In vitro comparison of the compressive strengths of seven different provisional crown materials

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ABSTRACT

Provisional crowns may be used for many weeks during healing of soft tissues, while other dental procedures are being performed and whilst the permanent restorations are being fabricated. The provisional occlusion they present serves a diagnostic purpose for fine tuning biological and biomechanical requirements. They need to be strong enough to withstand masticatory forces during this time, as it is costly, inconvenient and time consuming to repair breakages. There is no ideal provisional crown material, and new products appear on the market regularly. Dentists need to know which perform best in terms of strength, durability, ease of use, aesthetics and cost to facilitate selection and purchase. This study was undertaken to compare the compressive strengths of seven different provisional crown materials, consisting of three acrylic resins, three composites and one CAD/CAM fabricated sample set. A custom-made stainless steel split mould was constructed having a circular opening of 4mm in diameter and 6mm in-depth and was used to prepare ten specimens for each material. For the composites, the various materials were syringed into the circular openings and compacted using a ball burnisher. After five minutes, specimens were removed. The heat cured acrylic resin specimens were further processed in a pressure pot for five minutes. All samples were stored in distilled water at 37^{0}C for 24 hours before being tested. Test specimens were mounted into a jig on the Instron machine and loaded under a compressive force until they fractured or the compression limit was reached. The forces applied were recorded and used for statistical analysis. The results may help clinicians to select the most appropriate material for each clinical situation.

INTRODUCTION

In fixed prosthodontics, provisional crowns and bridges are placed after tooth preparation and used until the final fitting and luting of the fixed restorations. This time-frame may vary from a few days, required for single crowns, to many months such as following periodontal therapy, when assessing the results of endodontic treatment, during the restorative stages of implant procedures, or when used as diagnostic aids. During this time, the interim restoration(s) need to fulfil many functions and meet certain minimum requirements. They must be biologically compatible with the tooth and oral environment, must protect the pulp from microleakage, provide thermal protection, prevent sensitivity, be contoured to maintain periodontal health and help prevent tooth or core fracture. Mechanically they must be able to resist functional loads without excessive wear, avoid attrition of the opposing dentition, maintain stable inter-arch relationships and positional tooth stability, provide occlusal function and appropriate tooth guidance, resist removal forces, and also be relatively easy to manufacture and adapt at the chair side. Aesthetically they should mimic the prepared tooth or the final restoration as closely as possible.[1] In addition, their resistance to functional load and masticatory forces is an important mechanical requirement.[2] Breakages can result in patient discomfort, functional complications, may allow unwanted tooth movement, and may be an aesthetic concern, requiring time-consuming and costly repairs.[2] There is no one ideal material and hence new products are constantly coming onto the market. Dentists are faced with an increasing variety of materials to choose from and need to know which has the best combination of handling properties, aesthetics, cost, shelf life and mechanical strength.

There are currently two main groups of provisional materials in common use. The methacrylate resins, which come in powder: liquid form and are hand mixed, and the composite resins, which are usually paste: paste and auto-mixed.[3] More recently CAD/CAM manufactured provisional crowns have also come onto the market. These consist of a fibre-free, homogeneous, high molecular weight cross-linked acrylate polymer with microfillers.

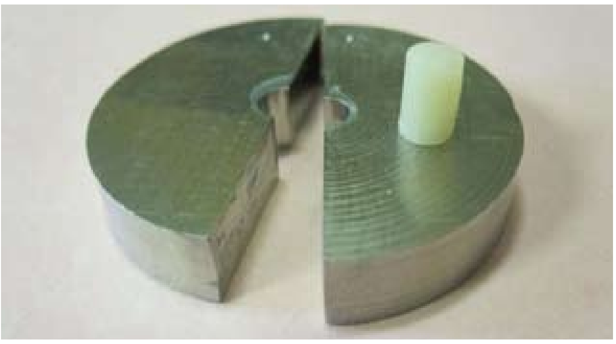

Figure 1: Custom-made stainless steel split mould.

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Table 1: Composition of test materials.

Material	Composition	Manufacturer
Enamel Plus	Acrylic resin, monomer (bench cured)	Micerium S.p.A
Enamel Plus	Acrylic resin, monomer (heat cured)	Micerium S.p.A
Snap	Acrylic resin, monomer	Parkell Inc.
Integrity	Bis-acryl composite, barium glass, fumed silica, methacrylate monomers, catalyst, stabilisers	Dentsply, Caulk
Cool Temp	Methacrylate, silanised barium glass, hydrophobed amorphous silica	Coltēne, Whaledent
Pro Temp	Dimethacrylate, strontium glass powder, silicic acid initiators, diacrylate, stabilisers, synthetic resins pigments	3M ESPE
CAD/CAM	MMA free composite, acrylate polymer	Vita Telio Cad, Ivoclar

The setting reaction of the resins affects mechanical strength, which determines their integrity during their time of use.[3] Normal masticatory forces are estimated to be in the range of 300-500 N, which places demands on the biomechanical properties of the material used, especially affecting fracture toughness and compressive strength.[4] Fracture toughness refers to the ability of the material to resist crack propagation. These cracks usually start out as microscopic defects on the surface of the material, and may only become evident after being subject to masticatory loads.[4] Compressive strength refers to the maximum stress that a material can sustain under crush loading.[5] These measures, together with surface hardness, may be used as indicators of material density, a denser material being presumed to be more resistant to masticatory forces and surface wear.[6]

AIM

The aim of this study was to compare the compressive strengths of seven different provisional restorative materials in order to determine which should perform best in withstanding masticatory forces.

MATERIALS AND METHOD

Seven different commercially available provisional crown materials were tested consisting of three acrylic resins -Enamel Plus bench cured, Enamel Plus heat cured, (Micerium S.p.A), and Snap (Parkell Inc.), three composite resins,- Integrity (Dentsply), Pro-Temp (Coltene Whaledent), and Cool Temp (3M ESPE), and one CAD/CAM (Vita) sample set (Table 1). All the acrylic resins were supplied in powder: liquid form and were manually mixed, the composites were all in paste: paste form and were auto mixed, and the CAD/CAM samples were machined.

A custom-made stainless steel split mould was fabricated having a circular opening of 4mm in diameter and a depth of 6mm (Figure 1). The mould was clamped shut in a housing jig and placed on top of a Mylar strip on a flat work surface. For the composites, the material was syringed into the circular opening and compacted using a ball burnisher. The opening was overfilled and another Mylar strip was placed on top of the composite and pressed flat, using a glass slab, to squeeze out any excess material. The composite was allowed to cure for five minutes according to the manufacturer's specifications. The material flash was trimmed with a sharp scalpel, the mould was then opened, and the sample was allowed to bench cure for a further one minute before being removed. The acrylic resin was similarly packed and bench cured at room temperature for five minutes before opening the mould. The Enamel Plus heat cured sample was then further processed for ten minutes at two bars and at a water temperature of 60°C.

In this way, ten specimens were prepared for each resin material. All samples were stored in sterile water while the remaining test specimens were being prepared.

An Instron machine (Figure 2) was used to measure the compressive strength of each specimen. Test samples were mounted into the Bencor Multi-T device (Figure 3) and a compressive force was applied at a crosshead speed of 1mm/min. Sensitivity of the machine was set at 10%, so the machine could detect specimen failure if the load dropped by 10% within a 100ms time period. This decrease was measured as sensitivity as a percentage of the load at the beginning of the 100ms period. The test was ended if specimen failure was detected at a sensitivity of 10% or if the crosshead moved a distance of 5mm, without detecting any specimen failure.

Compressive strength refers to the maximum stress a material can sustain before shattering fracture under a compressive load and can be defined within narrow limits as an independent property. However, the compressive strength of materials that do not shatter in compression must be defined as the amount of stress required to distort the material an arbitrary amount. Compressive strength is calculated by dividing the maximum load, expressed in Newtons, by the original cross-sectional area, expressed in mm^2, of a specimen in a compression test ($N/\pi r^2$).

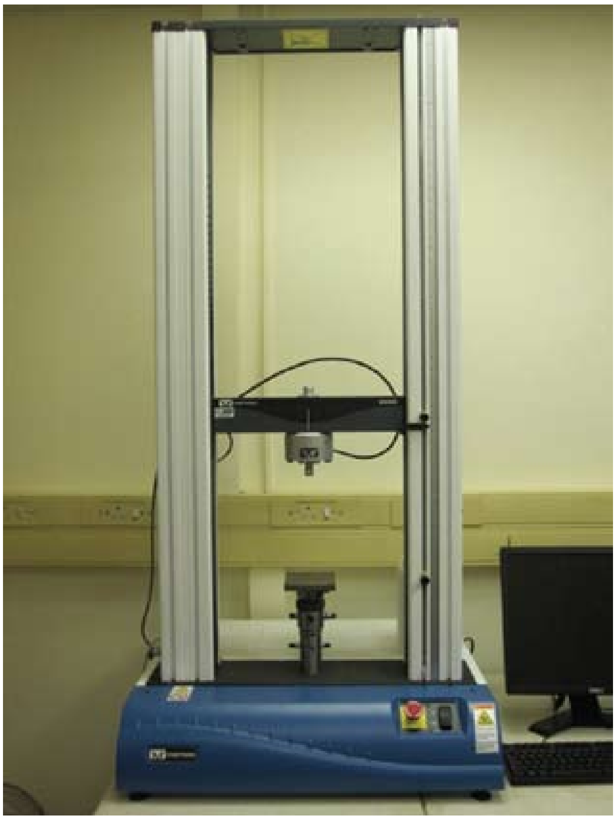

Figure 2: Instron testing machine.

Figure 3: Bencor Multi-T device.

Table 2: Mean maximum load.

Material	n	Mean Max. Compressive Load (kN)	Std Deviation
CAD/CAM	10	4.69	0.4
Enamel Plus	5	4.45*	1.06*
Enamel Plus (heat)	8	4.48**	0.57**
Snap	10	n/a	n/a
Pro Temp	10	4.82	0.7
Integrity	10	3.43	0.27
Cool Temp	11	2.36	0.58

* The mean and standard deviation values were calculated using only the five specimens that fractured.
**The mean standard deviation values were calculated using only the eight specimens that fractured.

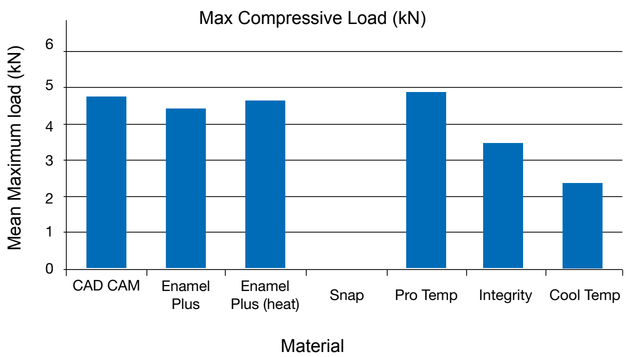

Figure 4: Graphic representation of Mean Maximum Load

RESULTS

The composite Pro Temp performed the best in terms of compressive strength (383.64 mPA), closely followed by the CAD/CAM samples (373.44 mPA). However, both recorded a 100 % fracture rate (Table 3, Figure 5). There was a wide variation in compressive strengths between the three different composites and the three acrylic resins. None of the Snap samples fractured, and only one of the acrylic resins (Enamel Plus bench cured) had fractures (25%); however, all of the composites had fractured specimens ranging from 30 – 100% (Table 4).

Table 3: Mean maximum compressive strengths.

Material	n	Mean Max. Compressive Strength (MPa)	Std Deviation
CAD/CAM	10	373.44	32.14
Enamel Plus	5	354.19*	84.48
Enamel Plus (heat)	8	356.63**	45.27
Snap	10	n/a	n/a
Pro Temp	10	383.64	55.58
Integrity	10	272.60	21.19
Cool Temp	11	187.64	45.76

* The mean and standard deviation values were calculated using only the five specimens that fractured.
**The mean standard deviation values were calculated using only the eight specimens that fractured.

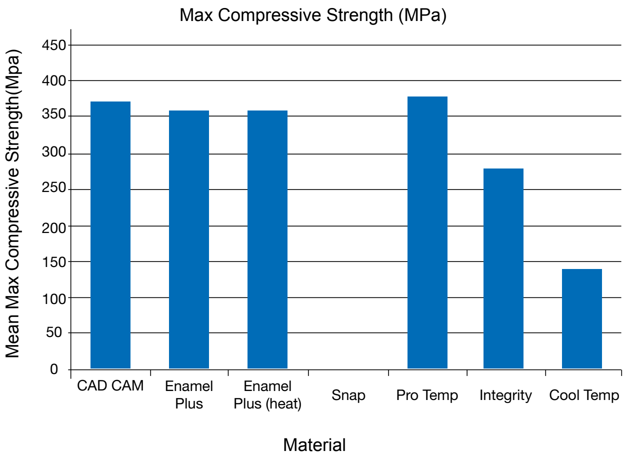

Figure 5: Graphic representation of Mean Maximum Compressive Strengths (MPa).

DISCUSSION

In the past, a variety of provisional materials have been used, having different desirable and undesirable properties. In comparison with other materials, Polymethylmethacrylate (PMMA) has been shown to be the strongest of the methacrylate resins and to have good aesthetics, but it undergoes polymerisation contraction via an exothermic reaction, which could cause pulpal damage.[6] The polyyethylmethacrylates have less polymerisation shrinkage and fewer exothermic reactions, but strength, wear resistance and colour stability have been found to be poorer.[6] The bis-acrylic composites in turn are less exothermic with less shrinkage and thus will cause less adverse pulpal damage. They are easy to add onto, but are brittle in thin sections.[6] Other advantages include a good range of colours, good marginal fit, minimal odour and taste, quick setting, easy trimming and a cartridge delivery system, which makes mixing easier and more consistent.

The specimens tested in this research were fabricated under strictly controlled laboratory conditions and all were made to standard dimensions. For this reason, the results may not be fully representative of clinical conditions where thinner and less uniform shapes are encountered. Based on this research Pro Temp and the CAD/CAM specimens had the

Table 4: Percentage of fractures at maximum load.

Material	n	Unfractured at Max Load	Fractured at Max Load	% Fracture
CAD/CAM	10	0	10	100
Enamel Plus	12	7	5	42
Enamel Plus (heat)	12	4	8	67
Snap	10	10	0	0
Pro Temp	10	0	10	100
Integrity	10	0	10	100
Cool Temp	11	3	8	73

highest compressive strength. These findings are in agreement with Alt *et al*., who also found that composite based materials (Pro-Temp) performed better in terms of mechanical strength than did PMMA based materials.[7]

They speculated that the syringed materials may perform better as spatula mixing may incorporate voids which could compromise the mechanical strength.[8] However, all of the Pro Temp and Integrity samples fractured under load as did 73 % of the Cool Temp specimens. This was in contrast to the acrylic resins where none of the Snap samples fractured, while only 42% of the Enamel Plus and 67% of Enamel Plus heat cured fractured. It may be postulated that the resins absorbed water during storage, making them softer and less prone to fracture under load compared with the composites which are known to be brittle. Indeed, some authors have stated that water storage of resins at 37ºC may lower their strength. This may be due to the water uptake acting as a plasticiser.[9,10] The extra heat curing of the Enamel Plus is not justified as it did not increase the strength of the material, and actually made it more prone to fracture (Table 4). It may be presumed that most provisional restorations are made and placed in the patient's mouths at the same appointment. If that is so, they will never be subject to extended periods of dryness and thus dryness was not considered a clinically relevant variable. All of the tested specimens were stored in sterile water from the time of fabrication until testing (this was always less than one week). Previous research tested four polymer-based temporary crown materials and found that all of them showed an increase in diametral tensile strength after one hour.[9] This could be an important clinical feature and future studies should be carried out comparing a wider range of temporary crown materials to establish whether this effect is common to all. If so, clinicians may be advised to fabricate their provisional crowns as soon as they have completed the tooth preparations and to allow them to bench cure for an additional time before cementation. One would also need to establish whether they should be immersed in water or left dry during this final setting.

The Enamel Plus which was bench cured had a surprisingly higher compressive strength than the heat cured Enamel Plus, and a lower fracture rate. The authors postulate that the added fractures in the heat cured specimens could have been due to stress fractures created by the release of residual monomer during the heating cycle. The CAD/CAM specimens were consistently strong, but all fractured under load. This high fracture rate, along with the extra clinical and laboratory time and expense needed to manufacture them, could count against their use for routine crown and bridge work. In special circumstances, where high strength and durability is needed they may be of value. If used in anterior regions, their opacity and aesthetics can be improved by the addition of light-cured composite veneers.

Preliminary recommendations based on this research would suggest that the CAD/CAM and the newer composites (Pro Temp) perform the best in terms of compressive strength. However both the CAD/CAM and all of the composites tested fractured under load. If the clinician is looking for weaker, but more fracture resistant provisional restorations then the conventional acrylic resins such as Snap and bench cured Enamel Plus would be a better choice. A word of caution is that this research was performed on standard samples which were all 6mm thick. Many provisional restorations are much thinner (1-2mm thick) and thus compressive strengths and fracture rates may differ clinically.

CONCLUSIONS

This study showed that Pro Temp, the newest generation composite, had the highest compressive strength, which is an improvement on the older composites. However, all of the composites still exhibited a high (100%) fracture rate. Considering its ease of clinical manipulation and excellent aesthetics, this material may still be considered for use in single and multiple unit provisional restorations where occlusal forces are not excessive. The CAD/CAM had the second highest compressive strength, but also exhibited high fracture rates. In addition, its high cost, the need for specialised equipment and increased time, may limit the practicality of daily usage. The methylmethacrylate based acrylic resins had much lower compressive strengths, but also were less prone to fracture under load. Even though Snap was the weakest material, none of these samples fractured. This fracture resistance makes the acrylic resins suitable for regular use, however, they are more difficult to manipulate clinically and less aesthetic than the composites. This study suggests that due to their brittleness, all composites and CAD/CAM provisional restorations should be used with caution in areas of heavy occlusal load or long span bridges.

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