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An *in Vitro* Study of Microleakage Comparing Total-Etch with Bonding Resin and Self-Etch Adhesive Luting Cements for All-Ceramic Crowns

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Abstract

Aim: The aim of the study was to assess the dye leakage present following cementation of all-ceramic crowns with 7 currently used cements to compare total-etch (TE) with dentine bonding agent (DBA) and self-etch (SE) systems. Methods: Forty-two Authentic® crowns were fabricated and cemented onto extracted human teeth using 7 currently available cements (2 two-stage adhesives (TE + DBA): Panavia 21 *Kuraray*; Paracore, *Coltene Whaledent* and 5 all-in-one adhesives (SE): MaxCem *Kerr*; Panavia F2.0 *Kuraray*; RelyX Unicem 3*MEspe*; seT *SDI*). Following storage in water and thermal cycling, the teeth were exposed to dye, sectioned and examined under confocal microscopy. Leakage was determined by two blinded examiners and scoring was carried out on a scale of 0 - 8 per tooth (0 = no leakage, 8 complete leakage across the section). One overall reading was obtained per tooth with 6 teeth per material. Results: The results showed a wide range of scores between the different cements. Only a few specimens which used TE + DBA showed slight marginal leakage: Paracore (mean score 0 ± 0) and Panavia 21 (0.3 ± 0.5). The majority of specimens using SE showed leakage: RelyX Unicem (0.8 ± 0.8), SmartCem (1.7 ± 2.1), MaxCem (3.2 ± 1.7), Panavia F2.0 (4.5 ± 2.4) then seT (5.2 ± 2.5). Statistical analysis was carried out showing that Paracore and Panavia 21 were significantly less prone to leakage than MaxCem, ($P = 0.002$) and seT ($P < 0.001$). Conclusion: In conclusion, the choice of luting cement is important in reducing dye leakage. This study strongly favours the use of a TE with separate adhesive system placed prior to the composite luting resin.

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Keywords

Cements; Leakage; Crowns

1. Introduction

All-ceramic crowns are increasing in popularity although remain less popular than metal-ceramic crowns particularly as the cost of metal rises and aesthetic demand increases [1]. A recent review suggested that relatively few all-ceramic systems will provide predictable long-term success for the restoration of molar teeth [2]. One particular concern is the high incidence of pulp death which may be related to marginal leakage. Therefore the choice of adhesive cement is critical to the success of all-ceramic crowns.

"All-in-one" cements are the most popular cements in use for all-ceramic crowns [1] despite a lack of supporting data presumably due to the ease of use associated with such self-etching systems. Donovan concluded that there was no documentary evidence to support the use of self-adhesive cements with all-ceramic crowns [3].

Composite luting cements are generally the first choice for all-ceramic restorations and there is a range of systems available. Clinicians currently have a choice of using a luting cement with or without a separate dentine bonding agent (DBA). Traditionally composite bonding required the application of phosphoric acid, followed by a primer and bonding resin, in the Total Etch (TE) technique. More recently manufacturers have developed cements with integrated self-etch (SE) components, sometimes referred to as "smart cements". Many clinicians however still favour the 4th and 5th generation adhesives where acid etching is carried out with phosphoric acid in the TE technique followed by rinse, gentle air drying and the application of a dentine bonding agent (DBA) either as a primer then bond (4th generation systems) or the application of a single prime and bond agent together (5th generation system). This is supported by the evidence where TE systems appear to be more favourable than SE, with SE associated with lower mean bond strengths [4], less favourable retention in one year clinical trial [5] and faster progressive marginal degradation [6].

As with composite restorations there is a trend with luting cements to move away from TE towards SE techniques as well as towards single bottle systems for ease of use. However this may contribute towards a reduction in bond strengths, an increased risk of leakage and subsequent pulp pathology. Toman *et al.* showed the excellent ability of luting resin cements to minimise leakage when enamel and dentine bonding was used as separate stages [7]. A comparison of zinc phosphate, resin without DBA and resin with DBA reported that the greatest fracture resistance and lowest microleakage was observed when resin with a DBA used [8].

Trajtenberg *et al.* investigated 3 SE luting cements in a study on 18 teeth showing there to be more leakage on dentine margins than on enamel margins with Pan F2.0 performing best in the group [9]. As clinicians increasingly use all-ceramic crowns there is likely to be more situations where margins need to be bonded to dentine, increasing the risk of leakage. As well as pulp death this may result in an increased risk of caries. Sailer *et al.* reported caries in 21.7% teeth with all-ceramic bridge abutments at 5 years with all-ceramic zirconia restorations [10].

Our hypothesis is that the trend away from TE with a DBA towards the use of "smart cements" based on SE and no separate DBA stage results in more leakage and hence increases the risk of pulp pathology. Therefore the aim of the study was to score and compare the amount of leakage present following cementation of all-ceramic crowns with 7 current cements to compare TE + DBA cements with SE only cements.

2. Materials & Methods

Forty-two freshly extracted human molars were prepared for all ceramic crowns (**Figure 1**) and stored in thymol. All ceramic crowns were fabricated using Authentic® (a Leucite-glass, heat-pressed reinforced pressable ceramic from Ceramay, Germany), as shown in **Figure 2**. Cements were obtained and stored according to manufacturer's conditions. Cements used in the study were:

Maxcem EliteTM (Kerr Dental)	SE all-in-one, self-adhesive, resin based
PanaviaTMF 2.0 (KURARAY Dental)	SE, dual-cure resin based adhesive
Panavia®21 (KURARAY Dental)	TE, self-cure resin with DBA stage

ParaCore® (Coltène/Whaledent)	TE, dual-cure resin with DBA stage
RelyXTM Unicem (3M ESPE)	SE all-in-one, self-adhesive, resin based
seT (SDI)	all-in-one, self-adhesive, GIC based
SmartCemTM2 (DENTSPLY)	SE all-in-one, self-adhesive, resin based

These adhesive cements were all in regular use at the time of designing the study and represent a range of cement types including self-etch systems (SE) and those with a separate acid-etching stage (TE). Two cements had a separate dentine-bonding stage (DBA) as used with direct composites in the 4^{th} and 5^{th} generation systems. All-in-one systems are those with a single stage etch, prime, bond and luting resin (6^{th} and 7^{th} generation). All cements were resin based except one glass ionomer cement (GIC).

Randomisation was carried out and the operators were unaware of the code until after the analysis was complete. The Authentic crowns were surface treated according to the manufacturer's instructions and cleaned using phosphoric acid.

Cementation was carried out in a clinical environment by the same clinician and dental nurse according to manufacturer's instructions for each material. The teeth were then stored in thymol post cementation. Thermal cycling was carried out at 5˚C - 55˚C, 1000 cycles.

Following thermocycling and storage in thymol, the teeth were prepared for exposure to the dye. Varnish was applied to the apices and roots. Then the teeth were immersed in rhodamine solution for 24 hours prior to sectioning and polishing.

Initial analysis recorded leakage as present or absent as this may be more relevant to pulp damage than how much leakage occurs. A second and more detailed analysis was then carried out to record the amount of leakage (**Figure 3**). Both left and right sides were scored and added together; therefore generating an overall score between 0 and 8 per tooth. Therefore, 0 represents no leakage and 8 represents the total leakage across the preparation. Scores were carried out independently by two markers unaware of the cement used for each sample and agreed scores used in the analysis. This method had been piloted and tested in-house and found to be rigorous for this application.

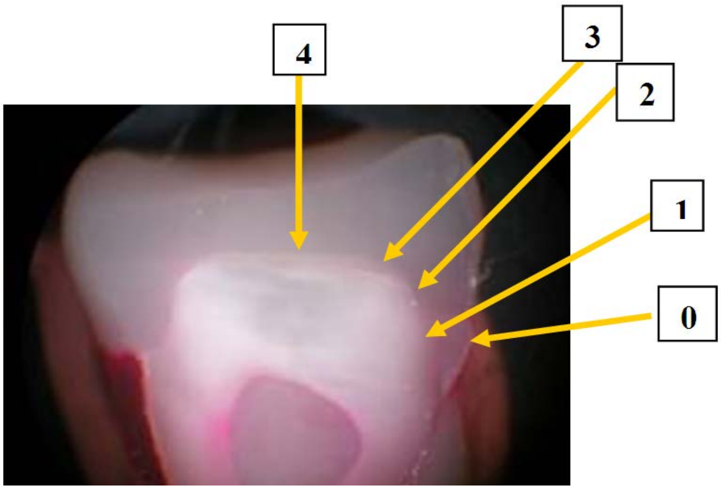
Statistical analysis was carried out on the data using Mann-Whitney test. The randomisation code for products was not revealed until after scoring and analysis was completed, so results were 100% blind.

3. Results

Leakage was observed in the majority of samples with a wide range of amount of leakage present. One typical example for each of the cements is shown in **Figures 4-10**. The initial analysis was to record leakage as present or absent as this may be more relevant to pulp damage than how much leakage occurs. The results are presented in **Table 1** which shows less leakage present in the TE + DBA group. A more detailed analysis recorded the amount of leakage and these results are shown in **Table 2** and illustrated in **Figure 11**.

Figure 1. Tooth preparation.

Figure 2. All-ceramic Authentic® crown.



Scoring system: 0 = no leakage; 1 = leakage from crown margin reaching axial wall; 2 = leakage on axial wall, but not occlusal surface; 3 = leakage as far as the occlusal surface; 4 = leakage to mid-point of the occlusal surface.

Figure 3. Scoring system used.

Figure 4. Sample of Panavia F 2.0.

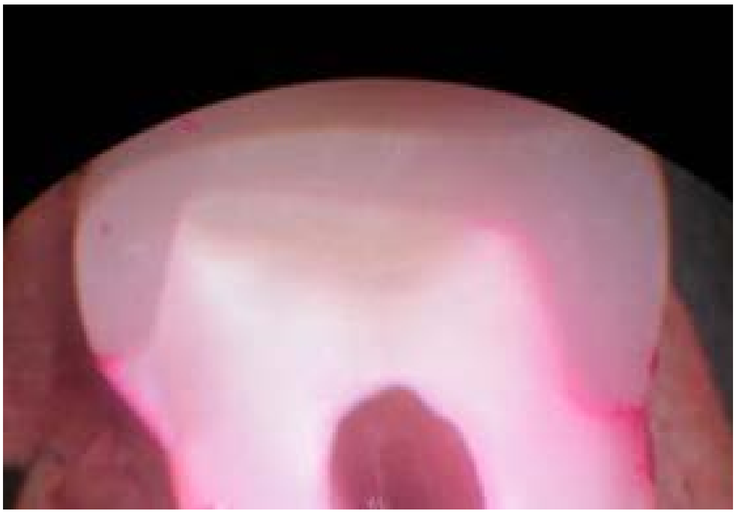


Figure 5. Sample of RelyX Unicem.

Figure 6. Sample of Maxcem Elite.

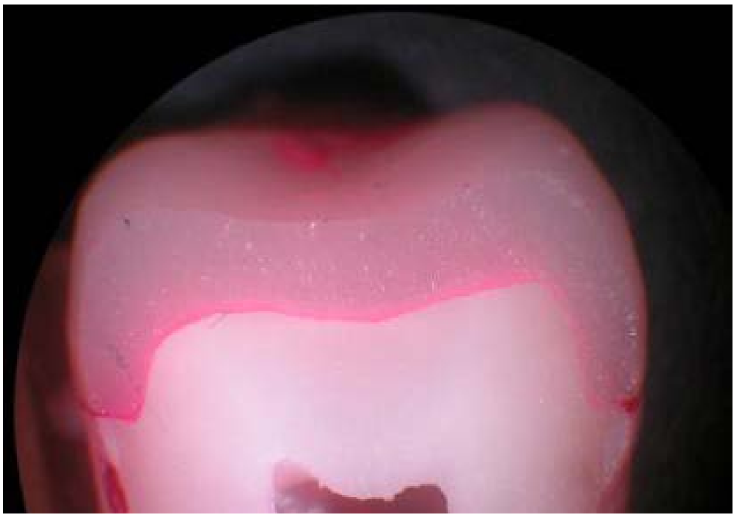


Figure 7. Sample of seT.

Figure 8. Sample of SmartCem2.

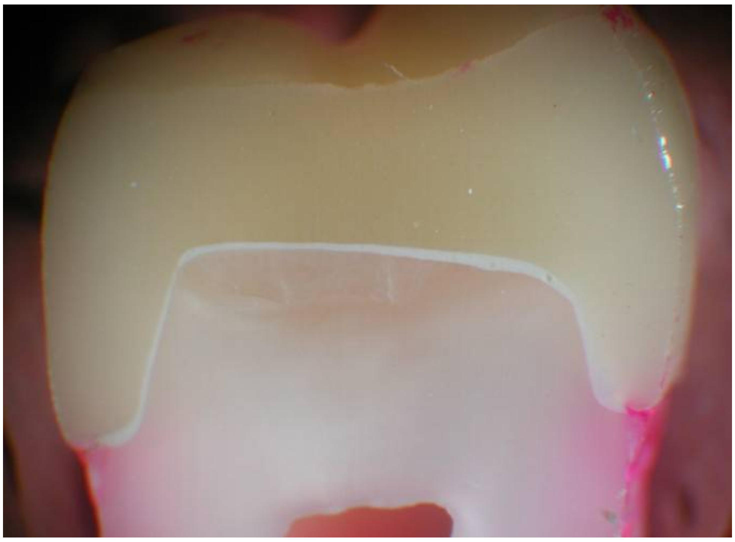


Figure 9. Sample of Panavia 21.

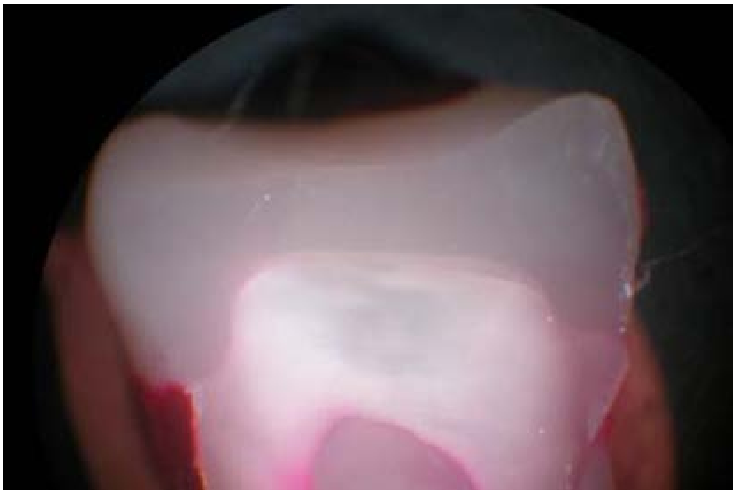


Figure 10. Sample of ParaCore.

Table 1. The presence or absence of leakage for the cements tested.

	Leakage present	No leakage
Luting cement with TE + DBA (n = 12)	2	10
Luting cement with SE (n = 30)	25	5

Table 2. The individual scores for each of the six teeth tested for each cement tested. The column on the right-hand side shows the mean score per cement.

	1	2	3	4	5	6	Mean	SD	Min	Max
PanX	4	6	8	3	1	5	4.5	2.4	1	8
RelX	2	1	0	0	1	1	0.8	0.8	0	2
MaxCem	5	2	1	5	4	2	3.2	1.7	1	5
seT	3	5	8	2	8	5	5.6	2.5	2	8
SmartCem2	0	2	5	3	0	0	1.7	2.1	0	5
ParaCore	0	0	0	0	0	0	0.0	0.0	0	0
Pan21	0	1	1	0	0	0	0.3	0.5	0	1

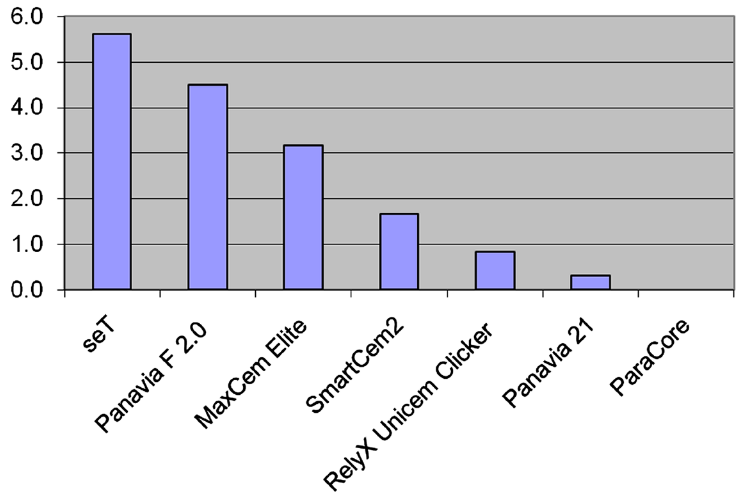


Figure 11. Comparison of the results showing dye leakage scores in rank order.

Statistical analysis revealed that ParaCore had statistically significant lower leakage scores than: seT ($P < 0.001$), Panavia™ F 2.0 ($P < 0.001$) and Maxcem Elite ($P = 0.002$). Although scores were less the data was not statistically significant for: SmartCem™ 2 ($P = 0.170$), RelyX™ Unicem ($P = 0.170$) or Panavia 21 ($P = 0.500$).

4. Discussion

A comparison of the dye penetration scores clearly show significant differences between the cements used for cementation of the all-ceramic, heat pressed crowns in this study. The two-stage TE + DBA adhesives used were ParaCore® (Coltène/Whaledent) and Panavia 21 (Kuraray) whilst the other 5 cements were all-in-one SE cements.

An initial analysis of the presence or absence of leakage, possibly the most relevant with regard to possibility of pulp pathology, is shown in **Table 1**, indicating that the SE cements without a DBA are more prone to leakage. A more detailed analysis involving a measurement of the amount of leakage present in **Table 2** shows that there are further differences between individual cements.

This supports the opinion of Donovan who concluded that there was no documentary evidence to support the use of self-adhesive cements with all-ceramic crowns [3].

Panavia 21 and ParaCore both require the application of an etch conditioner then DBA and show the least amount of dye penetration. ParaCore scored well and was significantly better than any other cement with Panavia 21 also being significantly better than the other cements. From a clinical perspective the dual-cure feature of ParaCore may make it more popular than the self-curing Panavia 21 which is not available in all regions.

These results indicate that the two-stage adhesives were more effective in cementation which may be attributed to their enhanced bonding. One can speculate that the application of a dentine bond before the application of the luting cement allows the dentine bond to form before the contraction of the luting composite takes place. This may reduce the risk of gap formation.

It is also possible to speculate that the primer used with the bond may accelerate the setting reaction of the composite cement, making it cure faster at the bond/cement/tooth interface. This could apply to Panavia 21 and ParaCore which could result in reduce the risk of gap formation. Panavia F 2.0 however has a slower setting reaction and when light-cured, it could shrink away from the surface, which could increase the risk of gap formation. The cements that do not have a separate bond layer may have less adequate dentine bond resulting in leakage observed.

There is a clear difference between the cements, which cannot as of yet be fully explained. The self-etching, all-in-one adhesive cements contain mixtures of various ingredients and the effectiveness of adhesion is compromised. It may be that the dentine bond is forming as the cement polymerises and contracts resulting in a marginal gap. There is no evidence that simply adding a DBA to existing smart cements would reduce leakage as this has not been tested in this study although has been shown to be beneficial by others [11]. The GIC based cement in this study performed least well.

Our explanation for the leakage observed in specimens where no DBA was used is that as the luting resin cures its shrinkage adds stress to the forming bond with the dentine which may then fail in places. As the luting cement has a high volume of resin to make it more flowable the shrinkage taking place will be greater than with a restorative composite resin. However, the two-stage adhesives have the advantage of forming a dentine bond before luting, by applying a separate DBA, and we speculate this reduces the risk of dentine bond failure. Another factor may be the reported benefits of TE over SE techniques for all-ceramic crown cementation [3]. Many studies have investigated the bond strength of various luting systems but this parameter, while important to crown retention, would not be expected to detect microleakage, hence may give clinicians false hopes with single-step systems [12]-[14].

The results of this study of crown cementation mirror the data from composite restorations in general where results using a TE and DBA step ($4^{th}/5^{th}$ generation) give improved results over restorations placed using a SE without a DBA stage ($6^{th}/7^{th}$ generation adhesives). The results support the conclusions from others that TE performs better than SE. The results also add weight to the use of IDS [15]-[17] although this was not investigated in this study.

The presence of marginal leakage under a crown can lead to pulp pathology such as tooth sensitivity, an increased thermal response, pulp necrosis and periapical periodontitis. Such clinical signs are observed and may be related to the method of cementation used [2]. This would include achieving good isolation, obtaining a dry surface including all marginal areas, preparing a clean bonding surface free from all debris, achieving good quality etching and bonding, and finally polymerisation of the luting composite resin. These are difficult to achieve particularly for posterior restorations. Choice of cement is a key factor in minimising the risk of microleakage and maximising the success rate of all ceramic crowns. This study supports the use of cements with a separate etching stage and separate dentine bonding stage as this appears to provide a more secure and reliable marginal seal to reduce microleakage.

5. Conclusion

The conclusion from the study is that this data clearly indicates that two-stage adhesives results in less leakage than the all in one cements tested. The clinical significance of this study is that the use of a two-stage adhesive cement appears to result in less coronal leakage which may result in a reduced incidence of pulp pathology, a recognised complication with all-ceramic crowns.

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