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Comparison of Marginal Fidelity and Surface Roughness of Porcelain Veneers Fabricated by Refractory Die and Pressing Techniques

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Abstract

Purpose: The aim of the present study was to compare the marginal fidelity and surface roughness of porcelain veneers fabricated by the refractory die and pressing techniques under in vivo conditions.

Materials and Methods: A total of 72 veneers were prepared for anterior teeth in 12 participants. Veneers on anterior teeth in the first and second quadrants were fabricated using refractory die (group I) and pressing techniques (group II), respectively. Surface roughness was evaluated using a profilometer in three areas (cervical, mesio-incisal, disto-incisal) for each veneer. Marginal adaptation of all the veneers (N = 36/group) was evaluated at each margin (cervical, incisal, mesial, and distal) at 7 days and at 3 months after cementation under a scanning electron microscope (SEM) at 200× magnification.

Results: The mean surface roughness of veneers in cervical, mesio-incisal, and disto-incisal areas was 0.41 ± 0.25, 0.33 ± 0.14, and 0.32 ± 0.14 μm, respectively, for group I; and 0.31 ± 0.11, 0.36 ± 0.18, and 0.29 ± 0.11 μm, respectively, for group II. Intra- and intergroup comparisons showed no statistically significant values for all areas ($p > 0.05$). In 144 margins evaluated for each group, a visible gap was present in 15 (10.4%) and 18 (12.5%) recordings at 7 days for groups I and II, respectively. They increased to 19 (13.1%) and 20 (13.8%) after 3 months. These gaps were further broken down into percent distribution of total recordings at the cervical, incisal, mesial, and distal margins. Intragroup comparison was made using the Cochrane test. The chi-square test and Fisher's exact test were used for intergroup comparison of margins, revealing no statistical difference ($p > 0.05$)

Conclusion: Within the limitations of the study, the surface roughness and marginal fidelity of porcelain veneers fabricated by refractory die technique and pressing technique were comparable.

Porcelain veneers have become a viable treatment modality for the restoration of damaged and discolored anterior teeth.[1] Irrespective of the technique or material used for the fabrication, a restoration can be considered successful if it fulfills the criteria of good esthetics, good marginal adaptation, superior strength, and biocompatibility.[2]

To simulate natural teeth precisely, a prosthesis should not only have the same color parameter as natural teeth, but also similar optical properties such as reflectance, transmittance, and translucency, which depend on the surface texture of the restorations.[2] A smooth surface texture is important for the color of the restoration, as it reflects a greater amount of light than a rough surface.[3]

Establishing an acceptable marginal adaptation of porcelain veneers is critical because luting composite resin cement has inherent limitations. Problems such as water sorption, polymerization shrinkage, and microleakage have made it the weak link in the porcelain laminate-resin cement-tooth complex. The

differences in the coefficient of thermal expansion between the tooth and composite cements may cause an eventual microgap, which can cause dental caries and staining at the margins,[4] as fluid, oral debris, and bacteria can penetrate the bonded zone along the margins. Therefore, it is paramount to minimize the exposure of composite resin cement to the oral environment by ensuring better marginal adaptation between the ceramic veneers and the tooth surface.[5] It has also been identified as crucial for the longevity of porcelain veneers.[6]

Marginal fit and surface roughness are affected by many variables during the fabrication and finishing process. These variables, which include the intrinsic properties of the materials and the clinical techniques used, may negatively influence definitive treatment.[7-10]

Various common techniques to fabricate porcelain veneers include the refractory die or a platinum foil technique, in which porcelain in powder form is stacked on top of a refractory die and then fired in the oven. Another method is the castable ceramic technique involving waxing up the restoration to the proper form and casting it in molten porcelain, similar to the lost wax technique for metal. The third technique uses the CAD/CAM system.[11]

Several studies have been done under in vitro conditions to compare the marginal adaptation of ceramic veneers fabricated by the refractory die and castable ceramic techniques.[5,12-14] But clinical studies are still lacking, so the aim of present study was to compare the marginal fidelity and surface roughness of the porcelain veneers fabricated by the refractory die and pressing techniques under in vivo conditions.

Figure 1 (A) Pretreatment view of discolored teeth. (B) Post-treatment view with cemented veneer.

Materials and methods

Ethical clearance was obtained from the institutional ethics committee, All India Institute of Medical Sciences, before starting the study (Ref. No. RT-18/30.09.2011). Twelve patients (age range of 20–30 years), irrespective of sex, were selected according to the inclusion/exclusion criteria. Patients in whom porcelain veneers were indicated to correct unesthetic surface defects on anterior teeth or to mask discoloration and were able and willing to maintain good oral health and sign the consent form were included in the study. Patients having a fractured incisal edge, compromised periodontal health, high caries activity, bruxism, a pipe smoking habit, or gross malocclusion were excluded.

A total of 72 veneers determined on the basis of power analysis were fabricated on maxillary anterior teeth. To maintain uniformity in the study, veneers on anterior teeth in the first and second quadrants were made using refractory die (group I) and pressing (group II) technique, respectively.

After a thorough clinical and radiographic examination, the required mouth preparations (i.e., oral prophylaxis, other small restorations) were done for all participants as per need. Figure 1A shows the pretreatment intraoral view of a patient. The primary impression and preliminary shade selection were followed by window-type preparation with an equigingival finish line and estimated depth of 0.5 to 1 mm to confine the preparation into enamel. The final impression was made after gingival retraction (Sure-Cord Plus, Sure Dent Corporation, Gyeonggi-do Korea), using custom tray addition silicon material (Affinis Precious, Coltene Whaledent, Altstätten, Switzerland), by the two-step technique. In the first step, an impression was taken in heavy-body material with polyethylene spacer to provide uniform space for light-body material. In the second step, the spacer was removed, and the impression was relined with light-body material.

The final impression was poured in type IV gypsum (Kalrock, Kalabhai, Karson Pvt. Ltd., Mumbai, India). The wax patterns for pressing technique were fabricated in blue inlay wax. The patterns were then invested in a phosphate-bonded investment material specifically indicated for all-ceramic restorations (PressVest Speed, Ivoclar Vivadent AG, Schaan, Liechtenstein). An investment ring was placed in a preheated burn-out furnace at 850°C for 30 minutes. Pressing of veneers was done in high transluscent (HT) lithium disilicate reinforced glass ceramic ingots of the respective shades chosen for each patient (IPS e.max Press, Ivoclar Vivadent AG), at 970°C under vacuum as recommended by the manufacturer.

For the refractory die technique, low-fusing feldspathic porcelain (IPS e.max Ceram, Ivoclar Vivadent AG) was used. The refractory dies for maxillary anterior teeth in the second quadrant were poured in phosphate-based refractory die material (BegoForm, BEGO Bremer Goldschlagerei Wilhelm Herbst GmbH & Co., Bremen, Germany). After heat treatment of the dies, the outlines of the preparations were marked with refractory marker and contour pencil (BEGO). Before application of each layer of porcelain, the refractory dies were soaked in distilled water for 5 minutes to 10 minutes, and

the excessive liquid was removed by cellulose cloth. This was done to maintain the moist surface of the dies during porcelain application. The porcelain was applied in subsequent layers. Wash firing with add-on ceramic, at 720°C was done to block all the dies' porosity. The first cervical, dentin/incisal firing was done with dentin and incisal ceramic to build a restoration layer at 770°C. The insufficient contacts were corrected with second dentin/corrective firing to adjust anatomy with incisal and transparent ceramic at 770°C. The final restoration was then contoured and overglazed at 740°C (without vacuum).

Veneers were divested using 50 μm glass beads and adjusted on dies as well as in mouth, individually and collectively using a porcelain veneer kit (Shofu, Kyoto, Japan). The veneers fabricated by the pressing technique were glazed after finishing, but since veneers fabricated by refractory die technique cannot be glazed after removal from the die, they were polished using diamond polishing paste and felt wheels (VITA Karat, Sirona, Chatswood, Australia).

Surface roughness was evaluated for only central incisors to avoid the bias of different tooth curvature, using an electrical stylus profilometer (Taylor Hobson, Ltd., Leicester, UK). Prepared laminates were fixed on a plaster block using double-sided tape to avoid accidental movement of laminate during measurements. A stylus was drawn across the surface at a constant speed for a distance of 2 mm at three sites: cervical, disto-incisal, and mesio-incisal of each laminate fabricated for the central incisor in each group. The numerical value characterizing the surface texture (i.e., the roughness average [Ra] value) was noted in micrometers.

Before cementation, veneers and teeth were cleaned with pumice. Sites were isolated using a cotton roll and saliva evacuator tip. Retraction cord was used for gingival retraction (Sure-Cord Plus) and proper margin visualization. One veneer was cemented at a time, and the adjacent teeth were separated from the operating area by Mylar strip. Tooth surfaces were etched with 37% phosphoric acid for 10 seconds, and bonding agent was applied after washing and drying. The inner surface of the veneer was etched with 15% hydroflouric acid followed by rinsing, drying, and application of silane coupling agent. The dual-cure composite resin (Calibra*, Dentsply India* Pvt. Ltd., Mumbai, India) was used to cement the veneers. Extra cement at the margin was removed before curing, using an explorer. Each margin was then cured for 10 seconds and finished with a superfine diamond bur followed by final curing for 20 seconds (according to manufacturer's instructions). Polishing of the margins was done with thin superfine rubber disk, flexibuff (Sof-Lex, 3M ESPE, St. Paul, MN) and diamond polishing paste (VITA Karat, Sirona). Margins were checked with an explorer and proximal contact with dental floss. Final curing was then done for 40 seconds at each margin (Fig 1B).

Marginal adaptation of all veneers in each group was evaluated qualitatively at each margin (cervical, mesial, distal, incisal) under SEM at 200× magnification at 7 days and at 3 months after cementation. To evaluate marginal fidelity, epoxy resin dies were made and gold sputtered to form a uniform layer of thickness of about 30 nm to 40 nm over the specimens. This made the dies conductive of electricity and helped in scanning by high energy electron beam. To measure the marginal gap of a curved surface with direct view method, the observer used the light reflected from the surface under microscope.[15] A darker and ragged interface was considered as a gap, where either veneer was not closely adapted to the tooth surface or the space between them was not sealed by resin cement.

Table 1 Intragroup comparison of surface roughness between two different areas of veneer in the same group

	Group I (refractory die technique)		Group II (pressing technique)	
Areas compared	Mean difference (μm)	*p* value	Mean difference (μm)	*p* value
Cervical vs. disto-incisal	0.0892	0.282	0.0208	0.651
Cervical vs. mesio-incisal	0.0150	0.790	0.0683	0.272
Mesio-incisal vs. disto-incisal	0.0742	0.374	0.0475	0.438

Table 2 Intergroup comparison of surface roughness at different areas of veneer (N = 12)

Areas	Group I (refractory die technique) Mean ± SD (μm)	Group II (pressing technique) Mean ± SD (μm)	*p* value
Cervical	0.4075 ± 0.25	0.3108 ± 0.11	0.602
Mesio-incisal	0.3333 ± 0.14	0.3583 ± 0.18	0.817
Disto-incisal	0.3183 ± 0.14	0.2900 ± 0.11	0.664

Data were analyzed using SPSS v15.0 software (SPSS Inc., Chicago, IL). An independent *t*-test and Mann-Whitney test were used for comparison between two groups. Statistically significant differences were tested using Fisher's Exact Test, Cochrane, and the chi-Square test wherever applicable. Statistical significance for all tests was set at $p < 0.05$.

Results

Surface roughness

A total of 24 veneers (12 in each group) were evaluated for surface texture. Thirty-six recordings were made in each group to evaluate the smoothness of veneers at three sites (cervical, disto-incisal, mesio-incisal). Surface roughness was expressed as Ra in micrometers. Comparison of three sites of the same group (intragroup comparison) showed a mean difference between cervical-disto-incisal, cervical-mesio-incisal, and mesio-incisal-disto-incisal of 0.089 μm, 0.015 μm, and 0.074 μm, respectively, for group I. For group II, the values were 0.021 μm, 0.068 μm, and 0.047 μm, respectively (Table 1); however, the differences were not statistically significant ($p < 0.05$). The intergroup comparison of surface roughness, in which the respective margins of two groups were compared using *t*-test, showed no statistical significance ($p < 0.05$) between groups I and II (Table 2).

Table 3 Distribution of specimens showing marginal gap in veneers fabricated by refractory die technique (group I) and pressing technique (group II) at 7 days and after 3 months of follow up (N = 36)

		7 days		3 months	
Groups	No. of recordings (4n)	No. (%) of recordings with visible gap	No. (%) of recordings with no visible gap	No. (%) of recordings with visible gap	No. (%) of recordings with no visible gap
Refractory die technique (group I)	144	15 (10.4%)	129 (89.5%)	19 (13.1%)	125 (86.8%)
Pressing technique (group II)	144	18 (12.5%)	126 (87.5%)	20 (13.8%)	124 (86.1%)

Table 4 Percentage breakdown of number of recordings showing visible gap in group I and group II, at 7 days and after 3 months of follow-up

	Refractory die technique (group I)		Pressing technique (group II)	
Region evaluated(n = 36)	7 days Visible gap no. (%)	3 months Visible gap no. (%)	7 days Visible gap no. (%)	3 months Visible gap no. (%)
Cervical	5 (13.9%)	7 (19.4%)	6 (16.6%)	7 (19.4%)
Incisal	6 (16.7%)	6 (16.7%)	2 (5.6%)	2 (5.6%)
Mesial	2 (5.6%)	3 (8.3%)	5 (13.9%)	5 (13.9%)
Distal	2 (5.6%)	3 (8.3%)	5 (13.9%)	6 (16.7%)
p value	0.292	0.409	0.375	0.463

Table 5 Intragroup comparison of percentage difference of specimens showing visible marginal gap for refractory die technique (group I)

	Refractory die technique			Pressing technique		
Follow-up combination and region evaluated	% difference of specimens showing visible marginal gap	*p* value	Significance	% difference of specimens showing visible marginal gap	*p* value	Significance
Cervical G1–0	5.6	0.687	NS	2.7	1.000	NS
Incisal G1–0	0	1.000	NS	0	1.000	NS
Mesial G1–0	2.7	1.000	NS	0	1.000	NS
Distal G1–0	2.7	1.000	NS	2.7	1.000	NS

Marginal fidelity

A total of 72 veneers were fabricated (n = 36). Thus, 288 margins were evaluated (36×4 cervical, mesial, distal, incisal; i.e., 144 margins in each group). Among these, 15 (10.4%) and 18 (12.5%) margins showed a visible marginal gap at 7 days for groups I and II, respectively. This value increased to 19 (13.1%) and 20 (13.8%), respectively, after 3 months of cementation (Table 3).

The marginal gap were not only calculated as a whole, but also categorized according to margin in order to discover which margin had minimum/maximum gap. The percentage of marginal gap was highest at the cervical margin except for the 7-day recording for group I, but the comparison of cervical, distal, mesial, and incisal margins among themselves at different time intervals in both groups using Cochrane test showed no significant differences (Table 4).

The intragroup comparison of marginal gap at 7 days and after 3 months of cementation showed that the difference was not statistically significant for all margins in groups I and II (Table 5). Similarly, the marginal gap for all margins were compared between groups I and II at 7 days and 3 months after cementation, and the differences were not statistically significant (Table 6).

Discussion

The high esthetic quality of porcelain is attributed to its surface texture, characterized by reflection and absorption of light rays.[16] Kim et al[17] stated that surface topography influenced the color of porcelain, especially the CIE L^* value.

This study showed that the surface smoothness achieved by glazing was comparable to the surface smoothness achieved by finishing and subsequent polishing of porcelain restorations with diamond paste (VITA Karat). Almost all the specimens evaluated showed an Ra value below that of enamel, 0.64 μm.[18]

This finding was comparable to the results of Klausner et al[19] and Sulik and Plekavich[20] who compared autoglazed and polished surfaces and found no significant differences between

Table 6 Intergroup comparison of visible marginal gap for groups I and II veneer, at 7 days and at 3 months of follow-up

	Recording after 7 days				Recording after 3 months follow-up			
Region and follow-up	Refractory die technique (group I)	Pressing technique (group II)	*p* value	Significance	Refractory die technique (group I)	Pressing technique (group II)	*p* value	Significance
Cervical	13.9%	16.6%	0.743	NS	19.4%	19.4%	1.000	NS
Incisal	16.7%	5.6%	0.260	NS	16.7%	5.6%	0.260	NS
Mesial	5.6%	13.9%	0.429	NS	8.3%	13.9%	0.710	NS
Distal	5.6%	13.9%	0.429	NS	8.3%	16.7%	0.478	NS

them. Scurria and Powers[21] concluded that finishing diamond points and diamond polishing gel produces the smoothest surface for feldspathic porcelain and machinable glass ceramic materials compared to natural enamel.

Ideally, porcelain veneers should retain their intact surface glaze,[22] but it is common clinical practice to adjust the glazed surface of a porcelain restoration by grinding before insertion.[23] Surface modifications are essential for correction of occlusal interferences and inadequate contours, finishing the margins of restorations, and improving the esthetic appearance and surface smoothness of porcelain restorations.[24] The adjustment procedures break the glaze layer and create a rougher surface. Therefore, glazing or polishing after adjustment procedures is necessary to improve the flexural strength and appearance of the restoration.[25] In situations that preclude reglazing, the use of finishing kits followed by polishing has been shown to reproduce surface smoothness comparable to the original glaze.[19,20,26-9] This study showed a greater number of specimens with marginal gaps in group II (pressing technique), but there were no statistically significant differences in the marginal fit among the veneers fabricated by two techniques immediately, at 7 days, or 3 months after the cementation.

The results of previous in vitro studies are not consistent. Sulaiman et al[12] reported greatest marginal discrepancy for In-Ceram (161 μm), followed by Procera (83 μm), and IPS Empress (63 μm). Sim and Ibbetson[13] reported best marginal adaptation of ceramic veneers fabricated with the platinum foil technique, followed by the refractory die technique, then the castable glass technique. Tjan et al[14] reported that the marginal leakage of Dicor castable ceramic veneers was significantly less than that of Ceramco II porcelain veneers.

A possible explanation of our result could be that as the quantitative measurement of marginal fidelity is not possible under in vivo conditions, the margins were evaluated qualitatively for gap absence or presence, but exact measurements were not made. Another reason for this difference could be inherent limitations of the material itself. These include influence of ceramic microstructure on effectiveness of acid etching or silane coupling agents.[30-32] In this study, feldspathic nanofluorapatite glass ceramic (IPS e.max Ceram) was used for the refractory die technique, and lithium disilicate reinforced ceramic (IPS e.max Press) was used for the pressing technique. This inherent difference in composition can affect the effectiveness of hydrofluoric acid and wettability of the veneer surface by resin cement. The other limitations are the delicate nature of porcelain veneers that can give rise to postoperative veneer cracking[33] and damage to veneer margins from grit blasting during divesting and laboratory finishing.[7]

Dimensional changes of resin cement due to polymerization shrinkage, thermal contraction, absorption of water, mechanical stress, dimensional changes in tooth structure,[34] and effects of epoxy resin shrinkage on the dimension of the master cast[35] can also affect the marginal gap. The variation of material and skill of the person who made the restorations may also influence the result.

This study showed no significant change in marginal fidelity of veneers from baseline (7 days) to after a period of 3 months. The findings were comparable to the results of longer clinical follow-ups, ranging from 1 month to 15 years. These studies reported a low prevalence of debonding, microleakage, fracture, and caries.[36-38]

Conclusion

Within the limitations of the study, the variation of the material and skill of the operator, the surface roughness of porcelain veneers at all the sites evaluated was comparable for both techniques. Veneers of both groups showed a comparable marginal fidelity at the microscopic level at 7 days and after 3 months after cementation. No patients showed any marginal discrepancy when checked clinically with explorer and via the naked eye. A further study is required with long-term follow-up periods.

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