Effect of Luting Cement Space on the Strain Response of Gold Crowns Under Static Compressive Loading

Keywords

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ABSTRACT

The aim the work was to investigate the effect of varying degrees of luting cement thickness on the strain of the cemented gold alloy crowns under compression. Five dies with their corresponding crowns were fabricated using a lost wax technique. Three gold crowns for each die were fabricated under the control of specific die spacer layers to provide a space of 40µm (10 layers of die-spacer thickness) and 80µm (20 layers of die-spacer thickness). The crowns were subsequently cemented using zinc phosphate cement. The crowns were subjected to gradual static compressive loading between 10N to 250N (Newton) and the strain measured simultaneously. The results were statistically analysed using Independent t-test for the different die-spacer thickness at the 95% confidence interval (p=0.05). It was found that a significant relationship in the three thicknesses. It was concluded that the absence of die-spacer significantly reduced strain response, whereas a very little change in the strain recorded as the die spacer layers has increased. Clinically, decreasing the number of die-spacer layers is advantageous as it provides a lower strain response under static compressive loading that would improve the longevity of the cemented full crowns inside the patient's mouth.

INTRODUCTION

The luting cement is the weakest link between the fitting surface of the casting and the tooth surface preparation. The application of a die-spacer to crown preparation dies prior to fabrication of the cast crown is an acceptable procedure to improve the fit of the restoration. Low film thickness is crucial for adequate seating of the prosthesis as it decreases plaque accumulation and its associated diseases. [1, 2, 3]

The ADA Specification No. 84 for zinc phosphate cement allows for 25Mictro meter(µm) cement film thickness, which is in the range of die-spacer relief recommended and used by most investigators. Cement lute film thickness depends on many factors related to the material such as, viscosity, particle size, ambient condition that include temperature and humidity. [5]

There are many studies that have investigated the effect of the cement film thickness under the control of die spacer thickness on the removal force of crowns, they provided controversial conclusions (crowns made from dies without spacer were significantly more retentive than those made from spaced dies, the opposite direction was it appears that increasing the application of die-spacer does not adversely affect the retention of cemented cast copings) [6, 7, 8, 9]. Other authors concluded that variation

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in the cement film thickness had only a moderate influence on retention.[10] They used 10º die and vented castings in their study. They concluded that an increase in retention as cement film thickness decreased from 140-20 μm.[10]

A previous study described a phenomenon called 'filtration' in which large agglomerations of zinc oxide powder act to filter the phosphoric acid and thereby wash the smaller particles out between the crown and tooth preparation and accumulate peripheral to their position. This would produce zones in which there was no cement or cement of low powder/liquid ratio, which would decrease mechanical properties and increase solubility. Further, the authors stated that "nearly complete elimination of defects in the cement film can be obtained by perforating the crown occlusally before cementation. Crown perforation eliminates the increasing hydraulic pressure that is developing as crowns seat on the prepared teeth during the cementation process.[11]

Here, a measurement system based on the mounting of strain gauges on the outer surface of the crown has been developed allowing an indirect non-destructive semi quantitative estimate of the state of the adhesion. The aim of this study was to assess the affect of different degrees of spacing for the luting cement under the control of die spacer on the strain records under a given amount of uni-axial load on fully cemented gold crowns on nickel chromium dies.

MATERIALS AND METHOD

The experimental samples consisted of five nickel chromium dies with a total occlusal convergence (TOC) of 12º and 6mm axial wall height (AH). Fifteen cast gold crowns were fabricated. The first five group was fabricated without die-spacer application, the second group with 10 layers of die-spacer, and the third group with 20 layers of die spacer. The type of die-spacer used was (Tru-fit,Geo Taub, Jersy City,USA). The thickness of die and layers measured using a micrometer.

Graph 1: Strain gauge on the axial surface and another on the Opposing surface (1mm above the crown margin).

Initially, five gold crowns (one on each die) without die-spacer were applied to the nickel chromium dies. For the crowns with die-spacer application, the application of the die-space on the dies were under the manufacturer's instructions. After each layer of application, the die-spacer was given two minutes for drying, layer by layer up to the required number of layers. A no. 10 scalpel blade was then used to delineate the die spacer 1mm of the preparation's finish line.

Three gold crowns were waxed using mould to standardise the thickness of the wax pattern and the subsequent cast gold crowns. for each of the five dies in each of the three groups. A total of fifteen gold crowns were produced. The produced gold crowns had an overall thickness of about 0.5mm, the measurements were based on calibre to assess the final thickness of cast gold crowns at the occlusal and axial walls.

Two miniature strain gauges, EA-06-031EC-350 (Vishay Measurements Group UK Ltd, Stroudley road, Basingstoke, Hants RG24 8FW, UK) were installed on each gold crown approximately 1mm above the crown margin opposing each others with their two solder terminals as seen in Graph 1.

All the samples were fully cemented using zinc phosphate cement (De Tray®Zinc Crown &Bridge Fixodont Plus, DENSPLY DETREY, DENTSPLY Limited, Hamm Moor Lane, Addlestone, UK-Weybridge, Surrey KT15 2SE). After cementation, the samples immediately were subjected to 5 Kilo Gram (Kg) weight in an axial direction.

Using a universal testing machine (Instron, Series 5560), a uni-axial compressive load was applied in increasing 10N increments from 10N to 220N. The cross-head speed was 0.05mm/min. The loading was repeated five times for each sample as seen in Graph 2. The strain readings were collected and calibrated according to the calibration factors for the two amplifiers. The mean of five repeats was taken and plotted microstrain (μm) against load (N).

Data were collected, revised and entered to the Statistical Package for Social Science (IBM SPSS) version 20. The data were presented as mean and standard deviation. The comparison between three groups were done by using One Way Analysis of Variance (ANOVA) for each given load while the comparison between two opposing strain gauges in each different die-spacer thickness scenario were carried out by using Independent t-test. The confidence interval was set to 95% and the margin of error accepted up to 5%. The p-value was considered significant at the level of <0.05 and highly significant at the level of <0.01.

Graph 2: Cemented sample under compressive loading.

RESULTS

The results for each group of cemented crowns were displayed in Figure 1 showing the mean compressive microstrain as positive values plotted against load in Newton (N). The standard deviation for each load among the three different thickness also displayed in Figure 2.

The results show that the use of no die spacer resulted in the lowest strains. There was a small increase in the strain with the use of die spacer. This was more evident for 20 coats of die-spacer compared with 10. However the strain differences between 10 and 20 of spacer were generally small whilst the greatest difference was seen between un-spaced and the 10 coats of space crowns. These differences were more marked at lower loads that about (around 50N).

One Way Analysis of Variance (ANOVA) test (Single Factor) was used to compare the three groups regarding slope of each run. The results showed that the p values >0.05, which were not significant as shown in Table 1. At the 95% confidence interval level, the expected slope of the strain gauge was the same for all the builds (samples).

The results were statistically analysed using Independent t-test to compare strain gauge 1 and strain gauge 2 (the two opposing strain gauges on each cement crown on their respective die) in the slope of each thickness (No die-spacer, 40µm die-spacer thickness and 80µm die-spacer thickness) at the 95% confidence interval. It was found that a significant relationship in the three thicknesses (No die-spacer (p=0.017), 40 µ die-spacer (p=0.009) and 80 µ die-spacer(p=0.008) as shown in Table 2. Additionally the two opposing strain gauges behaved similarly, as shown in Figure 3.

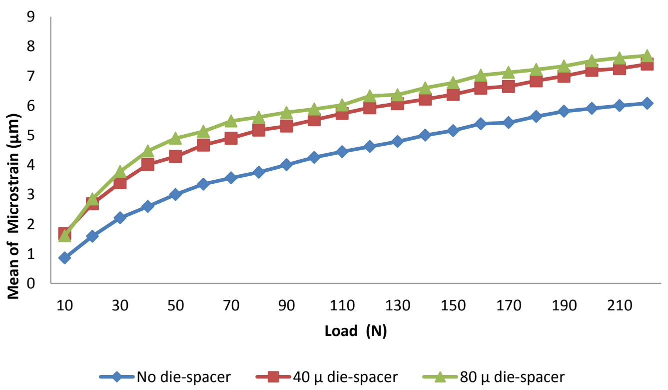

Figure 1: Load v mean-microstrain of fully cemented crowns fabricated with different thicknesses of die-spacer.

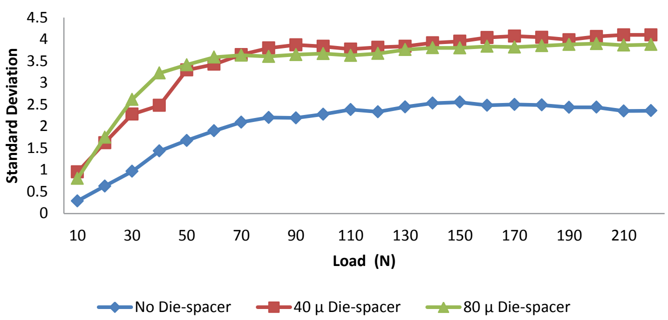

Figure 2: Standard deviation of the results of the micro-strain with different die-spacer thicknesses.

DISCUSSION

The casting seating is one of the most important criteria in crown tooth relationship. Die relief provides space for the luting cement layer between casting and tooth and facilitates escape of the excess cement, despite its viscosity or film thickness. Casting venting is the best method to improve casting seating as it eliminate the hydrolic pressure when the crown comes close to the preparation finish line.[12, 6]

According to an unpublished previous calibration study, 10 layers die-spacer represented about 40µm thickness and 20 layers die-spacer about 80 µm.

The mean was calculated for the five runs for each sample in their category (no die spacer, 10 layers die spacer, and 20 layers die spacer). The results generally showed that with the increase of the applied compressive load, there was an increase in the resultant strain on the axial surface of the gold crowns for the different degree of spacing. A reason for the strain measurements being different between the different number of layers of die-spacer (0, 10 and 20 layers) in that the cement film thickness between the crown and the die was different. However, as previously discussed the resulted strain differences between the two spaced groups were small. This might have been because the difference in the film thickness of the applied die spacer in the two groups was less than might have been expected. Alternatively, it would have been anticipated that the presence of die spacer would have improved the seating of the crowns on cementation as compared with the unspaced group. This hypothesis is in agreement with Eames *et al* (1978)[7] who carried out a comparative study between multiple luting cements and a die relief method and their relation to casting seating, they reported that die relief method was found to be the most suitable of casting seating.

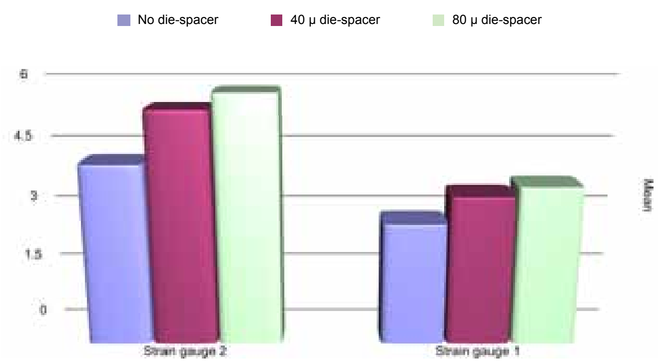

Figure 3: The behaviour of the two opposing strain gauge showing the means of with the three thickness.

Table 1: One Way ANOVA for the different thicknesses at a given load for the three thickness								
Compressive Load (N)	No DS		40Micron thickness die-spacer		80 Micron thickness die-spacer		One Way ANOVA	
	Mean	SD	Mean	SD	Mean	SD	F	P
10	0.86	0.29	1.68	0.95	1.60	0.80	1.885	0.194
20	1.59	0.63	2.68	1.62	2.85	1.75	1.152	0.348
30	2.21	0.97	3.40	2.28	3.78	2.62	0.774	0.483
40	2.59	1.43	4.01	2.48	4.47	3.22	0.776	0.482
50	3.00	1.67	4.28	3.29	4.89	3.41	0.553	0.589
60	3.35	1.90	4.67	3.42	5.13	3.59	0.293	0.751
70	3.56	2.10	4.90	3.65	5.48	3.63	0.471	0.636
80	3.75	2.20	5.17	3.80	5.61	3.60	0.440	0.654
90	4.00	2.19	5.31	3.87	5.77	3.65	0.382	0.690
100	4.25	2.28	5.52	3.84	5.88	3.67	0.329	0.726
110	4.44	2.38	5.73	3.77	6.02	3.63	0.321	0.731
120	4.61	2.33	5.93	3.81	6.32	3.67	0.361	0.705
130	4.79	2.45	6.06	3.84	6.36	3.76	0.299	0.747
140	5.00	2.53	6.21	3.92	6.60	3.80	0.255	0.755
150	5.15	2.55	6.37	3.95	6.77	3.80	0.292	0.752
160	5.38	2.48	6.58	4.04	6.83	3.83	0.243	0.788
170	5.42	2.50	6.64	4.07	6.94	3.82	0.260	0.775
180	5.63	2.49	6.84	4.04	7.02	3.85	0.230	0.798
190	5.81	2.44	6.99	3.99	7.12	3.88	0.212	0.812
200	5.90	2.44	7.19	4.06	7.22	3.90	0.226	0.801
210	6.00	2.35	7.24	4.10	7.33	3.86	0.223	0.804
220	6.08	2.36	7.40	4.10	7.41	3.88	0.235	0.795

Table 2: Independent t-test for the different die-spacer thicknesses						
	Strain gauge 1		Strain gauge 2		Independent t-test	
	Mean	SD	Mean	SD	t	p-value
No die-spacer	4.24	1.49	2.87	1.95	2.497	0.017
40 μ die-spacer	5.49	1.54	3.51	2.80	2.771	0.009
80 μ die-spacer	5.86	1.59	3.73	3.02	2.791	0.008

Improvements in seating potentially would have reduced the cement film thickness; however, there was an evident difference between the behaviour of the spaced groups compared with the unspaced. This was probably indicative of an increased cement film thickness in the two spaced groups. Thicker films of cement appeared to be associated with increased axial strain in the walls of the crown. It would have been helpful to evaluate the resulted space the cemented crown's fitting surface and their die surface according the number of die-spacer applied for each group.

It was considered that variations in the cement film thickness might influence the axial strain recorded in the crown. It was therefore appropriate to minimise variability in the thickness of the cement beneath each crown.

There was no need to know the actual cement film thickness beneath the crowns as long as the die-spaced layers were consistent. The protocol was established from the study of the measurement of the die spacer on the cylindrical rods which indicated that generally consistent results could be obtained. However, the thickness of the cement film would also have been influenced by the variables associated with the cementation of crowns and would have been likely to have been greater than the relief provided by the dies spacer.

Methods have been described for measuring the actual thickness of a film beneath crowns some involve retrieval of a silicone film or sectioning of the crown to allow direct visualisation. Neither was considered suitable for use in this study.

There are contradictory data relating to luting cement film thickness and retention of crowns as a function of die spacer. Some investigators found an increase in retention of cemented crowns as the film thickness increased[6, 13, 14]. In contrast, other reported a decrease in the retention[8,9]. On the same time, other authors did not report any changes[7,5]. These contradictory data might have been attributed the variations in their results to variations in their experimental designs[14]. The data from the present study recorded an increase in axial compressive microstrain with increased die-space and an assumed increase in cement film thickness.

According Griffith's theory of flaws: [15]

1. All materials contain defects that are randomly distributed inside the material.
2. Under load, each of these defects is likely to initiate crack growth.
3. The higher the volume of the material, the more numerous the defects and the larger the probability of crack initiation

Multiple studies have investigated the tension forces of a cemented crowns on their dies.[17,18] However these experiments investigated the retentive power of the cement lute layer against its removal force which is not representative of the clinical situation.

This force direction only happened on sudden experimental environments. There is a lack of understanding of the effect of the cement film thickness under compressive load on strain response which is the normal load direction in the patient's mouth after the casting have been cemented. In this study, using compressive gradual loading would make it more clinically representative.

CONCLUSION

With the limitation of this study, the following conclusions could be drawn:

Strain measurements from the axial surface of gold crowns could be used to assess the effect of increased cement film thickness.

Strain gauges as a measurement devices used here provided sufficient accuracy to assess the small differences of cement lute thickness created by measurable layers of die spacer.

Increased thickness of cement was associated with increased axial wall strain particularly at lower loads.

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