (Vitadur, Vita Zahnfabrik, Bad Sackingen, Germany) was used to make the porcelain inlays.

Porcelain Inlays Cementation

One week after preparation and impressions, the temporary restorations were removed and the teeth were cleaned with pumice powder and rinsed. No pulpal protection material was used. The inlays were evaluated radiographically and visually, and the marginal fit of all of the restorations was considered clinically adequate. The inlays were sandblasted on their internal surfaces with a Dentalfarm Base 3 machine (Dentalfarm, Torino, Italy) using clean 50 μm aluminum oxide abrasive powder at 2.5 atmospheres pressure. The inlays were etched with hydrofluoric acid (Cerec etching gel, Vita Zahnfabrik, Bad Sackingen, Germany) for 1 minute, rinsed, dried, and treated with a silane coupling agent (Monobond-S, Ivoclar Vivadent AG, Schaan, Liechtenstein.).

Cementation was performed under a rubber dam with the Syntac system (Ivoclar Vivadent AG) by carefully following the manufacturer's instructions. The enamel surfaces were etched for 40 seconds with phosphoric acid at 37% (Total-Etch, Ivoclar Vivadent); the teeth were rinsed and dried, and the dentin surfaces were conditioned with a solution of maleic acid at 4% for 15 seconds (Syntac Primer, Ivoclar Vivadent). The adhesive (Syntac Adhesive, Ivoclar Vivadent) and the resin (Heliobond, Ivoclar Vivadent) were carefully applied. The inlays were seated into place, and excess cement was wiped away before light-curing for 120 seconds (40 seconds buccal, occlusal, and lingual/palatal aspects) with a light curing unit (Visilux 2, 3M ESPE, St. Paul, MN). Occlusal adjustments were carried out. The occlusal scheme had to be carefully equilibrated to avoid occlusal contacts in eccentric movements. Occlusal schemes for the establishment of identical occlusal cusp-fossa contacts were established. Gross finishing was performed with diamond burs (Komet, Gebr. Brasseler Gmbh & Co. KG); final finishing and polishing were accomplished with the Porcelain Laminate Polishing Kit (Shofu Dental GmbH, Ratingen, Germany).

Figure 1. Three specimens of teeth during the cutting procedures prior to microscopic observation to evaluate the pulpar tissues.

Tooth Extraction and Specimen Preparation

All eight patients in this study followed appropriate hygiene procedures. One year after cementation of the inlays, the 32 teeth, 24 with the cemented porcelain inlays and eight of the control group, were extracted, using great care to avoid any damage to the restorative material. After extraction, the apical portions of the roots were cut with a diamond wheel (FG-835C, Teledyne Getz, Elk Grove Village, IL) to allow the immediate fixation of the pulpal tissues with formalin. The teeth were dehydrated and decalcified. They were embedded in SamplKwick resin (Buehler, Lake Bluff, IL) and allowed to polymerize overnight (Fig 1). The teeth were sectioned with a Leitz saw (Leitz, München, Germany); uninterrupted serial sections 6 μm thick were obtained. The sections dried for one night at 40°C and then were painted with Eosine-Ematossiline to evaluate the status of the pulpal tissues. The eight untreated teeth of the control group were handled after extraction in the same manner as the teeth with porcelain inlays.

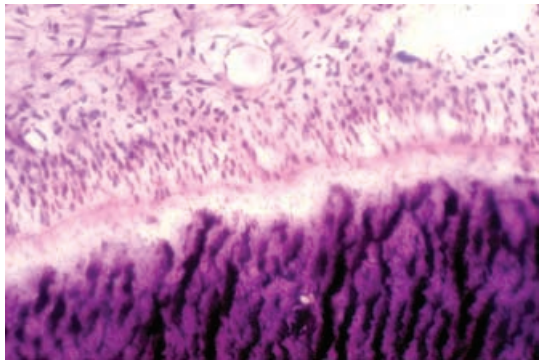

Figure 2. Microscopic observation at 400× magnification of pulpar tissues: no visible pathological or reactive modifications of the pulpar tissues are exhibited.

Microscopic Evaluation

Ten randomly chosen sections for each tooth were analyzed with a Zeiss microscope (Zeiss, Oberkochen, Germany) up to 600× magnification. The status of the pulpal tissues of the experimental and control groups were evaluated according to the histologic criteria published by Cox et al[68] (Fig 2). The number of inflammatory cells (polymorphonuclear leukocytes or mononuclear lymphocytes) for each specimen was counted.

Statistical Analysis

The data relating to the number of inflammatory cells were evaluated by one-way analysis of variance to assess quantitative differences between the group of teeth with porcelain inlays and the untreated group. Mean and standard deviations were calculated for both groups. Differences were considered to be significant at $p < 0.05$.

Results

Observation of the sections of the teeth with porcelain inlays exhibited no visible pathological or reactive modifications of the pulpal tissues when compared with the pulpal tissues of the intact teeth belonging to the control group. All pulps showed normal soft tissue architecture and no pulp inflammation. The visible cells were the ones usually present in the normal pulp.

Polymorphonuclear leukocytes or mononuclear lymphocytes were not detected. No bacteria were seen in any section. The analysis of variance did not reveal statistical differences between the two groups compared.

Discussion

All-ceramic restorations have become increasingly popular because of their outstanding esthetics and high strength. During the 1-year follow-up period in this study, none of the porcelain inlays included in this study demonstrated recurrent caries. They did not experience any fractures. None of the studied inlays had to be re-cemented.

As previously mentioned, all eight patients in this study followed appropriate hygiene procedures. Five patients experienced some initial sensitivity in the prepared teeth after the cementation of the porcelain reconstructions. The sensitivities disappeared in 10 to 15 days and did not come back during the year of function. Numerous researchers have demonstrated that when pulpal tissues are irritated by thermal shocks during the cavity preparation procedures or by the action of chemical agents used during the restorative phase (for example the acid etching procedure), they usually recover.[50-58]

The results of this study suggest that accurate and meticulous procedures during the cementation phase helped minimize the bacterial attack on dental tissue. Several authors have suggested that the presence of a hybrid layer between composite cement and dentin sealed the dentinal tubules and allowed a cellular reorganization of the pulpal tissues.[59-66] This permits the pulp to recover from the primary irritation that was clinically demonstrated by the initial post-insertion sensitivity. The smaller amount of composite resin used in the cementation procedures of the inlays considered in this study probably reduced polymerization shrinkage to lower levels when compared with those accomplished by composite resin restorative materials used for direct posterior restorations. The use of composite resins merely as luting cements under porcelain inlays might reduce the adverse effects of bulk polymerization contraction peculiar to direct posterior composite resin restorations, since the volume of resin is reduced; however it should be considered that the microleakage magnitude can be influenced by the length of time inlays spend in the oral environment; this could explain the more positive clinical results achieved by this study compared with those obtained with a longer clinical trial.[40] It should be noted that the small number of specimens studied represents a limitation of this study. Furthermore, in this research only virgin premolars were restored. In clinical practice more common scenarios involve large restorations performed in previously damaged teeth. The pulpal reactions in these teeth would seem to be clinically more relevant.

Conclusions

Thirty-two vital, healthy, caries-free, and previously untreated maxillary and mandibular first premolars needing extraction for orthodontic reasons in eight young volunteer patients were

included in this study. Within the limitations of this study, the pulpal tissues of the teeth with the porcelain inlays did not show any inflammatory reaction when compared with the untreated teeth of the control group.

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