WATER ABSORPTION AND SOLUBILITY OF PROVISIONAL CROWN AND BRIDGE: THE EFFECT OF THE INCLUSION OF POLYETHYLENE FIBERS

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ABSTRACT

Objective: This study was designed to investigate the effect of the inclusion of chopped lengths of ultra-high-modulus polyethylene fibers on the water absorption and solubility of two commercially available provisional crown and bridge materials, Protemp (Bis acrylic composite) and Trim (Polyvinylethylmethacrylate).

Methods: Twenty specimens were made of each material, 10 without any fiber loading served as a control, and 10 with 4% by weight fiber loading were used. The water absorption was measured after 7-day storage in de-ionized water at 37±1 °C.

Results: In the water absorption test, Trim exhibited significantly more water absorption than Protemp. The inclusion of fibers increased the water absorption of Protemp but had no effect on Trim. However, it decreased the water solubility of Trim.

Conclusion: Incorporation of ultra-high-modulus polyethylene fibers produced a statistically significant increase in the water absorption of Protemp and a statistically significant decrease in the water solubility of Trim. Water absorption of Trim was unaffected by the inclusion of fibers.

Key words: Provisional crown and bridge restorations, Polyethylene fibers, Absorption and solubility.

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Introduction

There is no question that patients today demand a sophisticated level of restorative dentistry, in terms of both esthetics and function. No elective restorative dentistry should be undertaken without a clear understanding of the patient's expectations and the limitations of the restorative therapy. The dentist should have a clear picture in mind of the final results before initiating irreversible therapy. The use of mounted diagnostic wax-ups and provisional restorations permits patient acceptance to be obtained before the definitive phase is initiated. Too often the dentist does not take advantage of this important restorative option, with disastrous results when definitive restorations are viewed by the patient for the first time[1].

Provisional crown and bridge restorations are used for the protection of full or partial coverage preparations that are to receive definite fixed restorations. In addition, they are used to establish a harmonious plan of occlusion, both inter-arch and intra-arch, as well as for the establishment of aesthetic guidelines for the definitive fixed restoration. Therefore, the clinician should envision the provisional restoration as a template for the definitive restoration[2].

The choice of material to be used depends on complexity of the work, the load being applied, the period for which the temporaries are to be worn and the length of span.

Provisional crown and bridge restorative materials have several limitations, including lack of inherent strength, poor marginal adaptation, and poor dimensional stability. Water absorption and solubility can dramatically affect the dimensional stability.

A number of different materials have been used to reinforce and improve the properties of provisional

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restorations. These include: stainless steel wires, Kevlar polybromide fibers, stainless steel orthodontic bands, and carbon fibers[3,4], with a varying degree of success. The use of a metal casting[4] improves the strength of provisional restorations. However, this process increases the cost and complexity of provisional restoration fabrication.

In dentistry fiber reinforcement can be used for a wide range of clinical applications, including periodontal splints, bridges, long-term temporaries, denture repairs and framework for composite onlays and crowns. The physical properties of fiber-reinforced materials are dependent on the type of matrix, type of fiber, fiber distribution, fiber matrix ratio, diameter and length of the fibre[5].

Earlier work by Capaccio and Ward[6] has shown that polyethylene, a crystal polymer, may be drawn at temperatures below its melting point to produce a material of enhanced modulus and strength in the axial direction. This recently developed material offers an array of properties of particular interest to dentistry, including high stiffness and strength, proven biocompatibility, white translucent appearance, and negligible water absorption[7]. Ultra-high-modulus polyethylene fibers (UHMPE) in the chopped form (short lengths) have received the attention of several investigators because of their potentially simple incorporation technique into the resin and their adaptability to conventional denture construction[8].

Aims

The purpose of this study was to investigate the effect of the incorporation of chopped lengths (3-6mm) of UHMPF on the water absorption and solubility of two commonly used cold cure provisional crown and bridge materials, Protemp (Bisacrylic composite) ESPE Germany and Trim (Polvinylethylmethacrylate) Harry Bosworth.Co.Illinois USA.

Methods

Where possible the methods followed the British standard 7651 (1993), which is identical to the ISO 10477 (1992) specification for dental polymer based crown and bridge materials. All the test specimens were prepared and tested at 23±1°C. The relative humidity was not less than 30%.

Water absorption and solubility were tested in this study. The fibers were incorporated in the resin by weighing the unmixed specimen in an analytical balance to an accuracy of ± 0.1mg and calculating the weight of the required fiber for a given percentage loading. For Trim, fibers were added to the powder component whereas for Protemp they were added to both the base and accelerator paste. Each material was mixed according to the manufacturer's instructions. All the test specimens were prepared and tested at 23±1°C. The relative humidity was not less than 30%.

A total of 40 specimens were prepared consisting of 10 Protemp controls (without fiber loading) and 10 test specimens with 4% by weight fiber loading. Similarly, there were 10 Trim controls and 10 test specimens with a 4% by weight fiber loading. Each specimen was mixed according to the manufacturer's instructions and placed into a cylindrical copper ring (Fig. 1). This was covered by polyester film and a glass slab, at both ends, with a weight of 10 Newton over the glass slab until setting was complete. After setting the specimen was removed from the ring, wet ground and polished to a high gloss using Metalographic abrasive paper P600 (BUEHLER-MET) to a thickness of 1.0 ± 0.2 mm. The surface area was calculated by measuring the diameter and the mean of five thickness measurements, one at the center and four points at the periphery. Each specimen was placed in a dessicator containing silica gel at 23±1°C for 24±1 hours. After removal from the dessicator each specimen was weighed to an accuracy of ± 0.2 mg (M1) more than once until the loss of mass remained less than 0.2 mg within 24 hours. The specimens were then stored in a container containing 20 ml deionized water in the incubator at 37±1°C for 7 days. Each specimen was then removed, washed with water, and dried with a thin tissue paper until it was free from visible moisture. It was then waved in the air for 15 seconds and weighed (M2). The specimens were then placed in the dessicator for seven days and weighed several times until the loss of mass was less than 0.2 mg within 7 days (M3).

The water absorption and solubility for each specimen were calculated according to following formulae:

$$\text{Water Absorption} = \frac{M2 - M3}{S}$$

$$\text{Water Solubility} = \frac{M1 - M3}{S}$$

Where

M1 = Original dry mass
M2 = Wet mass
M3 = Final dry mass
S = Area of disc (mm^2)

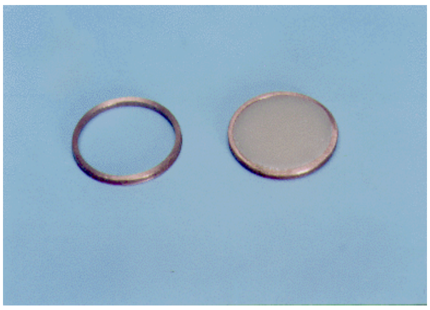

Fig. 1. The cylindrical ring used in the absorption and solubility measurement.

Results

All the results were statistically analyzed using the one-way analysis of variance (ANOVA) and the post hoc Tukey test by Minitab statistical software installed on a computer. The results are presented in Fig. 2, Table I and Table II.

Water absorption: The inclusion of fibers resulted in an increase in the water absorption of Protemp, which was statistically significant ($P<0.05$). There was no statistically significant difference resulting from the inclusion of fibers on the water absorption of Trim and Trim exhibited more water absorption than Protemp in both control specimens (no fiber addition), which was statistically significant ($P<0.05$).

In the water solubility test the Inclusion of fibers resulted in a decrease in the water solubility of Protemp although it was not statistically significant ($P>0.05$) and a decrease in the water solubility of Trim, which was statistically significant ($P<0.05$). In the control specimens Trim exhibited more water solubility than Protemp although it was not statistically significant ($P>0.05$).

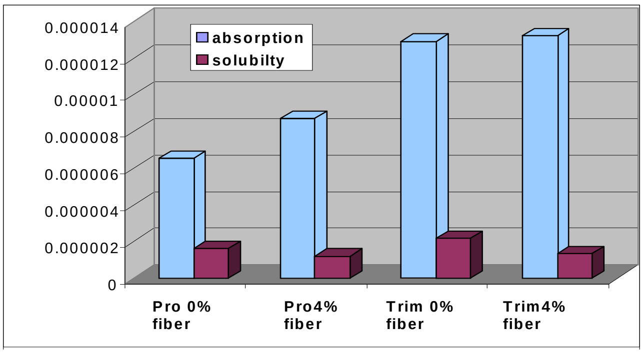

Fig. 2. Water absorption and solubility in relation to surface area (mg/mm^2)

Discussion

Water sorption and solubility of provisional restorations are properties that are often overlooked in the evaluation of these materials. Water absorbed into a material acts as a plasticizer. Water sorption and solubility can dramatically affect the dimensional stability and are associated with swelling, distortion, absorption of odors, support of bacteria and color changes. To our knowledge this is the first study, which examines the water sorption and solubility of Trim and Protemp and the effect of the inclusion of fibers on these parameters.

The results of this study indicate that Trim exhibited more water absorption and solubility than Protemp and is less likely to be dimensionally stable. This could affect other properties including color stability. Other investigators have concluded that trim is less color stable than Protemp[(9)] and this may be due in part to the presence of residual monomer and the presence of water.

The behavior of Protemp can be related to composite resin restorative materials. It has been shown that the uptake of water by composite resins seems to be a diffusion-controlled process[(10)]. Absorbed water may react with the resin filler interface-causing breakdown of the interface and it is accompanied by a hygroscopic expansion, which may be able to compensate for the effects of polymerization shrinkage and relieve the stress[(11)].

Inclusion of the fibers increased the water absorption and reduced the water solubility of both Trim and Protemp. In Protemp this may be explained by the poor adhesion between the fiber and the matrix. Water could access the interface between fiber and matrix thus increasing absorption. The Trim specimens were not pressure packed or heat cured, nor were they crossed linked to a significant degree. As a result, they may have had an increase in the number of micro porosities, monomer retention, and a large polarity that would enhance the rate of water absorption. On the other hand, the fibers are insoluble in water and this might lead to a decrease in the water solubility of both Trim and Protemp. Chow *et al.*[(12)] showed that the incorporation of UHMPE fibers into an acrylic denture base resin is associated with a very significant decrease in water sorption and an even more pronounced decrease in the accompanying dimensional changes. It was explained that the fibers are hydrophobic and replace the hydrophilic resin, resulting in the decrease in water uptake. Also, they suggested that the fibre-resin interface does not allow ingress of water. The difference between their findings and those of this study may be related to the greater degree of cure in the heat processed acrylic denture base resins.

Conclusions

The following conclusions can be drawn from this study:

1. Trim exhibited more water absorption and solubility than Protemp, which will tend to make it less dimensionally stable clinically.
2. Incorporation of UHMPE fibers produced a statistically significant increase in the water absorption of Protemp and a statistically significant decrease in the water solubility of Trim. Water absorption of Trim was unaffected by the fibers.
3. In this study the UHMPE fibers were incorporated by hand mixing which unfortunately resulted in the inclusion of air bubbles and there was poor adhesion between the fiber and material's matrix.
4. Further work is clearly needed to investigate the effects of surface treatment of fibers, the

incorporation of fibers during manufacturing and heat curing in improving the adhesion of the fibers to provisional crown and bridge materials.

Table I. Water absorption of Protemp and Trim in relation to the surface area (mg/mm^2)

	Protemp 0% fiber inclusion	**Protemp 4% fiber inclusion**	**Trim 0% fibre inclusion**	**Trim 4% fiber inclusion**
1	7.46E-06	7.85E-06	1.34E-05	1.27E-05
2	6.21E-06	7.18E-05	1.44E-05	1.22E-05
3	5.31E-06	9.47E-06	1.22E-05	1.48E-05
4	6.82E-06	8.60E-06	1.28E-05	1.27E-05
5	7.07E-06	8.01E-06	1.35E-05	1.76E-05
6	6.58E-06	8.43E-06	1.37E-05	1.19E-05
7	6.94E-06	8.23E-06	1.26E-05	1.23E-05
8	6.41E-06	9.25E-06	1.25E-05	1.19E-05
9	5.86E-06	7.19E-06	1.25E-05	1.23E-05
10	6.58E-06	8.35E-06	1.16E-05	1.37E-05
Mean	6.53E-06	8.72E-06	1.29E-05	1.32E-05
Standard deviation	6.20E-07	1.26E-06	8.07E-07	1.78E-06

Table II. Water solubility of Protemp and Trim in relation to the surface area (mg/mm^2)

	Protemp 0% fiber inclusion	**Protemp 4% fiber inclusion**	**Trim 0% fiber inclusion**	**Trim 4% fiber inclusion**
1	1.79E-06	6.04E-07	2.68E-06	1.82E-06
2	1.18E-06	3.24E-06	2.94E-06	1.49E-06
3	8.86E-07	9.16E-07	2.09E-06	2.97E-06
4	1.48E-06	1.19E-06	1.79E-06	1.80E-06
5	2.06E-06	8.90E-07	1.80E-06	1.17E-06
6	1.49E-06	9.36E-07	2.08E-06	5.94E-07
7	1.51E-06	9.15E-07	1.79E-06	1.50E-06
8	2.04E-06	1.19E-06	2.87E-05	1.83E-06
9	1.46E-06	8.99E-07	2.08E-06	1.76E-06
10	2.09E-06	1.19E-06	1.19E-06	2.44E-06
Mean	1.60E-06	1.20E-06	2.71E-06	1.74E-06
Standard deviation	3.97E-07	7.41E-07	6.22E-07	6.47E-07

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