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Effectiveness of a Self-Adhesive Resin Luting System on Fracture Resistance of Teeth Restored with Dentin-Bonded Crowns

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Abstract - *Laboratory studies have demonstrated satisfactory fracture resistance of all-ceramic crowns placed using a conventional resin-composite luting material and a dentine bonding system. This study investigated the fracture resistance of teeth restored with dentine-bonded ceramic crowns luted with a self-etching luting material. Standardized preparations were carried out on two groups of ten sound, unrestored, maxillary premolar teeth. Ceramic crowns were constructed, their internal surfaces etched and placed using two luting system combinations. Compressive fracture resistance was determined for each group using a Universal Testing Machine. Mean compressive fracture resistance of 890 (222) N and 760 (271) N were recorded for the RelyX™ Unicem Aplicap™ and Mirage groups, respectively. There was no significant difference in the mean compressive fracture resistance of the restored teeth in both groups (P<0.05). The failure modes were different for each cements with more severe (Mode V) failures associated with the Mirage group compared with the consistent Mode II failures associated with RelyX™ Unicem Aplicap™. We conclude that the fracture resistance of dentine-bonded crowns luted with a self-adhesive resin-based luting material was no different from that of a conventional resin-based luting system. The fracture resistance of dentine-bonded ceramic crowns may be clinically satisfactory when a self-adhesive resin-based luting material is utilised.*

KEY WORDS: Crowns, fracture, self-adhesive luting material

INTRODUCTION

The dentine-bonded crown has been defined as "a full coverage restoration in which an all-ceramic crown is bonded to the underlying dentine (and any available enamel) using a resin-composite based luting material, with the bond being mediated by use of a dentine bonding system and a micromechanically retentive ceramic surface" [1]. Previous laboratory investigations have demonstrated that the resistance of such restorations to compressive forces has been satisfactory.[2-4]. The aesthetic properties of dentine-bonded all-ceramic restorations has been considered to be potentially ideal[5] because of the improved light transmission through the restoration when compared with metal-ceramic crowns[6].

A large number of resin-based luting and bonding systems have become available in recent years, but acceptance of these among UK-based dental practitioners has been at a level of less than 30% for luting of metal ceramic restorations[7]. Reasons for this low level of acceptance may relate to the technique sensitivity of these cements in use, which, in turn, may relate to the need for an etching and bonding stage prior to the use of the resin-based luting material. A self-adhesive resin-based luting material has recently been introduced (RelyX™ Unicem Aplicap™: 3M ESPE, Seefeld, Germany) which is not considered by its manufacturers to require the use of a separate etching or bonding system prior to placement of the restoration. As a result, use of this material may be considered to reduce the technique sensitivity of the technique for luting dentine-bonded restorations such as dentine-bonded crowns.

The introduction of a new material should stimulate its laboratory and clinical testing from the viewpoints of ease of use and clinical effectiveness. Since failure due to fracture is a catastrophic incident in the life of a restoration, it could be considered essential that laboratory testing to failure should be carried out in an effort to demonstrate whether this is likely to be a problem in the clinical situation. It was therefore the purpose of this study to assess the fracture resistance of teeth restored with standardized dentine-bonded ceramic full crown restorations cemented with RelyX™ Unicem Aplicap™ and compare these with the previously-published results on fracture resistance of teeth of similar size restored with standardized dentine-bonded ceramic full crown restorations cemented with Mirage ABC/FLC (Chameleon Dental: Kansas City, KN, USA)[1,2].

MATERIALS AND METHODS

Selection of teeth

Ten sound extracted maxillary premolar teeth, which had been examined visually and had been found to be sound and free from defects and cracks, were selected. The teeth were chosen so that the mean measurement of the bucco-palatal width (BPW -the distance from the maximum convexity on the buccal and palatal surfaces) of the teeth

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varied by no more than 2.5% and that these did not vary by more than 2.5% from a group of teeth previously used in a fracture resistance experiment[2]. Any calculus deposits or soft tissue were removed using a hand scaler. Following post-extraction storage in buffered formal saline for 24 h, the teeth were stored in water at room temperature (23 ± 1°C) except when aspects of the experimental procedure required isolation from moisture. Each tooth was fixed, crown uppermost and long axis vertical, in a cubic stainless steel mould (15 mm^3) which had a central cylindrical hole of 12 mm diameter, using auto-polymerised resin, with the resin extending to 2 mm of the cement-enamel junction (CEJ).

Preparation of teeth

The preparation design chosen was considered to be typical of the minimal preparation suggested for dentine-bonded ceramic crowns and similar to that utilized in previous investigations[1,2]. The previously-described [1] standard preparation was carried out as follows:

(1) A 2 mm groove was cut along the central fissure with a diamond bur marked to a depth of 2 mm.

(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 (1) using a tapered diamond fissure bur.

(3) Any convexity from the buccal, palatal, mesial and distal surfaces was removed using a tapered diamond fissure bur, with a finish line on enamel, 1 mm from the CEJ.

(4) An axial taper of 6° was created using specially constructed tapered diamond burs of 6° divergence held in a laboratory hand-piece operating at less than 8000 revs/min without water coolant, placed in a Bachmann design parallelometer.

(5) Any sharp preparation angles were rounded using a tapered diamond fissure bur in a high-speed hand-piece operating with water coolant.

(6) The preparation margins were completed to a 0.5 mm shoulder preparation.

Stages 1-3 and 5-6 were carried out using a high-speed hand-piece operating with water coolant.

Construction of crowns

A one-stage impression was made of each prepared tooth using a polyvinylsiloxane putty and light-bodied paste (Affinis: Coltene Whaledent: Altstatten, Switzerland) in a stock plastic tray painted with tray adhesive. Original impressions were poured using artificial diestone and duplicated using silicone duplicating material into which refractory casts were poured. Crowns were constructed in a standardized manner by one technician. Following construction, the internal surface of each crown was etched with a nitric acid, hydrochloric acid and hydrofluoric acid mixture (Mirage Super Etch; Chameleon Dental Products, Kansas City, KS, USA). The internal surface of each crown was then treated with a silane bond enhancer (Mirage, Chameleon Dental Products, Kansas City, KS, USA) and the crowns were placed in protective packaging.

Crown placement

Following examination of the fit of each crown, any specimens in which the fit was not satisfactory (namely where there was a defect visible to the operator wearing x2.5 magnifying loupes or in which a defect was felt at the crown margin with an explorer), a new impression was taken and a new crown fabricated. In specimens where the fit was satisfactory, the internal surface of the crown was rinsed with water and dried, and one coat of silane bond enhancing solution was applied to the internal surface. The crowns were luted using RelyX™ Unicem Aplicap™ (shade A2) mixed in accordance with the manufacturer's instructions in a Rotomix (3M ESPE, St.Paul, MN, USA).

Crowns luted with the Mirage luting material were washed, dried and treated with the dentin-bonding components of the Mirage ABC kit (Chameleon Dental Products, Kansas City, KS, USA) used in accordance with the manufacturer's instructions. In addition, the light activated component (Shade A2) of the Mirage FLC kit (Chameleon Dental Products, Kansas City, KS, USA) was mixed with the dual-cure component, and applied to the internal surface of the crowns, which were placed in position using gentle finger pressure.

Excess luting material was removed using sponge pellets. The luting material was light-cured using a light-curing unit (Optilux 501:Kerr, Orange, CA, USA) for 40 seconds with an output intensity of 740 mW/cm^2 from mesial, distal, buccal, palatal and occlusal directions. Any remaining excess luting material was removed using 30 µm grit diamond finishing burs (Composhape, Intensiv SA, Viganello-Lugano, Switzerland) operating at high-speed with water coolant.

Compressive fracture resistance determination

Each tooth was immersed in water at room temperature for 24 h prior to testing, to allow for any additional polymerization of the luting materials to occur. The restored teeth were subjected to compressive fracture resistance loading at a cross-head speed of 1 mm/min in a Universal Testing Machine (Instron Model 1544:Instron, High Wycombe, England, UK). The 'crunch-the-crown' compressive fracture resistance test has been widely used to determine resistance to a compressive load applied to both natural and crowned teeth by employing a 4 mm diameter steel bar placed along the midline fissure of upper premolar crowns. The associated compressive force required (N) to cause fracture was recorded and these results subjected to statistical analysis by a one-way analysis of variance (ANOVA) at the 95% significance level to identify differences in mean compressive fracture resistance. The mode of fracture was also recorded following visual inspection, using a classification designed for the investigation, as follows [1]:

I minimal fracture/crack in crown.

II < ½ of crown lost.

III Crown fracture through midline; ½ of crown displaced/lost.

IV > ½ of crown lost.

V Tooth and crown fracture

RESULTS

In the current study the ten crowns luted with RelyX™ Unicem Aplicap™ produced a range of compressive fracture resistances varying between 560 and 1230 N with an associated mean compressive fracture resistance of 890 (222) N. Previously, the group of ten crowns luted with Mirage ABC/FLC produced compressive fracture resistances varying between 480 and 1330 N with an associated mean compressive fracture resistance of 760 (271) N[2]. Examination by the one-way ANOVA identified that the mean compressive fracture resistance of the restored teeth of the two groups was not significantly different ($p>0.05$). There were, however, differences in fracture mode between the groups, with one (severe) mode V fracture occurring in the Mirage group and 40% of crowns were identified with mode III fractures. In contrast, the fracture mode for all the crowns in the RelyX™ Unicem Aplicap™ group were consistent, whereby less than half of the crown was lost, namely mode II fractures (Table 1).

DISCUSSION

Laboratory testing of dentine-bonded crowns under compressive loading conditions has shown satisfactory *in vitro* resistance to fracture in previous tests [1,2], with fracture strengths having been shown to be not statistically different from a group of sound teeth [2]. The 'crunch-the-crown' compressive fracture resistance test has been described as distributing the stress through the restoration as a function of the extent and properties of the cement lute and the level of adhesion between the cement, crown and remaining tooth structure [8]. The strength of the ceramic, porcelain thickness, crown configuration, cement layer and the supporting tooth structure were identified as major factors in determining the strength of a restoration [9]. The current study attempted to isolate the cement layer as the only variable, although there may be variations in the quality and amount of supporting tooth structure despite attempts to minimize these by the use of strict exclusion criteria and attempting to match tooth sizes, bucco-palatally, in each group outlined previously. In addition, the preparation design chosen for this investigation may also be considered minimal, with its 0.5 mm cervical shoulder and 2 mm occlusal reduction, since previous in vitro tests have indicated that more extensive tooth preparation did not result in improved resistance to fracture [1]. The experimental protocol in respect of tooth preparation and crown placement followed methods used in clinical dentistry, with the teeth being prepared at high speed under water coolant and with the preparation being finished at slow speed without water coolant, as could be considered to be common in dental practice. Indeed, the only aspect of the protocol which did not closely simulate the *in vivo* situation was the method by which the restored specimens were fractured, since loading through either a ball or bar loading arrangement dramatically affects stress concentrations and failure initiation sites within the crown [10]. Differences in the fracture resistance of cemented crowns using a variety of luting cements and different crown types have resulted in certain combinations of materials may have some beneficial effect on fracture strengths[10-13].

However, the 'crunch-the-crown' compressive fracture resistance test has not been universally accepted in the dental materials literature. In this respect, the methodology utilized in the present study has been criticised as using loads to failure which are high, compared with those measured during mastication and not replicating the manner in which ceramic restorations fail in the mouth [14] and Kelly has also argued that the testing procedure does not reproduce the types of fractures routinely identified in clinically retrieved failed crowns [14]. For Dicor (Dentsply, Weybridge, UK) crowns, Harvey and Kelly [15] identified no differences in fracture resistance for crowns cemented with three markedly different luting agents and suggested that failure was dependent only on loading-point failure initiation. As a result, the authors concluded that failure was independent of the type of cement or condition of the crown away from the point of loading. However, the compressive fracture resistance forces at failure in the present investigation do fall within the range of masticatory forces seen in the mouth, and, as the method used may be standardised for each specimen, it may be considered appropriate to make comparisons between groups, since all other variables are standardised. This would appear to be confirmed by Pröbster [16] who considered that compressive

Table 1. *Compressive fracture resistance and failure mode for a series of teeth restored with dentin-bonded ceramic crowns luted with a novel self-etching luting material.*

	RelyX™ Unicem Aplicap™		*Mirage[2]*	
Crown	*Fracture Resistance (N)*	*Failure Mode*	*Fracture Resistance (N)*	*Failure Mode*
1	740	II	860	I
2	560	II	700	I
3	950	II	1040	I
4	1100	II	600	II
5	880	II	920	III
6	660	II	480	III
7	1230	II	610	III
8	900	II	620	III
9	750	II	1330	V
10	1170	II	490	II
Mean (SD)	890 (222)		760 (271)	

fracture resistance studies do give an indication of the load bearing capacity in simulated clinical situations and can provide useful information for the design of clinical studies. In addition, Burke [17] noted that biting forces of up to 800 N have been measured clinically in natural teeth and that experimental forces of this value may be considered clinically relevant.

The luting material and its associated bonding agent (Mirage FLC/ABC) chosen for comparison with the novel, recently-introduced self-adhesive luting material employed in this study (RelyX™ Unicem Aplicap™), was selected because it has achieved widespread clinical use, and had been utilised in clinical studies which indicated success of the dentine-bonded crown technique[18]. Resin composite-based luting systems have been considered an appropriate choice for luting ceramic restorations[19,20] and the creation of a micromechanically retentive cutting surface by etching with hydrofluoric acid has been shown to provide effective long term clinical results when resin luting systems are employed [21]. Despite this, resin-based luting materials have not enjoyed widespread acceptance in the UK [7], possibly because of their technique sensitivity in the form of the etching and bonding stages needed to optimise their effectiveness. The avoidance of the etching and bonding stages may therefore be considered to be a clinical advantage for RelyX™ Unicem Aplicap™, especially as the lack of need for these stages does not appear to lead to reduced functioning under laboratory compressive loading conditions. Since the Mirage bonding and luting materials have been shown to be clinically effective[18], it could be surmised that crowns luted with RelyX™ Unicem Aplicap™ could perform similarly, at least with respect to catastrophic fracture resistance. It could therefore be considered that this self-adhesive luting material could be the material of choice for the luting of ceramic restorations, given its ease of use [22] and the satisfactory laboratory performance demonstrated in the present work. Additionally, it could be considered that self-etch /self-adhesive luting materials, such as the one evaluated in the present study, may hold an advantage similar to self-adhesive dentine bonding systems, namely, that they are not associated with post-operative sensitivity [23]. However, like any other novel or recently-introduced material, this, and other factors relating to the performance of the material in clinical practice, must be assessed by long-term clinical evaluation of the material in clinical practice.

CONCLUSION

It is concluded that the fracture resistance of dentine-bonded ceramic crowns luted with a novel self-adhesive luting material is not significantly different from those luted with a conventional resin-based material that has demonstrated satisfactory clinical performance. Further work is indicated to more elucidate the performance of the self-adhesive luting material in clinical practice.

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REFERENCES

1. Burke FJT. Fracture resistance of teeth restored with dentin-bonded crowns: The effect of increased tooth preparation. *Quintessence Int* 1996; **27**:115-21.
2. Burke FJT, Watts DC. Fracture resistance of teeth restored with dentin-bonded crowns. *Quintessence Int* 1994; **25**: 335-40.
3. Jensen ME, Sheth JJ, Tolliver D. Etched-porcelain resin-bonded full-veneer crowns: In vitro fracture resistance. *Compend Contin Dent Educ* 1989; **10**: 336-47.
4. McCormick JT, Rowland W, Shillingburg HT, Duncanson MG. Effect of luting media on the compressive strength of two types of all-ceramic crown. *Quintessence Int* 1993; **24**: 405-8.
5. Crothers AJR, Wassell RW, Allen R. The resin-bonded porcelain crown; A rationale for use on anterior teeth. *Dent Update* 1993; **20**: 388-95.
6. Crocker WP. The cementation of porcelain jacket crowns with adhesive resins. *Br Dent J* 1992; **172**: 64-7.
7. Brunton PA, Christensen GJ, Cheung SW, Burke FJT, Wilson NHF. Contemporary dental practice in the UK: indirect restorations and fixed prosthodontics. *Br.Dent.J.*2005:**198**:99-103.
8. Grey NJA, Piddock V, Wilson MA. In vitro comparison of conventional crowns and a new all-ceramic system. *J Dent* 1993; **21**: 47-51.
9. Scherrer SS, de Rijk WG. The effect of crown length on the fracture resistance of posterior porcelain and glass-ceramic crowns. *Int J Prosthodont* 1992; **5**: 550-7.
10. Casson AM, Glyn Jones JC, Youngson CC, Wood DJ. The effect of luting media on the fracture resistance of a flame sprayed all-ceramic crown. *J Dent* 2001; **29**: 539-44.
11. Burke FJT. The effect of variations in bonding procedures on fracture resistance of dentine-bonded all-ceramic crowns. *Quintessence Int* 1995; **26**: 293-300.
12. Dwan A, Yaman P, Razzooog ME, et al. Effect of cement on fracture resistance of all-ceramic crowns. *J Dent Res* 1996; **75**: Abstr No 2136.
13. Pameijer CH, Nilner K. Long term clinical evaluation of three luting materials. *Swed Dent J* 1994; **18:** 59–67
14. Kelly JR. Clinically relevant approach to failure testing of all-ceramic restorations. *J Prosthet Dent* 1999; **81**: 652-61
15. Harvey CK, Kelly JR. Contact damage as a failure mode during in vitro testing. *J Prosthodont* 1996; **5**: 95–100.
16. Pröbster L. Compressive strength of two modern all-ceramic crowns. *Int J Prosthodont* 1992; **5**: 409–14.
17. Burke FJT. Tooth fracture in vivo and in vitro. *J Dent* 1992; **20:** 131–9.
18. Burke FJT, Qualtrough AJE. Follow-up retrospective evaluation of dentine bonded restorations. *J Esthet Dent* 2000; **12**: 16-22
19. Burke FJT, Fleming GJP, Nathanson D, Marquis PM. Are adhesive technologies needed to support ceramics? An assessment of the current evidence. *J Adhes Dent* 2002; **4**: 7-22.
20. Kramer N, Lohbauer U, Frankenberger R. Adhesive luting of indirect restorations. *Am J Dent* 2000; **13**: 60D-76D.
21. Malament KA, Socransky SS. Survival of Dicor glass-ceramic dental restorations over 14 years: Part 1. Survival of Dicor complete coverage restorations and effect of internal surface acid etching, tooth position, gender and age. *J Prosthet Dent* 1999; **81**: 23-32.
22. Crisp RJ, Burke FJT, Windmueller B. Handling evaluation of a self-adhesive universal resin cement by UK dental practitioners. *J Dent Res* 2003; **82**: Abstr No 1279.
23. Burke FJT What's new in dentine bonding? Self-etch adhesives. *Dent.Update*.2004:**31**:580-589