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Crown Retention for Non-Retentive Preparations using Adhesive Resin Cements

Saad A Osman*, A.W.G Walls† and John F. McCabe‡

Abstract - *This study examines the effect of preparing teeth with six varying convergence angles (ranging between 12 and 120 degrees) and height (1 and 2 mm) on the retention of cast gold crowns. Six groups of 4 human premolar teeth were prepared to give a flat occlusal surface in dentine with very short axial wall heights (1 or 2 mm) and variation in axial wall convergence (between 12 and 120 degrees). Impressions were recorded of the prepared teeth and custom castings made using a high copper content precious metal alloy. The castings were luted with an adhesive resin and stored in water at 37°C for 24 hours prior to determining the pull-off force in an Instron Universal testing Machine at a cross head speed of 1mm min^{-1}. Twenty two of the twenty four tested specimens failed within the dentine of the tooth, irrespective of preparation orientation. Statistical testing using ANOVA demonstrated that there were no differences between the bond strength values for any of the preparation convergence angles or between preparations with 1 and 2 mm axial wall heights. This suggests that attachment strength of adhesively bonded castings with minimal axial wall height preparations is not influenced by the convergence angle of the preparation. The attachment strength exceeded that cohesive strength of the underlying dentine in nearly all of the adhesively luted restorations.*

KEY WORDS: Retention, Crowns, Angle, Adhesive

INTRODUCTION

Traditional cements, such as zinc phosphate, have been used successfully for many years for cementing indirect metal, metal ceramic and all ceramic restorations. The designs of tooth preparations have been modified to optimise retention and stability relying on the characteristics of these traditional cements. One of the primary shortcomings of zinc phosphate cement however is its inability to bond to both tooth structure and casting. Consequently, it relies upon mechanical interlocking rather than adhesion to retain castings in place and the retention of cast restorations is significantly affected by the convergence angle [1] and the length of the axial walls of the prepared tooth [2]. When a tooth has a short clinical crown or has been aggressively prepared previously then the available surface area of tooth, and hence retention and resistance, will be much reduced. In this circumstance retention and resistance can be increased using auxiliary retention features (slots, grooves and pins), or by undertaking crown lengthening surgery to increase the length of the clinical crown followed by further tooth preparation. Both of these approaches will result in the destruction of more sound tooth tissue [3, 4]. In the situation where the use of secondary features will be insufficient to compensate, the tooth may be built up with a core material prior to crown preparation.

Increasingly, resin-based adhesive luting agents have been advocated to help to overcome this problem, however the studies that have been undertaken into this technique have used preparations with "normal" axial wall height but increased convergence angle [5,6,7]. Nevertheless, dentists are often faced with having to attach restorations to the surfaces of teeth with little or no conventional retention and short "axial wall height" [8]. The objectives of this approach are to minimise the need for removal of tooth sound tissue, particularly when managing fractured or worn teeth where considerable quantities of tooth tissue have already been lost. There are no data currently available which assess the retentive capacity of such restorations when bonded to a mixture of enamel and dentine.

The objective of this study was to measure the retentive strength of precious metal castings to human teeth with minimal height crown preparations and varying convergence angles of preparation.

Conventional wisdom suggests that the retention should decrease with reducing preparation length and increasing convergence angle. However, when the major retention factor becomes the strength and adhesive characteristics of the cement the usual retentive design characteristics may be less important. The null hypothesis of this study is therefore that axial height and convergence angle do not significantly affect retention when using an adhesive resin cement luting agent.

METHODS AND MATERIALS

Twenty four freshly extracted intact human premolars (upper 4, 5, and lower 5) were cleaned and refrigerated in distilled water for two months before testing. A metal pin was inserted through the root dentine and the surface of the root was notched to facilitate retention of the tooth in the resin block, the teeth were embedded in cylinders of polyester resin and stored in distilled water.

* MDS, MSc, PhD
† BDS, PhD, FDSRCS
‡ BSc, PhD, DSc

The mounted teeth were divided into six equal groups of 4 teeth each. Cusps and occlusal enamel were completely removed and a flat occlusal surface produced using a lapping guide on wet, 100 and 400 grit silicon carborundum papers, such that the occlusal surface of the tooth was parallel to the surface of the resin block and all occlusal enamel was removed

An air rotor hand piece with a diamond bur (Medium Grit F/G 877/010 Diamond Torpedo Komet) was mounted in a fixed position on the rigid upper arm of a parallelometer. A line was drawn 1mm apical to the flattened occlusal surface of the tooth prior to any bur preparations. The tooth block was mounted on an adjustable table and the orientation of the block adjusted relative to the bur to give the desired taper for the preparation. All tooth preparations were undertaken with copious water cooling, with preparation stopping once the gingival extent of the preparation had reached to line on the axial surface of the root.

Five groups of teeth were prepared to give axial convergence angles of 12, 30, 60, 90 and 120 degrees to the 1mm long axis of the tooth. A second group of specimens were prepared to give an axial convergence angle of 12 degree to a 2 mm long axis using the same methodology. The convergence angle equals the sum of the taper of the two opposing walls. For example, a convergence angle of the preparation of 12 degree resulted from a taper angle of 6 degrees.

Addition-cured silicone rubber impressions were recorded for each prepared tooth and a precious metal casting made using the lost wax casting technique with standard laboratory methods. The castings were made from Midi-Gold alloy (Table 1). A metal loop was incorporated onto the occlusal surface of each casting to facilitate de-bonding.

After the investment was removed from the metal castings, these castings were carefully evaluated with a binocular microscope to inspect their internal surfaces for positive irregularities. If these were present, they were removed with a No. ½ round bur. The castings were seated on the die initially and subsequently onto the prepared tooth to evaluate the quality of marginal fit and tipping or twisting movements. All castings were air-abraded with 50 mm aluminium oxide particles for 30s and steam cleaned for 10s immediately prior to bonding.

The adhesive luting resin, Panavia 21, was applied (Table 1) following the manufacturer's instructions to the etched primed dentine / enamel tooth preparations and to the prepared metal surface. To simulate a clinical situation, the casting was seated on the abutment tooth and held under finger pressure for one minute, before the excess material was removed. Oxygard gel (Kuraray, Japan) was applied to the margins to prevent oxygen coming into contact with the adhesive until fully polymerised.

After 24 hours storage in distilled water at 37 degrees, the specimens were mounted in an alignment jig in an Instron Universal testing machine and were loaded to failure axially using cross-head speed of 1 mm/ min. The maximum force, N required to pull off each crown was recorded.

Table 1. *Materials used in the study*

Material	*Composition*	*Manufacturer*
Panavia 21	MDP monomer, Catalyst, Inorganic Filler, Tooth Primer: [liquid A + liquid B]	Kuraray Co., Osaka, Japan
Midi-Gold alloy	50% Au, 35% Ag, 3.5% Pd, 9.5% Cu	Ivoclar, Liechtenstien

Statistical Method

A one-way analysis of variance, ANOVA, was used to compare the mean values of the pull-off force of the five preparations which have variable convergence angles but the same height [1 mm]. An unpaired t-test was used to compare the mean values of the pull-off force of the preparations with the same convergence angles [12 degree] but different height [1 mm and 2 mm].

Examination of Fracture Surfaces

The inner surface of the metal castings and the surfaces of the teeth were examined using a binocular microscope to determine the mode of failure of the bond interface. This was characterised as having failed at the resin/metal interface, within the resin, mixed failure at the resin/ tooth interface or within the structure of the tooth.

RESULTS

The mean retention forces and standard deviations for different convergence angle groups tested are listed in Table 2. ANOVA revealed no difference between the mean values of these groups.

The retention forces and standard deviations for different axial wall height groups tested are listed in Table 3. There was no difference between the castings with a 12 degree convergence and a 1mm or a 2 mm preparation height.

The pattern of failure of the bonds was almost wholly within the tooth structure. There were only 2 of 24 specimens where failure occurred at the resin/metal interface or within the luting agent

Discussion

Adhesive resin luting cements such as the one used in this work (Panavia 21) include an enamel and dentine primer to improve the attachment of the resin lute to tooth tissue, particularly to dentine. Kawashima *et al* [9] reported that the tensile bond strength of Panavia 21 to dentine increased from 4.1 to 11.2 MPa when it was used in conjunction with ED primer. Panavia 21 has relatively few steps in the bonding procedure, which may help in reducing the time required for such a procedure and in producing better results. Moreover, Channa *et al* found that of film thickness of Panavia 21 is less than 50 mm, which was below the maximum limit (50 mm) set for crown and bridge cementation by polymer-based luting materials in ISO 4049[10]. They also found such a value has a minimal affect on the tensile bond strength between Panavia 21 and Ni-Cr alloy [11].

The relationship between the convergence and retention of crowns has been a primary consideration when evaluating the potential for success of tooth preparations for metal castings. This relationship was established by Jørgensen, and confirmed by Kaufman and Gundler [1,12,13]. These

Table 2. *Retention (pull-off) force for different convergence angles*

Convergence Angle [Degree]	*Mean Force [N]*	*S. D.*
12	609	151
30	771	222
60	495	289
90	638	97
120	541	120

The mean and standard deviations of the retention (pull-off) force of Panavia 21 when used for bonding metal crowns to abutment preparations with different **convergence angles** but the same axial walls [1 mm], n = 4.

ANOVA showed no significant difference among the convergence angle means

[P = 0.335]

Table 3. *Retention (pull-off) force for different preparation heights*

Preparation Length	*Mean [N]*	*S. D.*
1 mm	609	151
2 mm	674	196

The mean and standard deviations of the retention (pull-off) force of Panavia 21 when used for bonding metal crowns to abutment preparations with different vertical heights [1 mm and 2 mm] and a 12 degree convergence angle, n = 4.

Unpaired t- test showed there is no significant difference between the two mean values

[P = 0.622].

studies were based on the use of non-adhesive cements which rely on the mechanical form of the preparation to retain the crown and to resist to forces of displacement on the restoration. There have been other studies that have explored the relationships between preparation taper and the use of adhesive and resin lutes for conventional crown preparations (with axial wall heights of 3-5 mm). These have demonstrated the benefits of using adhesive and resin lutes with both classical preparations and where preparation taper is excessive[5,6]. Other workers have confirmed the poor retentive strength of Zinc Phosphate and related cements and their dependence on a suitable axial wall height and taper [7].

However any full coronal preparation is destructive of sound tooth tissue, there have been a number of case studies published in the literature advocating the use of cast metal occlusal surfaces (gold hats or gold shims) bonded directly to enamel and dentine, particularly for fractured or worn teeth. The relevance of past work to this new style of tooth preparation is unclear as any axial tooth preparation is confined to very short axial walls and is designed more to facilitate location of the casting and possibly to prevention of cuspal flexure than anything else. The purpose of this study was to examine the attachment strength of this new style of cast metal restoration to prepared enamel and dentine surfaces and to clarify whether the angle of tooth preparation had any influence on retention with such short axial wall heights. Our data show that the angle of tooth preparation is not a key factor to the retentive strength of the casting which seems to be determined more by the intrinsic mechanical properties of the tooth-resin-alloy complex.

CONCLUSION

Within the limitations of this study we can conclude the following:

- The attachment strength of this style of precious metal casting to minimal non-retentive tooth preparations exceeded the tensile strength of the teeth concerned in the vast majority of tests.
- The angle of tooth preparation and increasing the axial wall height from 1mm to 2 mm had no effect on the measured bond strengths.
- The development of adhesive luting agents that produce a reliable bond between metal crowns and tooth structure, such as Panavia 21, would preserve the remaining tooth structure and the periodontium from being damaged. This concept may alter views on the concepts of retention and resistance form.

ADDRESS FOR CORRESPONDENCE

Professor A.W.G Walls, BDS, PhD, FDSRCS, Professor of Restorative Dentistry, Honorary Consultant in Restorative Dentistry School of Dental Sciences,Newcastle University, Framlington Place,Newcastle upon Tyne, NE2 4BW, UK.
E--mail: a.w.g.walls@newcastle.ac.uk

REFERENCES

1 Jorgensen, K. D. The relationship between retention and convergence angle in cemented veneer crowns. *Acta. Odont. Scand.*, 1955; **13**: 35-40.
2 Maxwell, A.W., Blank, L.W. and Pelleu, GB. Effect of crown preparation height on the retention and resistance of gold castings. *Gen. Dent.*, 1990; **38**: 200-202.
3 Bragger, U., D. Lauchenauer, *et al*. Surgical lengthening of the clinical crown. *J. Clin. Periodontol.*, 1992; **19**: 58-63.
4 Goodacre, C.J., Campagni, W.V. *et al*. Tooth preparations for complete crowns: an art form based on scientific principles. *J. Prosthet. Dent.*, 2001; **85**: 363-376.
5 El-Mowafy, O.M., Fenton, A.H., Forrester, N. and Milenkovic M. Retention of metal ceramic crowns cemented with resin cements: effects of preparation taper and height. *J. Prosthet. Dent.*, 1996; **76**: 524-529.
6 Mitchell, C.A., Abbariki, M *et al*. The influence of luting cement on the probabilities of survival and modes of failure of cast full-coverage crowns. *Dent. Mater.*, 2000; **16**: 198-206.
7 Zidan, O. and G. C. Ferguson, G.C. The retention of complete crowns prepared with three different tapers and luted with four different cements. *J. Prosthet. Dent.*, 2003; **89**: 565-71.
8 Briggs, P., H. Chana, *et al*. The clinical application of posterior resin-bonded cast metal restorations. *Dent. Update.*, 2002; **29**: 331-337.
9 Kawashima M, Omura and Yamauchi J Bonding of a new dental adhesive resin cement to tooth structure. *Transaction Second International Congress on Dental Materials.*, 1993; 116 (Abst).
10 ISO 4049 (2009) International Standard. Dentistry – Polymer-based restorative materials.
11 Chana, H.S., Ibbetson, R.J., Pearson, G.J. and Eder A. The influence of cement thickness on the tensile strength of two resin cements. *Int. J. Prosthodont.*, 1997; **10**: 340-344.
12 Kaufman, E.G., Coelho, D.H. and Colin L. Factors influencing the retention of cemented gold castings. *J. Prosthet. Dent.*, 1961; **11**: 487-502.
13 Gundler, A., Lockowandt, P. and Erhardson, S. Crown retention and cyclic loading (*in vitro*). *Scand. J. Dent. Res.*, 1993; **101**: 252-256.