

Photoelastic experiments on facings laminated to teeth

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The influence of various cervical designs of laminated facings was investigated. A variation in the attachment between tooth and facing was also investigated, to examine the influence of partly bad adherence of the resin. The facings were incisally loaded at three different angulations. The study was made in a polariscope, using an Na light source and quarter wave plates. Lack of adhesion of the laminate incisally or cervically created a higher fringe order than when the middle part suffered from insufficient bonding. The shape of the cervical part had only a minor effect on the stress distribution in the facing. □ *Dental materials; esthetics, dental; porcelain; resin cement*

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The upper front teeth are of great importance in giving a characteristic impression of the human face, so discoloration or staining is often a problem for the person affected. When patients need restorations, it is important not only to restore the masticatory functions but also to offer a natural appearance of the teeth. In fact, most patients judge the craftsmanship of the work in front teeth from the color and shape of the labial surface of the front teeth and consider this important.

Dental porcelain has since the early 20th century been the natural choice for crowns and bridges for a good esthetic result, both as all-ceramic crowns and as metal–ceramic constructions. The material is not abraded by toothbrushing or affected by staining or discoloring substances. Crowns and bridges are usually fixed to the teeth with a zinc phosphate or polycarboxylate cement as luting agent. These cements act without adhesion and perform only mechanical interlocking, but the new adhesive technique may provide better support for ceramic crowns (1, 2). A porcelain crown also requires a heavy preparation of the tooth to offer satisfactory thickness of the crown, which, on the other hand, weakens the tooth and may also cause pulpal affections.

Modern porcelains can also be used as inlays, onlays, or facings as alternatives to crowns and amalgam or composite fillings. Porcelain veneers have advantages over large composite restorations and even crowns, such as minimal tooth reduction and better control of color (3). Resin cement combined with the acid etch technique was first used to laminate a methacrylate veneer to the tooth, but since the early resins lacked color stability and wear resistance, the long-term results were unsatisfactory. The first time bonding between porcelain and acrylic resin was used was when porcelain teeth were attached to dentures by etching the porcelain and using silane coupling agents (4). In the beginning

no preparation of the teeth was recommended when laminating porcelain to enamel (5, 6), which resulted in increased total thickness of the tooth, but during the development of the technique a small reduction of the enamel surface of about 0.5 mm was advised (7–9). Since the first report there has been a great interest in this technique, but questions have been raised concerning the strength of the laminate (10–14).

The aim of this study was to examine the stress distribution in facings adhesively attached to teeth, in model experiments, under various conditions. The experiments were made with the two-dimensional photoelastic technique.

Materials and methods

Three different-shaped photoelastic models of prepared teeth, enlarged fivefold, were made. The models were first fabricated in aluminum with various cervical designs. The first was a featheredge preparation with an angulation of 80° from a horizontal plane perpendicular to the long axis of the tooth, numbered 1 in Fig. 1 and Table 1. The second was a chamfer preparation with an angulation of 55°, numbered 2, and the third was a bevel preparation, angulated 30°, numbered 3. Silicone impressions were taken (Provil, Bayer, Germany) and filled with epoxy resin (Araldit F with setting agent 956, Ciba-Geigy, Switzerland) and soft methacrylate (a 10:2 mix of Paladur/Palasisiv both powder and liquid, Kulzer, Germany). The ratio of the E modulus was 4:1, which corresponds to those of dental porcelain and dentin. The two parts were glued together with Loctite 406 (Loctite Corp., Ireland). Three sets of models were made, containing one tooth and facing of each kind, and several spares were also made, to be used later in case of fractures and to test the influence

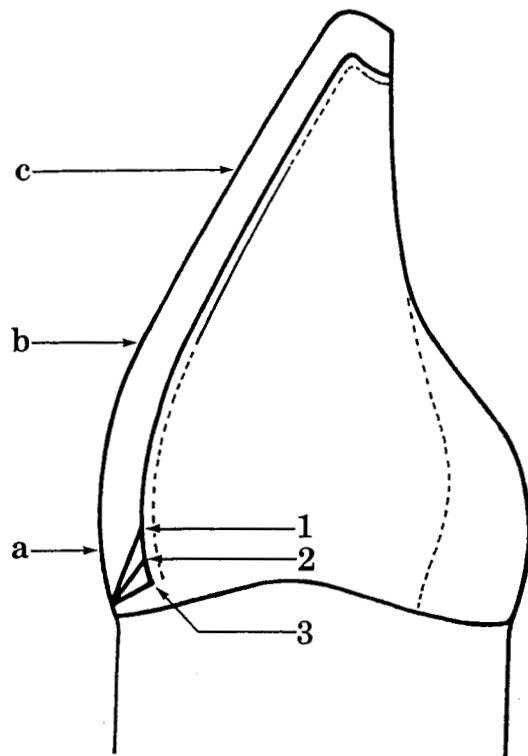


Fig. 1. The three different shapes of the cervical part of the facings, and the different extensions of gluing. The inclination of the load was then varied, with the angulation related to a vertical plane through the long axis of the tooth. Type 1 = featheredge preparation; type 2 = chamfer preparation; type 3 = bevel preparation; G = facing glued in full extent; H = facing glued in the middle third; and I = facing glued in the end thirds. The points where the fringe order was measured correspond in points c and b to the upper and lower points of lamination, in cases H and I. The extension of lamination between the different types is marked inside the bucal profile of the tooth and the thinned profile inside the lingual tuberculum.

of the thickness of the tooth. Every set of models was glued in three different ways. The first (G) was glued in its full extent, the second (H) was glued in the middle third, and the third set (I) was glued in the two end thirds.

The facings were loaded to 125 N in the incisal area in an Alwetron (Stockholm, Sweden) testing machine with a round loading probe ($r = 0.75$ mm) under an angulation of 0° , 30° , and 60° to the long axis of the tooth and placed in a polariscope with a monochrome Na light and quarter wave plates to obtain a black and white image of the fringes. The fringes show how relative stress is distributed in the facing, and the same relative stress is present along a fringe. The fringe order is counted from the O fringe, and the more fringes, the higher the relative stress. Before the facings are loaded, a calibration is made of the polariscope with a standard setup. The loading point was placed on the incisal edge except for 60° angulation, in which the load was lingual. The facings were loaded five times under the same load, and no difference in fringe order was observed between the different occasions.

Photographs were taken of each loading condition, using Agfa Ortho 25 ASA film. Readings were made at three points (Figs. 1a, b, c). The fringe order was counted as principal stress differences in the area. The models 1 H, 2 G, and 3 I were reduced lingually to two-thirds of their thickness, and the same loads were used to examine whether the thickness of the abutment tooth had any influence on the stresses in the facing. Totally, 12 different models were examined under 3 different angulations. The facings were loaded 5 times to ensure reproducibility, and the number of fringe orders is directly proportional to the magnitude of stress.

Results

G: Facings glued in full extension of tooth (Table 1)

In this group only small differences in the fringe orders were noted, but there was a fringe order of two instead of one at the upper limit of lamination of the slice preparation and an increased fringe order with inclination for reading points a and b. The stress patterns looked very much the same for the different cervical designs, compared under the same angles. The main stress distribution is right under the loading point,

Table 1. Fringe order for the three lamination types G, H, and I with regard to lamination (0° , 30° , 60°) and reading point (a, b, c). Three types of facing were analyzed: 1 = featheredge preparation cervically; 2 = chamfer preparation; 3 = bevel preparation

Type of facing	Angulation			0°			30°			60°		
	Registration point			a			b			c		
	G	H	I	G	H	I	G	H	I	G	H	I
1	0	2	2	0	2	2	2	2	2	0	3	3
2	0	1	2	0	0	2	1	2	2	0	2	2
3	0	1	0	0	2	0	1	2	2	0	3	1
1r		2			2			2			3	
2r	0			1			1			0		
3r			1		0			2			1	
						2			2		2	

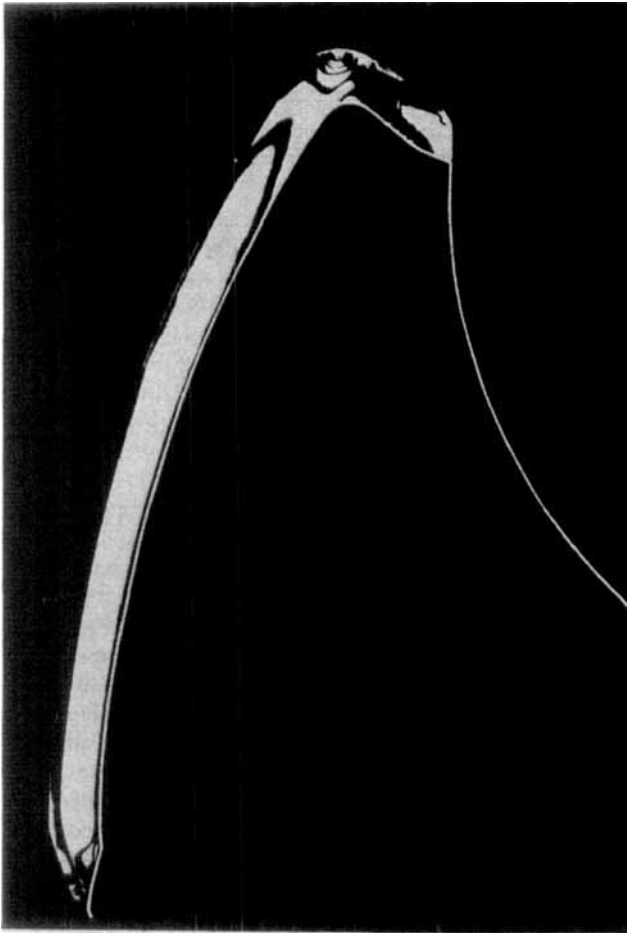


Fig. 2. Type-1 facing, lamination G, inclination 0°.

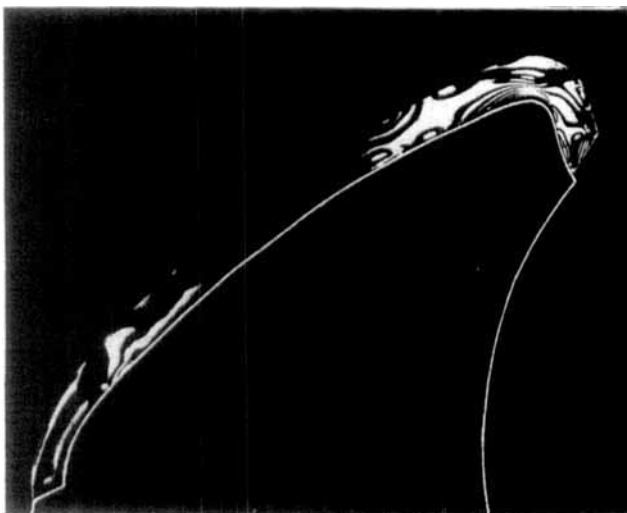


Fig. 3. Type-3 facing, lamination H, inclination 60°.

but the stresses are also distributed along the facing down to the cervical edge following the curve of the facing (Fig. 2). In the case of a 60° angulation of the exposed load, the stresses are mainly distributed in the incisal part of the facing.

The thinned abutment tooth with a chamfer preparation type named type 2 r (G in Table 1) shows an increase in fringe order for reading point b.

H: Facings glued in the middle third of tooth (Table 1)

The bending of the facing in the upper third under load created stresses around the area where the glued interface ended (Fig. 3). Three facings of this type fractured while loading under the angulation of 60°. A comparison between the behavior under load between the different types of lamination showed a greater difference in the fringe order for type-B lamination under the 30° and 60° angles than under 0° angulation (Fig. 4) when compared with the other two types of lamination.

With 60° load, differences between the stress patterns in the facings and the different cervical shapes could be detected. The chamfer preparation also showed a point of stress concentration around the lower border of lamination, and the facing feathered away from the abutment tooth in the cervical part of the facing, which was not found in the other two cases (Fig. 3).

The facing with a bevel also showed a concentration of stresses in the area below the gluing border but not with the same concentration of stresses in a point, and no feathering away from the abutment tooth could be observed.

For the shoulder preparation the stresses were more evenly distributed over a greater area in the facing, and the direction was more axial. Even though load direction of the 60° angulation was made in an unfavorable manner, the load was corrected from behind, incisally-lingually, and the facing was made to move away from the tooth in the upper third, no bending effect in the lower part of the facing was seen (Fig. 5).

I: Facings glued in the upper and lower third of tooth (Table 1)

The stress patterns in the incisal third are equal to those in a total glued case (Fig. 6). In the middle third a bending out from the abutment tooth was observed, and in the cervical third the stress direction was altered. The fringe order varied between the different shapes, especially at reading points a and b. No significant difference was observed between any of the thinned abutment teeth and the original teeth and facing.

Discussion

The G-type lamination was supposed to simulate the optimal manner to fix the porcelain facing to a tooth,

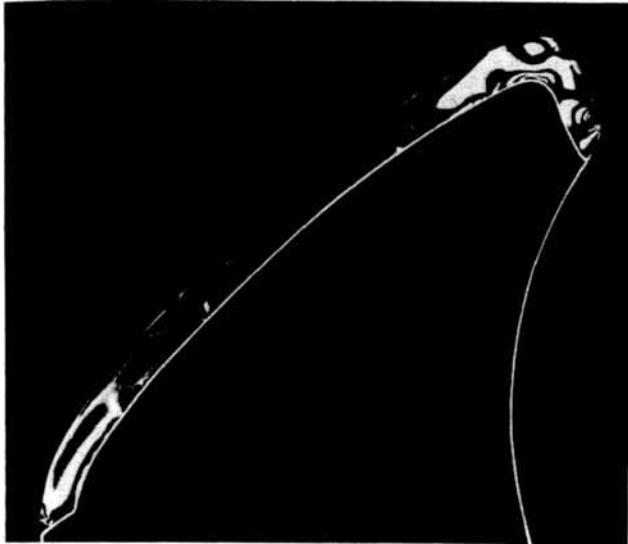


Fig. 4. Type-2 facing, lamination I, inclination 60°.

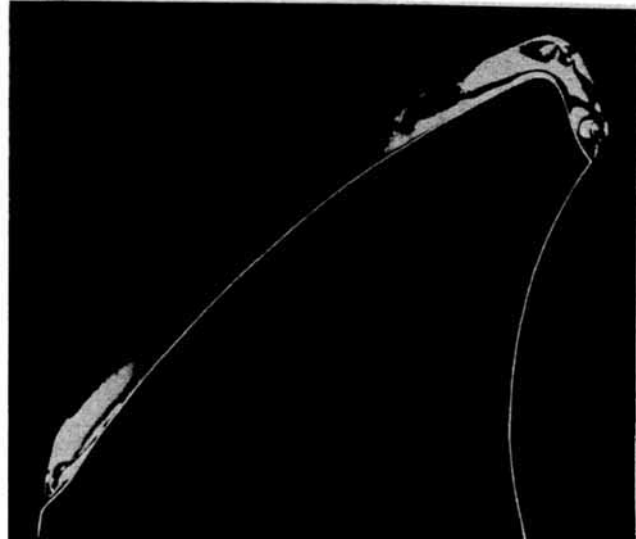


Fig. 6. Type-1 facing, lamination H, inclination 30°.



Fig. 5. Type-1 facing, lamination I, inclination 60°.

and the H-type was supposed to simulate a case in which the bonding between the facing and the tooth is reduced by outside factors such as contamination or moisture. The I-type simulated a case of incomplete polymerization of the resin—for example, insufficient light transmission through the porcelain (15). There were two areas in this study where stress were concentrated in the facings. The first was around the loading point and the second around the cervical area. The fringe orders around the loading point showed that the distribution of stress was inside the facing, and this is to be expected from this construction, in which the laminating layer serves as a stress distributor to the porcelain. This result is in line with the results of Hui et al. (16). Since the aim of this study was to investigate the influence of the cervical shape on the distribution of stresses in porcelain facings, no evaluation of the incisal area was made. The results showed that an optimal fixation of the facing to the tooth created the most favorable stress distribution, with only small differences between the cervical shapes. But there are some important factors to consider. A possible risk of distortion or crack in the porcelain is of course dependent on the thickness. If a facing is thin in the cervical area, like type G, the fringe order is lower before a crack appears than in type I, which is around five times thicker.

The facings in case H were not fixed to the tooth by any gluing interface under the loading point, so the facings could glide along the tip of the tooth, and fractures occurred in some cases in the upper boundary of the gluing interface. The distribution of stresses, in the upper third inside the facing, was very complex, and the facing was kept in place partly by the lingual overlap. The I-type facings tended to lift from the tooth



Fig. 7. Type-1 thinned facing, lamination H, inclination 30°.

when loaded, and it can be assumed that after a number of cycling loads in the incisal direction either the facing or the luting interface would fracture. A comparison of the different buccolingual thicknesses in the abutment teeth showed very similar distribution of stress in the facings and a difference of 1 between the fringe orders (Figs. 3 and 7). We concluded that because the magnitude of stresses varied little between the two cases, the thickness of the teeth was of minor importance, at least down to two-thirds of the size of a normal tooth

under these loading conditions, compared with a poor lamination.

A shoulder-shaped preparation or a chamfer gave the lowest fringe order. Only in the case I, with a poor adhesion in the middle third, was the distribution of stresses more favorable in the facing with a shoulder shape.

Considering the small differences between a shoulder preparation and a chamfer, and the advantages for the dentist from a technical point of view, on the basis of the findings of this study we recommend a chamfer shape for the cervical part of a porcelain facing.

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