Fracture resistance of teeth restored with dentin-bonded crowns: The effect of increased tooth preparation

F. J. T. Burke*

Abstract This investigation assessed the effect of variations in preparation on fracture resistance of teeth restored with all-ceramic crowns placed with a resin composite luting material after the dentinal surface had been treated with a dentinal bonding system. Four groups of 10 sound, unrestored, maxillary premolars were prepared. In group A, minimal preparations of 6-degree taper, 2-mm occlusal reduction, and a knife-edged margin were carried out. Preparations in group B received 6-degree taper, 3-mm occlusal reduction, and a 1-mm shoulder. Preparations in group C were as in group B, but with 2-mm occlusal reduction over buccal cusp and minimal cervical preparation buccally. Preparations in group D were as in group B, but with 2-mm occlusal reduction. The restored teeth were subjected to compressive loading. Mean fracture loads of 0.77 kN, 0.99 kN, 0.91 kN, and 0.78 kN were recorded for groups A, B, C, and D, respectively. Statistical analysis failed to reveal any difference among the groups. (Quintessence Int 1996;27:115-121.)

Clinical relevance
Increasing tooth preparation to provide an occlusal porcelain thickness of greater than 2 mm does not appear to improve the fracture resistance of dentin-bonded crowns and may increase the potential for pulpal damage. A minimal cervical preparation, such as a minimal shoulder or knife-edged margin or chamfer, appears adequate from the aspect of fracture resistance and such a preparation should also provide optimal esthetics.

Introduction
The dentin-bonded crown may be defined as a complete-coverage restoration in which an all-ceramic crown is bonded to the underlying dentin (and any available enamel) with a resin composite-based luting material; the bond is mediated by the use of a dentinal bonding system and a micromechanically retentive ceramic surface. Such restorations have demonstrated good fracture resistance in laboratory studies and have been considered to have the potential for good esthetics because transmission of light through the restoration is better than that provided by metal-ceramic crowns.

Current considerations for tooth preparation for ceramic crowns have been based on the technical requirements for traditional porcelain crown construction and restorative concepts that use conventional retention form, given that such restorations will be placed with materials that do not adhere to either tooth substance or crown. Accordingly, while preparation designs for all-ceramic crowns placed using zinc phosphate, carboxylate, and glass-ionomer cements have been accepted, there are no design standards for the ideal tooth preparation for dentin-bonded all-ceramic crowns, although designs have been suggested by manufacturers, by clinical experience, and for castable ceramic crowns luted without the use of a dentin-bonding procedure.

In a previous investigation, maxillary premolar teeth were prepared for dentin-bonded crowns and results indicated no statistically significant difference in fracture resistance between a group of 10 teeth prepared to a 6-degree taper and a group of 10 sound

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Fig 1 Preparation for group A, involving 6-degree taper, 2-mm occlusal reduction, and a 0.5-mm knife-edged margin.

teeth. In that investigation, specimen fracture predominantly occurred over the palatal aspect of the restoration; therefore, increased tooth preparation and crown thickness in this area might provide increased fracture resistance. Furthermore, a cervical shoulder rather than a minimal shoulder or knife-edged margin might resist forces applied to the occlusal surface of the restoration in a manner similar to that demonstrated by Sjögren and Bergman in a study of Cerestore crowns. It was the aim of this investigation to examine the fracture resistance of specimens restored with dentin-bonded crowns placed on alternative preparations to the minimal preparation previously assessed.

Method and materials

Selection of teeth
Forty sound maxillary premolar teeth were chosen, having first been examined visually and found to be sound and free of hypoplastic defects, and having been examined by transillumination and found to be free of cracks. The teeth were divided at random into four equal groups, designated A, B, C, and D, so that the mean measurement of the buccopalatal width (the distance from the maximal convexity on the buccal and palatal surfaces) between and within each group varied by no more than 2.5%. Any calculus deposits and soft tissue was removed from the selected teeth with a hand scaler. Following postextraction storage in buffered formal saline for 24 hours, the teeth were stored in water at room temperature (20°C) except when aspects of the experimental procedure required isolation from moisture. A light-cured resin was used to fix each tooth, crown uppermost and long axis vertically, in a stainless steel mold (15 x 15 x 15 mm), which had a central cylindrical hole of 12 mm in diameter. The resin extended to within 2 mm of the cementoenamel junction (CEJ).

Preparation of teeth

Group A
A preparation design was chosen that was considered to be typical of the minimal preparation suggested for dentin-bonded ceramic crowns and similar to that utilized in previous investigations. The standard preparation was carried out as follows for one group of ten teeth (Fig 1):
Fig 2 Preparation for group B, involving stages 1 through 4 as for group A, 6-degree taper, 3-mm occlusal reduction, and a 1-mm shoulder.

1. A 2-mm groove was cut along the central fissure with a diamond marked to a depth of 2 mm (233/010, Hi-Di, Dentsply).
2. A line was marked on the buccal and palatal cusps 2 mm from the cusp tips. This line was joined to the bottom of the groove prepared in the first step with a tapered diamond fissure bur (848/016, Bayer Dental).
3. Any convexity was removed from the buccal, palatal, mesial, and distal surfaces with a tapered diamond fissure bur (848/016, Bayer Dental), with a finishing line on enamel, 1 mm from the CEJ.
4. A wall taper of 6 degrees was applied to the preparation with tapered diamonds (6-degree Horico) held in a laboratory handpiece operating at 8,000 rpm without water coolant, placed in a Bachmann-design parallelometer (Cendres & Metaux).
5. Any sharp preparation angles were rounded with a tapered diamond fissure bur.
6. The preparation margins were completed to a minimal (0.5-mm) shoulder preparation.

Stages 1, 2, 3, 5, and 6 were carried out with a high-speed handpiece operating with water coolant.

Group B
Preparations in group B were similar to those in group A, except that 3 mm of tooth substance was removed from the occlusal aspect of the preparation. A 1-mm shoulder was prepared 1 mm above the CEJ on all aspects of the tooth (Fig 2).

Group C
In group C, preparations were similar to those in group A, except that 3 mm of tooth substance was removed from the occlusal aspect of the teeth on the palatal aspect of the groove cut in the first step. A 1-mm shoulder was placed 1 mm above the CEJ on the palatal aspect only of the preparation to the midline of the interproximal surfaces (Fig 3).

Group D
Preparations in group D were similar to those in group A, with 2 mm of occlusal reduction, but a 1-mm shoulder was prepared 1 mm above the CEJ on all aspects of the tooth.
Construction of crowns

A one-stage impression was taken of each prepared tooth with a poly (vinylsiloxane) putty and light-bodied paste (Provil, Bayer Dental) used in a stock plastic tray painted with Bayer tray adhesive. Original impressions were cast in artificial stone with low absorption hard surface and then duplicated with exact addition-cured silicone duplicating material. Refractory casts were poured in Mirage T. J. vest refractory cast material (Chameleon Dental), which was mixed, as per its manufacturer's instructions, under vacuum for 10 seconds.

Crowns were constructed in a standardized manner by one technician, who used a technique that has previously been described. Following construction, the fitting surface of each crown was etched with Mirage Superetch (Chameleon Dental), a mixture of nitric acid, hydrochloric acid, and hydrofluoric acid. The fitting surface of each crown was then treated with a freshly mixed silane bond enhancer (Chameleon Dental), and the crowns were placed in protective packaging.

Placement of crowns

The marginal fit of each crown was examined on the tooth. For any specimen where the fit was considered unsatisfactory, a new impression was taken and a new crown was constructed. In specimens where the fit was considered adequate, the fitting surface of the crown was washed with water and dried, and one application of silane bond-enhancing solution was made.

The tooth was treated with the dentin-bonding components of the Mirage ABC kit (Chameleon Dental). First, the dentin was treated with the 3% nitric acid solution, for 1 minute. The tooth was dried, and four applications of a mixture of solutions A and B (as per manufacturer's instructions) were applied. Further applications were made as necessary to give the dentin a shiny appearance. Unfilled resin and activator were mixed and applied to the dentinal surface.

At the same time, the light-activated component (shade A2) of the Mirage FLC kit (Chameleon Dental) was mixed with the dual-cured component and applied to the fitting surface of the crown, which was placed in position with gentle finger pressure. Excess luting material was removed with sponge pellets, and the lute was polymerized with a light-curing unit (Luxor, ICI Dental) for 40 seconds each from the mesial, distal, buccal, palatal, and occlusal directions. Excess luting material was removed with 30-μm grit finishing diamonds (Composhaper, Intensiv) operated at high speed with water coolant.

Fracture testing

Each tooth was stored in water at room temperature for 24 hours prior to testing, to allow any immediate postcure polymerization of the lute to occur. The restored teeth were subjected to compressive loading at a crosshead speed of 1 mm per minute in a universal testing machine. Compressive force was applied by means of a 4-mm-diameter steel bar placed along the midline fissure of the maxillary premolar crown. The force (in Newtons) required to cause fracture was recorded, as was the mode of fracture, using a classification designed for the investigation.

I. Minimal fracture or crack in crown
II. Less than half of crown lost
III. Crown fracture through midline; half of crown displaced or lost
IV. More than half of crown lost
V. Severe fracture of tooth and/or crown

These results were subjected to one-way analysis of variance and Tukey's multiple comparison procedure.

To verify the thickness of porcelain on the occlusal aspect of the fractured specimens, the specimens of groups A, B, and D were sectioned as necessary and measured under ×4 magnification with digital calipers.

Results

Mean fracture loads of 0.77 kN, 0.99 kN, 0.91 kN, and 0.78 kN were recorded for groups A, B, C, and D, respectively (Table 1). One-way analysis of variance and Tukey's multiple comparison procedure did not reveal any statistically significant difference among the groups. The modes of fracture of the specimens are also shown in Table 1.

Measurement of porcelain thickness at the midline fissure of the occlusal surface of the fractured specimens showed that the mean depth of porcelain in specimens in groups A, B, and D was 1.85 mm, 2.84 mm, and 1.92 mm, respectively.

Discussion

Among the aspects of any new restorative system that require investigation are fracture resistance, marginal leakage, biocompatibility, and esthetics. This study investigated fracture resistance and used conditions as
### Fracture loads of various preparations for dentin-bonded crowns

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<td>0.62</td>
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<td>1.33</td>
<td>V</td>
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<td>0.49</td>
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<td>0.77 ± 0.27*</td>
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<td>0.91 ± 0.31*</td>
<td>0.78 ± 0.33*</td>
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* Classification designed for this investigation: I = minimal fracture or crack; II = less than half of crown lost; III = fracture through midline; IV = more than half of crown lost; V = severe fracture.

+ Mean ± SD.

Similar to the clinical situation as possible, except for the actual fracture of the restored specimen. Nevertheless, because the only experimental variable was preparation design, the study may be considered to provide a comparison between the various preparations utilized and may provide an indication about the ideal preparation to be used in the clinical situation. Ultimately, however, there is no substitute for clinical evaluation of the restoration in the long term.

The preparation designs were chosen following analysis of fractured specimens from previous investigations. In these, a high proportion of the specimens fractured over the palatal aspect of the restoration, possibly because the loading bar was placed along the midline fissure of the (maxillary premolar) crown, this fissure being placed in the anatomic situation on the palatal aspect of the buccopalatal midline of the tooth. It was therefore considered desirable to test an alternative preparation design in which the palatal aspect of the crown would be thicker than the remainder. It was also considered that a cervical shoulder preparation would assist in transmission of occlusally directed forces. It was also considered desirable to test the effect of increasing porcelain thickness over all the occlusal surface to assess whether this would lead to improved fracture resistance, given that Hopkins on loading porcelain specimens of various thickness to fracture, found that increasing the thickness of porcelain improved the fracture strength.

Preparation designs were utilized to incorporate these features. However, there may be disadvantages in some of these designs. For example, the shoulder preparation may prevent the blend of shade from tooth to restoration that is possible with a knife-edged or chamfer preparation. Furthermore, the increased occlusal preparation, to 3 mm, may have adverse effects on pulpal vitality, which is of paramount importance, because it has been reported that many teeth receiving crowns require endodontic treatment within 5 years of crown placement. In this respect, of the specimens in the 3-mm porcelain group, 30% (three) of the pulps were exposed during tooth preparation (and were subsequently sealed with glass-ionomer cement), which would appear to obviate such a preparation in maxillary premolar teeth.

The results did not indicate any statistically significant difference among the four groups, with their varying degrees of tooth preparation, although results suggested that the increased occlusal and cervical
preparation, in group B, provided enhanced protection to fracture. The results of the present study appeared to indicate that, when the porcelain is bonded to tooth structure, increasing the porcelain thickness from 2 to 3 mm occlusally is of less significance than when porcelain specimens are tested without bonding to tooth, as carried out by Hopkins. He concluded that the thickness of dentin should be reduced and that of the ceramic core should be maximized to provide increased resistance to fracture.

The shoulder preparation in groups B, C (palatal aspect only), and D did not appear to provide enhanced resistance to fracture and, therefore, at least from the aspect of fracture resistance, may not be indicated clinically. The knife-edged finish of group A should provide a more esthetic blend of shade from restoration to tooth than would a shoulder. Accordingly, given the risk of pulpal damage and the lack of advantage in terms of fracture resistance, there would appear to be little, or no, advantage in preparing the specimens to a greater amount than the 2-mm occlusal reduction, minimal shoulder, and cervical knife-edged margin used for the specimens in group A.

The failure of increased porcelain thickness to provide enhanced resistance to fracture may also be because increased tooth preparation may reduce the amount of residual enamel available for bonding, leading to a possible reduction in bond strength.

A number of studies have investigated fracture resistance of all-ceramic crowns on resin or metal dies, but a review of the literature has shown no studies investigating the fracture resistance of all-ceramic crowns of varying preparations when these are placed with a resin-composite lute and dentinal bonding. Results of a study by Friedlander et al suggested that a 1.2-mm shoulder, sharp axiogingival line angle, 2-mm occlusal reduction, and 10-degree occlusal convergence provided the strongest Dicor crowns (Dentsply), but these were luted to the metal master dies with zinc phosphate cement. McCormick et al investigated fracture resistance of two types of all-ceramic crown but did not use a dentinal bonding system, while Jensen et al used one standardized preparation in their investigation, which confirmed that the use of a dentinal bonding system helped transfer of the occlusal load to underlying tooth structure rather than catastrophic failure at the luting interface.

The results of these studies may be of interest, because they have provided principles for preparations for ceramic restorations luted with nonadhesive cements, some of which may be appropriate to the adhesive restorations examined in the present study. Accordingly, in the light of these previous studies on nonadhesive preparations, and on examination of the results of the present investigation, it may be considered that the following features may be appropriate to dentin-bonded all-ceramic crown preparations, at least with respect to fracture resistance:

1. Occlusal preparation of 2 mm is sufficient. Increasing the occlusal preparation to 3 mm does not significantly improve fracture resistance, and may increase the potential for pulpal damage. Preparation of maxillary premolars should include a V-shaped groove running mesiodistally to enable the laboratory technician to develop correct occlusal anatomy.

2. A minimal cervical preparation, such as a minimal shoulder or knife-edged margin or chamfer, is adequate from the aspect of fracture resistance. Such a preparation may also provide optimum esthetics.

3. All line angles should be rounded to prevent concentrations of stress in the restoration.

4. A cavity wall taper of 6-degrees may be satisfactory, although it has been reported that the use of dentinal-bonding and resin composite luting may overcome a reduction in traditional retention.

Further work is now indicated to examine other aspects of these restorations, such as marginal leakage.

Conclusion

It is concluded that increasing the occlusal preparation of teeth prepared for dentin-bonded crowns from 2 to 3 mm and preparing a 1-mm shoulder cervically rather than a knife-edged margin does not significantly increase the fracture resistance of the crowns investigated in this study.

References