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An Investigation Into the Integrity of Fit of Provisional Crowns Using Current Proprietary Temporary Crown Materials

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ABSTRACT

Three methods of direct provisional crown construction were investigated for accuracy of marginal fit. A modified proprietary crown coping was compared to Bis GMA and isobutyl methacrylate resin provisional crowns with margins modified by using a flowable composite and 'bead on' isobutyl methacrylate respectively. Measurement was at 50x magnification at seven sites over the fit surface. Data was analyzed using SPSS version 13.0.1 and measurement compared using the Mann Whitney test set at a significance level of 0.05. Reliability was checked using the Bland Altman test. Statistical significant differences were found between the three groups. The order of best fit was Bis-GMA and flowable composite >isobutyl methacrylate with 'bead on' margins > Bis-GMA modified implant temporary coping. The clinical significance is that the Bis GMA and flowable composite combination can be used with equal confidence to traditional methods of temporarisation.

INTRODUCTION

The importance of temporary and provisional restorations both in conventional and implant prosthodontics is well documented in the dental literature[1] and the requirements for satisfactory provisional restorations differ only slightly from the definitive treatment they precede. Provisional restorations play a vital role in the long term success of fixed restorations. The health and integrity of the pulp and gingival tissues depend on the quality of interim restorations prior to the placement of the definitive prostheses. Numerous studies[1-4] have identified areas of concern with provisional restorations including appearance, speech, function, comfort, periodontal health, and continued evaluation of the proposed treatment plan. Table 1 summarizes the rationale for provisional treatment over natural teeth and Table 2 over dental implants.

Historically, auto polymerizing polymethyl methacrylate (PMMA) and polyethyl methacrylate (PEMA) resins have been the materials used by the dental profession for the construction of provisional crowns and bridges. However, Bis acryl composite resin materials have become a popular alternative choice due to the ease of mixing in the cartridge dispenser and no odour or bad taste which are associated with the methacrylate materials.

Table 1. Rationale for provisional treatment over natural teeth

1. Protect pulpal tissue
2. Protect teeth from dental caries
3. Protect teeth from sensitivity
4. Evaluate parallelism of abutment teeth
5. Prevent the migration of abutments
6. Immediate replacement of missing teeth
7. Improve the patient's appearance
8. Provide both comfort and function
9. Maintenance and sometimes improvement of periodontal health
10. Evaluate and reinforce patient's oral hygiene
11. Provide a matrix for the retention of periodontal surgical dressings
12. Stabilize mobile teeth during periodontal therapy
13. Provide anchorage for orthodontic treatment
14. Aid in developing and evaluating an occlusal scheme
15. Allow evaluation of vertical dimension, phonetics, and masticatory ability
16. Assist in determining the prognosis of questionable abutments during Prosthodontic treatment

Table 2. Rationale for provisional treatment over implant abutments

1. Improve patients appearance
2. Provide both comfort and function
3. Promote guided tissue healing around implant abutments
4. Provide anchorage for orthodontic treatment
5. Aid in developing and evaluating the occlusal scheme
6. Allow evaluation of vertical dimension, phonetics, and masticatory ability

Research has shown that Bis-GMA acryl resin composites provide some advantages in physical properties including low polymerization shrinkage[5] and good marginal adaptation[6-8] low exothermic reaction[9, 10] minimal pulpal and soft tissue irritation,[11] good surface hardness,[12] and increased colour stability.[2, 10]

Although there are over fifty different materials available on the market they all fall into either the poly(methyl) methacrylate's, poly(ethyl) methacrylate's, poly(vinyl) methacrylate's, Bis acryl composites or visible light cured urethane dimethacrylates. Epimine resin was also formally available. Wang R.L *et al*[10] showed no one material was superior to another in all respects and each has advantages for certain situations.

Until recently, alterations for repairs and additions to Bis-GMA acryl resin composite materials were difficult, even though they are compatible with other composite materials.[1,2] An 85% decrease in transverse strength after repair of a Bis-GMA acryl resin provisional material[13] has been reported and for that reason it has been suggested by the same authors that it might be more advantageous to make new provisional restorations than repair restorations made from Bis-GMA acryl resin provisional materials. However, clinical experience has shown that flowable composite resins can be used to repair Bis-GMA acryl resin provisional restorations with ease and success.[14]

Accuracy of fit has been studied mainly on teeth[4,5,6,7,19,20,21,23] in order to ensure that marginal integrity is maximised to prevent microleakage. This though is equally important in implant therapies as often the margin of the restoration is below the mucosal margin and any positive or negative marginal discrepancy could cause gingival irritation.

The purpose of this investigation is to compare the accuracy of fit of three manufacturing methods under the test conditions *in vitro*.

MATERIALS AND METHODS

In this investigation provisional single crowns were made over an implant abutment using three different methods. The accuracy of fit of provisional crowns made from poly ethyl methacrylate acrylic resin with their margins refined with the 'bead on' or 'paint on' technique was compared with those made from Bis-GMA acryl resin composite relined with flowable composite, and those produced using the implant abutment temporary coping modified to tooth shape with Bis-GMA acryl resin composite as above but no marginal modification.

The 'bead on technique' uses fine camel hair brushes, soaked in monomer by capillary action due to their hollow configuration, to pick up a small ball of powder as this becomes wetted by the monomer. This ball is transferred to the margin of the temporary crown which in turn is refitted to the tooth or implant surface where it makes an accurate impression of the margin, a process often called 'margination'.[2,15,19]

ANALOGUE PREPARATION

A standard ITI Straumann 4.8mm regular neck implant fixture was embedded into a brass cylinder and a Solid abutment (7mm) torqued into position leaving a sloping shoulder margin to replicate an ideal crown preparation with a shoulder finish line. Two location notches were prepared on the brass cylinder to allow reproducibility. A canine tooth was waxed up over the abutment to mimic a clinical situation *(Figures 1 and 2*). A cylinder using light cured composite tray material was made to fit accurately around the brass casting which included two lugs on its internal surface.

Figure 1:
a) Implant fixture and ITI Straumann Solid abutment embedded into brass cylinder with 2 location notches to allow reproducibility.
b) Canine tooth waxed up over abutment.
c) Cylinder from light cured composite tray material made to fit accurately around brass casting including 2 location lugs on the internal surface.

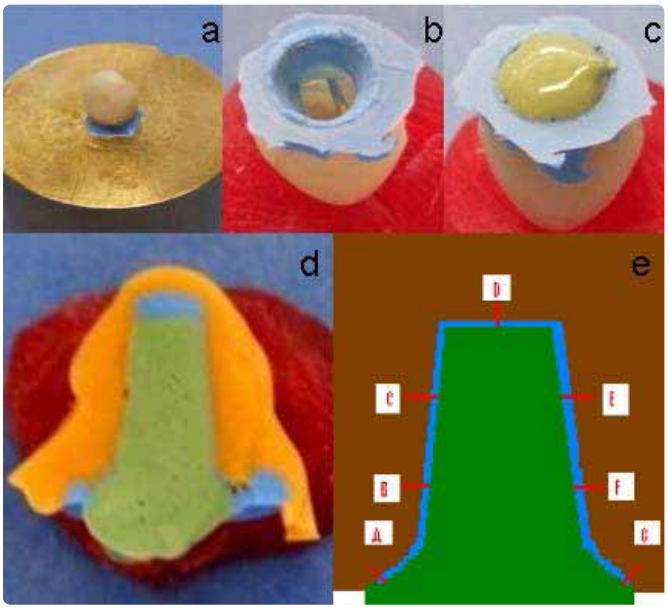

Figure 2:
a) The restoration fitted over the Solid ITI Straumann abutment filled with polyvinylsiloxane light body impression material to mimic a cement lute.
b) The provisional crown removed from the implant abutment leaving the light body polyvinylsiloxane in the fit surface.
c) The remaining space filled with medium body polyvinyl siloxane impression material.
d) Sectioned specimen.
e) Schematic presentation of the seven measurement points used.

Silicone putty was used to create a matrix, which was used for the construction of the provisional crowns. In the surface of the putty matrix a notch was created with a number 10 scalpel, in order to allow the excess of provisional material to be vented and secure the complete seating of the matrix over the analogue. Twenty-five provisional crowns were made in each of the three groups tested.

SAMPLE PREPARATIONS

Group 1: Poly (Ethyl) Methacrylate

Poly(ethyl) methacrylate provisional material (Trim II) was mixed according to the manufacturer's instructions. A plastic pipette was used to place 7ml of liquid into a plastic mixing cup and 12.5g of powder were added. The material was mixed for 1 minute with a metal spatula. The putty matrix was filled with the provisional material and after another minute, when the material reached the dough consistency, the putty matrix was seated over the abutment. The material was left for 3 minutes to ensure polymerization before the putty matrix was carefully removed from the analogue without touching the margins and was left to completely cure on the bench for 15 minutes according to the manufacturer's instructions.

The excess material at the margin was trimmed with polishing discs at 2.5 magnification. The crown margin was redefined with the same material using the 'bead on' technique as described by Zwetchkenbaum *et al.*[15] The fresh provisional material was left to polymerize for 15 minutes. Once cured the acrylic resin provisional crown margin was further trimmed and then polished under x2.5 magnification loupes with medium, fine and super fine polishing discs.

Group 2: Bis-GMA acryl resin composite

The Bis-GMA acryl resin composite provisional material was supplied in a GarantTM Dispenser which was used for mixing of the two pastes and its subsequent application of the provisional material directly into the putty matrix. This was then seated over the analogue and left to set for 2 minutes. The provisional crown was carefully removed from the analogue without touching the margins and was left to completely cure on the bench for 5 minutes according to the manufacturer's instructions and then trimmed in the same manner as described in Group 1 except for this group the relining procedure involved the application of bonding agent to the restoration's margin which was light cured for 15 seconds. The provisional crown was then relined around the margins with flowable composite and re-positioned. This in turn was light cured using a 3M ESPE Elipar S10 LED light cure unit (mesially, distally, buccally, and lingually) with 1200mW/cm2 for 15 seconds on each surface after placement back on the analogue.

Group 3: Modified stock templates provided from the implant manufacturers

The ITI Straumann temporary coping for regular neck Solid abutment was used for the preparation of the third group of this investigation. According to the manufacturer the temporary coping is made from PMMA and has a height of 8.5mm. The surface of the temporary coping is serrated to provide mechanical retention for the provisional material used over it. A wide range of provisional materials can be used over it to construct an anatomical crown shape.

Table 3. Mean values and standard deviation in all points of measurement for all groups

Group	Point of measurement	N	Mean	Standard Deviation
1.Poly ethyl methacrylate	Measurement A	25	83.61	12.22
	Measurement B	25	29.30	20.00
	Measurement C	25	34.36	21.99
	Measurement D	25	184.52	97.28
	Measurement E	25	19.91	19.75
	Measurement F	25	19.81	15.71
	Measurement G	25	84.46	14.85
2. Bis-GMA acryl resin composite	Measurement A	25	69.97	16.21
	Measurement B	25	17.49	11.37
	Measurement C	25	14.67	10.52
	Measurement D	25	35.94	18.68
	Measurement E	25	15.83	7.82
	Measurement F	25	16.90	9.45
	Measurement G	25	71.12	18.07
3.Modified stock templates	Measurement A	25	203.00	31.67
	Measurement B	25	72.30	22.77
	Measurement C	25	74.72	18.33
	Measurement D	25	392.15	126.36
	Measurement E	25	63.51	22.71
	Measurement F	25	61.43	23.70
	Measurement G	25	240.70	67.91

After the ITI Straumann temporary coping was clipped in place over the fixture head the putty matrix was filled with Bis-GMA acryl resin composite, and fitted over the coping. The procedure for polishing was repeated for this group except that no reline or margin modification procedure was used.

SAMPLE MEASURING

An in vivo technique for the estimation of cement thickness on definitive fixed restorations has been proposed by McLean and von Fraunhofer.[16] A modification of this technique was used in this experiment by using silicone impression materials. The fit surface of the provisional crowns was filled with low viscosity polyvinyl siloxane impression material (Kerr) and the restoration was fitted over the solid abutment to mimic the cement lute *(Figure 2*a) and left to set for 7 minutes. The provisional crown was then removed from the implant abutment leaving the low viscosity polyvinyl siloxane on the fit surface *(Figure 2*b). The remaining space was filled with medium body polyvinyl siloxane impression material (Kerr) *(Figure 2*c) and left to set for further 7 minutes. Seven minutes being the recommended manufacturers setting time for this material.

The light and medium body silicone was removed from the fit-surface of the provisional crowns and covered with an alternative manufacturers low viscosity polyvinyl siloxane impression material of another company (Dentsply) which has a different colour than the one used to record the fit surface of the provisional crown. The low viscosity impression material was left to set for a further 7 minutes and after setting sectioned down the centre with a number 10 scalpel. The sections were cut from the mesial to distal aspect as proposed by McLean and von Fraunhofer.[16]

An Olympus BX60 optical travelling microscope was used to measure the thickness of the low viscosity ExtrudeTM impression material on all the sections of the rubber impression samples under 50x magnification. Seven measurements were made in total on each rubber impression sample *(Figure 2d)*.

The points of measurement for each sample are presented schematically in Figure 2e.

- Measurement A: The first measurement was made on the most external point of the margin on the mesial site (left hand side) of the rubber impression sample.
- Measurement B: The second measurement was made 2mm occlusally of the restoration's margin on the mesial axial wall of the rubber impression sample.
- Measurement C: The third measurement was made 4mm occlusally from the restoration's mesial margin on the mesial axial wall of the rubber impression sample.
- Measurement D: The fourth measurement was made at the middle of the occlusal surface of the rubber impression sample.
- Measurement E: The fifth measurement was made 4mm occlusally of the restoration's distal margin on the distal axial wall of the rubber impression sample.
- Measurement F: The sixth measurement was made 2mm occlusally of the restoration's distal margin on the distal axial of the rubber impression sample.
- Measurement G: The seventh measurement was made on the most external point of the margin on the distal site (right hand side) of the rubber impression sample.

STATISTICAL ANALYSIS

Data analysis included descriptive and analytical statistics using the Statistical Package for Social Science (SPSS Inc. version 13.0.1). All data in the present study were quantitative; therefore, descriptive statistics included the presentation of measurement's mean and standard deviation.

Analysis of the data in the study involved two parts. The first part assessed the reliability of the measures used in this study. The method described by Bland and Altman[17] was used to demonstrate the precision of measurements taken.

Non- parametric tests were selected, because the sample's size was small, thus the assumptions for parametric tests were not met. The Mann-Whitney test was chosen to compare the differences in the calculated distances of the samples produced by the three provisional materials under investigation. The level of statistical significance was set at 0.05.

RESULTS

The first part assessed the reliability of the measures used in this study using the method described by Bland and Altman.[17] Repeated measurements were taken from seven randomly selected samples of each group and their agreement with the original measurements taken in the study was tested. All measurements demonstrated very good agreement; the majority of them differentiate with the original measurements by less than 1 μm in most cases.

Descriptive statistics are presented at Table 3. Analytical statistics resulted in significant differences between the poly ethyl methacrylate and Bis-GMA acryl resin composite groups in almost all points of measurement. Results on the accuracy of fit indicate that Bis-GMA acryl resin composite produced better fitting provisional crowns compared with poly ethyl methacrylate types. Only at points E and F the differences were not of statistical significance (P > 0.05) although Bis-GMA acryl resin composite exhibited better fitting restorations than poly ethyl methacrylate. The results of this comparison are presented at *Table 4*.

Table 4. Statistical comparison between Group A and B using Mann-Whitney test

Point of measurement	Group	Mean Rank	P value
Measurement A	Group A	31.50	0.004
	Group B	19.50	
Measurement B	Group A	30.80	0.010
	Group B	20.20	
Measurement C	Group A	32.48	0.001
	Group B	18.52	
Measurement D	Group A	38.00	0.000
	Group B	13.00	
Measurement E	Group A	25.08	0.839
	Group B	25.92	
Measurement G	Group A	26.20	0.734
	Group B	24.80	
Measurement F	Group A	31.28	0.005
	Group B	19.72	

Overall, highly statistical significant differences were found between the poly ethyl methacrylate and the ITI Straumann temporary coping modified on tooth form with Bis-GMA acryl resin composite resin groups in all points of measurement. Results on the accuracy of fit indicate that poly ethyl methacrylate produced the best fitting provisional crowns over the ITI Straumann temporary coping modified to tooth form with Bis-GMA acryl resin composite. Detailed comparison of discrepancies produced by the two materials under investigation are presented at Table 5.

Table 5. Statistical comparison between Group A and C using Mann-Whitney test

Point of measurement	Group	Mean Rank	P value
Measurement A	Group A	13.00	0.000
	Group C	38.00	
Measurement B	Group A	15.24	0.000
	Group C	35.76	
Measurement C	Group A	15.48	0.000
	Group C	35.52	
Measurement D	Group A	15.40	0.000
	Group C	35.60	
Measurement E	Group A	14.68	0.000
	Group C	36.32	
Measurement G	Group A	14.72	0.000
	Group C	36.28	
Measurement F	Group A	13.00	0.000

DISCUSSION

In this *in vitro* investigation, provisional restorations were made by a direct method. The restorations were removed from the analogue at the onset of the initial polymerization, according to the material manufacturer's advice, and allowed to complete polymerization at room temperature. Removal of provisional restorations before significant curing can result in distortion especially in critical areas such as the restoration margins.[7] The removal technique in which restorations are left on the bench to complete polymerization also results in increased marginal discrepancies compared with other techniques that allow curing of the restorations on the prepared natural tooth or implant abutment[18] or the indirect fabrication of provisional restorations.[18,19] Relining techniques with or without venting of the restoration are proven to significantly improve marginal adaptation.[15, 18, 20]

All groups in this experiment exhibited better fit in the axial walls than at the restorations margins or under the occlusal surfaces *(Table 3*). This observation can be explained from the fact that polymerization shrinkage occurs away from the constricted surface towards the bulk of the material forcing the material to shrink away from the margin of the restoration. The increased space under the occlusal surface of the restoration for Groups 1 and 2 *(Table 3*) might be the result of incomplete seating of the material on the analogue due to the close fit of the axial walls.

For Group 3 the significantly increased space under the occlusal surface, 518.51 µm in one restoration, can be explained by the fact that the temporary coping is a hollow cylinder, 1.5 mm higher than the ITI Straumann Solid abutment and that space was not completely filled with the provisional material during its modification in tooth form. Even the use of low viscosity silicone impression material to record the space between the provisional crowns and the analogue used in this *in vitro* investigation might have caused incomplete seating of the crowns resulting in increased marginal discrepancies and increased space under the occlusal surfaces of the restorations. The use of cement lute in clinical practice can have the same effect on the restorations, thus the technique employed can result in a fit similar to that produced in clinical practice.[16]

McLean and von Fraunhofer[16] reported that the use of polyether rubber to mimic the cement lute can reproduce films as thin as 10 µm quite accurately. It was observed in our investigation that the use of modern polyvinylsiloxane impression materials could reproduce film thickness less than 10 µm. Films as thin as 5 µm were recorded on the axial walls of provisional restorations made from poly ethyl methacrylate and Bis-GMA acryl resin composite. As the ISO standard for acceptance as a cement lute is 25 µm, such a close adaptation of the provisional restorations to the axial walls of the analogue may cause incomplete sitting of the restorations during clinical practice.

Studies that have compared acrylic methacrylate based provisional materials with Bis-GMA acryl resin composite materials[5,6,8,10] report the superiority of Bis-GMA acryl resin composite in terms of marginal fit, however, the fit of the restoration on the axial walls and under the occlusal surfaces has not been evaluated.

A study which compared six different provisional materials including those used in our study reported similar findings in terms of marginal integrity.[10] The mean marginal discrepancies reported were 110 µm for poly ethyl methacrylate and 95 µm for Bis-GMA acryl resin composite. No information is given in that study whether the restorations were left to complete polymerization over the analogue or whether they were removed. Contrary to this study, no margination technique was performed in that study, which may explain the small differences with our study.

The materials used in our experiment were also compared in terms of marginal adaptation in another study which concluded that both materials result in mean marginal discrepancies of 60 µm.[21] In that study the restorations were only removed once from the analogue for a short period of time, and then they were reseated on the analogue and polymerization completed by immersing them in a water bath at 37°C. No reline or margination technique was performed.

Tjan et. al.[7] reported marginal discrepancies of 40.1 µm and 23.6µm for Bis-GMA acryl resin composite and polyethyl methacrylate respectively. The same group of investigators in

a more recent study reported an improved marginal fit for provisional crowns made from Bis-GMA composite resin using a similar methodology.[6] In that study Bis-GMA acryl resin composite provisional material resulted in 22 µm of marginal opening, and a visible light cured provisional material 29 µm. The explanation of why Bis GMA in the original experiment performed less well than in the second is not clear in the literature.

The difference in findings here and the aforementioned previous studies might be explained by the fact that the provisional restorations were placed in a water bath to complete polymerization at 37°C in an attempt to mimic body temperature. However, the mouth is often not subject to such high temperatures especially when open during treatment. Further, has been shown that curing of acrylic provisional materials in water baths significantly improves marginal fit of produced restorations.[22]

In our investigation the materials were left to complete polymerization at room temperature which was significantly lower than 37°C and resulted in increased polymerization time and probably increased polymerization shrinkage.[19] The clinically unrealistic use of a spring loaded device to secure the restorations over the analogue in some experiments[6, 7] and the direct measuring of the marginal opening in just one axis[6, 7] might have also influenced the results due to compression of the provisional restorations over the analogue.

The differences in marginal discrepancies can also be the result of increased polymerization shrinkage of provisional restorations in our investigation as they were stored on dry air for one hour prior to the application of McLean and von Fraunhofer[16] technique. Polymeric materials exhibit continuous polymerization even after one week storage in dry air resulting in increased marginal discrepancies.[23] The more clinically realistic method used in this experiment may mimic the clinical situation more accurately.

CONCLUSIONS

The superiority of Bis-GMA acryl resin composite both in terms of physical properties and, from this experiment, the improved accuracy of fit compared to acrylic resin materials indicates that it may be the material of choice for fabrication of provisional restorations for implant abutments. The third group of implant manufacturer produced temporary coping gave the worst marginal fit and cannot be depended on alone to provide acceptable margins.

MANUFACTURERS DETAILS

- ITI Straumann implant fixture 12mm length [code number 033.253S] Crawley, W. Sussex, UK
- ITI Straumann solid abutment 7mm high [code number 048.927] Crawley, W. Sussex, UK
- ITI Straumann Implant abutment temporary coping [code number 048.655] Crawley, W. Sussex, UK
- Trim II; Poly (ethyl) methacrylate temporary material H.J. Bosworth, Skokie, Illinois USA
- ProtempTM 3 GarantTM Bis-GMA Temporary material 3M ESPE UK
- Protemp TM Add On; flowable composite 3M ESPE UK
- ExtrudeTM XP polyvinylsiloxane impression materials; Kerr UK
- Aquasil XLV Ultra; low viscosity impression material Dentsply UK
- Soflex Polishing Discs; 3M ESPE UK
- Optibond Solo plus dentine bonding agent; KERR UK
- Light cured composite tray material; Brackon Ltd UK
- 3M ESPE Elipar S10 LED light cure unit; ESPE UK

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