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A novel approach to reinforce provisional material using silica gel powder

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ABSTRACT

Aim: To evaluate a novel approach for reinforcing 2 types of provisional restoration materials [polymethylmethacrylate (PMMA) and bis-acryl resin] with different concentrations of silica gel powder (0%, 0.5%, 1%, 1.5%, 3%, 5%, 10% by weight). **Methods:** A total of 60 rectangular fracture toughness specimens were prepared in this study according to the ISO 13586 Standard with dimensions of 2 mm × 5 mm × 25 mm. The specimens were divided into 2 groups according to the materials used PMMA or bis-acryl. Each subgroup was divided into 6 subgroups according to the different silica gel concentrations (0%, 0.5%, 1.5%, 3%, 5%, and 10% by weight) added where the 0% subgroup was used as a control group. Fracture toughness for the specimens was determined by loading the specimens in a universal testing machine. **Results:** The results showed that addition of 0.5% by weight of the silica gel powder for PMMA recorded the highest mean value (2.69 ± 0.08 $MPa•m^{1/2}$) and this was statistically significant. **Conclusion:** Within the limitation of this study it was concluded the addition of 0.5% by weight silica powder gel could increase the fracture toughness of PMMA.

INTRODUCTION

Provisional restorations are used routinely in the dental office to restore prepared teeth until the final restoration are ready. These restorations must be biologically compatible to restore function, esthetics, and have high mechanical properties to withstand various forces in the oral cavity.[1-4] Many available materials can be

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used by clinicians for this purpose. In 1937, heat cured resin was introduced to fabricate such restorations.[5] Since 1937, there have been significant modifications and improvements.[6] Bis-acryl was introduced in the 1980s, and further developments are being introduced every day.[7] These restorations should have adequate strength, color stability, are easily fabricated, and have no damaging effect on the pulp and surrounding tissue. Polymethylmethacrylate (PMMA) and bis-acryl are the most commonly used materials for that purpose.[6-8]

Although provisional restorations are utilized for a short period of time, some situations require long term provisional restorations. These cases are complete mouth rehabilitation, restoration of the vertical dimension of occlusion, and in patients who have para-functional habits. Long-term provisional restorations require materials with enhanced mechanical properties.[9-11] Several attempts have been made to reinforce provisional restoration materials. These included the use of metal wire,[12-14] fibers including plasma treated polyethylene fibers, carbon fibers, and glass fibers.[15-19] Recent studies investigated the addition of polyoctahedral silsesquioxane to the polymer.[20] In general, additives used to reinforce provisional restoration should increase the strength of the material without affecting the color.

Silica gel is a form of silicon dioxide made synthetically from sodium silicate. It has a thin, porous, and granular structure. Silica gel is a tough and hard material with an average pore size of 2.4 nanometers. The crushing of silica gel produces a powder used as a catalyst in different chemical processes.[21]

The structure of silica gel [Figure 1] is characterized by the presence of individual functional moieties, such as siloxane (≡Si–O–Si≡) with the oxygen located on the surface as well as silanol groups (≡Si–OH).[22-24]

To a limited extent, silica gel is used as a reinforcing filler in silicone rubber; however, there is very little information available on the reinforcement properties of silica gels.[25] Balos *et al*.[26] in 2014 conducted a study reinforcing PMMA by adding small concentrations of nano silica (0.023%, 0.046%, 0.091%, 0.23%, 0.46%, and 0.91%) with the PMMA to improve the mechanical properties. The results of the fracture toughness and micro hardness tests showed that the 0.023% concentration (the lowest concentration) of the nano silica exhibited the highest mechanical properties. The higher concentrations of nano silica demonstrated that the fracture toughness gradually diminished.

Material toughness is the ability to resist crack propagation. The tougher the material, the shorter the crack will propagate within it. The measurement of fracture toughness requires knowledge of the pre-existing crack and the specimen's geometry. Within the material, arresting of crack propagation is a common method to reinforce a material.[27]

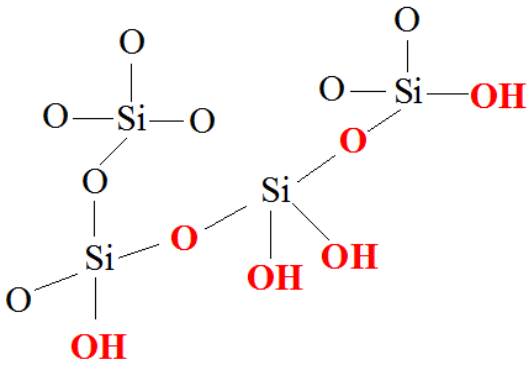

Figure 1: Structure of silica gel

The purpose of this study was to evaluate a novel approach for reinforcing two types of provisional restoration materials (PMMA and bis-acryl resin) by adding different concentrations of silica gel powder (0%, 0.5%, 1%, 1.5%, 3%, 5%, and 10% by weight) to the polymer. The hypothesis of this study is that the addition of a silica gel powder at different concentrations will increase the fracture toughness of the provisional restoration material.

METHODS

This study evaluated the fracture toughness of 2 types of provisional restoration materials (PMMA and bis-acryl resin) after the addition of different concentrations of silica gel powder (0.5%, 1.5%, 3%, 5%, and 10% by weight).

A total of 60 rectangular fracture toughness specimens were prepared in this study. These specimens were divided into 2 groups according to the material used (PMMA or bis-acryl). Each subgroup was divided into 6 subgroups according to the silica gel concentration (0%, 0.5%, 1.5%, 3%, 5%, and 10% by weight). The 0% silica gel concentration was used as the control group.

The dimension of each specimen was 2 mm × 5 mm × 25 mm according to the ISO 13586 Standard.[27] Specimens were fabricated using a stainless steel split-mold which was specifically constructed for this study. PMMA specimens fabrication was as follows: 0.5 g of powder polymer was added to 0.25 mL of the liquid monomer and mixed with a clean stainless steel

spatula; when the mixture reached the dough stage, it was packed slowly into the split-mold to avoid trapping of air; a glass slab was then seated over the mold to pack the mix and to help remove the excess material; the specimens were allowed to polymerize for 15 min at room temperature. After the specimen was removed, a razor was used to remove all of the flash material.

The bis-acryl specimens were prepared in a similar manner as the PMMA specimens. The single difference was that the bis-aryl was mixed using an auto-mix gun supplied by the manufacturer. Reinforced specimens were formed in a similar manner by adding the tested concentrations (0.5%, 1%, 1.5%, 3%, 5%, and 10% by weight) of the silica powder gel.

The specimens were examined for voids, and any defective specimens were discarded. The specimens were finished to the desired dimensions with 400 grit and 600 grit abrasive paper. The specimen's dimensions were then verified with a digitalized caliper (CD-60 CS, Mitutoyo, Japan). The specimens were then stored in deionized water at 37 °C for 24 h.

A pre-crack was placed in each test specimen by placing a sharp scalpel at the middle of each specimen and applying hand pressure using a measuring microscope (Nikon Measure scope MM-11, Nikon Corp).[15] The crack length value was recorded.

The specimens were loaded in a Lloyd Universal Testing Machine until fracture to determine the fracture toughness of the material. Each specimen was positioned on the bending fixture, consisting of 2 parallel 2-mm-diameter supports, 20 mm apart. The load was applied at a crosshead speed of 1 mm/min, with a third 2 mm rod placed centrally between the supports [Figure 2]. The peak "force to fracture" in Newtons was derived from the stress-strain curve and recorded. This force was used to calculate the fracture toughness (K_{1c}) in MPa•$m^{1/2}$.

The following equation was used to determine K_{1c}:[28]

$K_{1c} = (p_c/bw^{1/2})*F(a/w)$;
$F(a/w) = [(2 + a/w)*(0.886 + 4.64*a/w - 13.32*a^2/w^2 + 14.72*a^3/w^3 - 5.6*a^4/w^4)]/(1 - a/w)^{1/2}$;
p_c is the maximum load before the crack advance in kilonewtons (KN); b is the average specimen thickness in centimeters (cm); w is the width of the specimen in centimeters (cm); a is the crack length.

The fracture toughness data of each type of provisional material was tabulated and analyzed with a 2-way analysis of variance, followed by the Tukey standardized range test (α = 0.05) to determine statistical significance.

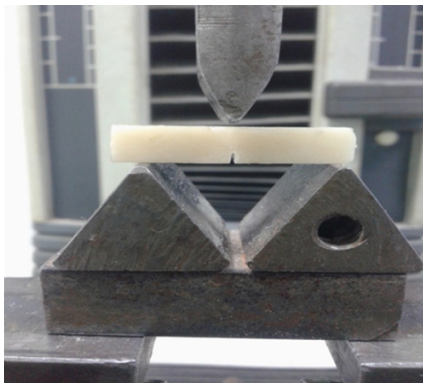

Figure 2: Photograph showing samples loaded in the universal testing machine

RESULTS

For the PMMA groups, the results showed that the 0.5% concentration recorded the highest mean value (2.69 ± 0.08 MPa•$m^{1/2}$) followed by 1.5%, 3%, 5%, control, and then 10% respectively. The difference between the subgroups was statistically insignificant except between the 0.5% group and both the control group and the 10% group and was statistically significant (P < 0.05). In the bis-acryl group, the results showed that the 0.5% concentration recorded the highest mean value (2.522 ± 0.27 MPa•$m^{1/2}$) followed by 1.5%, 10%, 3%, 5% and then the control group respectively. The difference between the subgroups was statistically insignificant (P > 0.05) [Table 1].

DISCUSSION

The hypothesis of this study was selectively accepted dependent on the concentration of silica gel studied. The only concentration that showed a statistically significant increase in the fracture toughness was 0.5% silica gel in PMMA. The remainder of the concentrations tested did not show statistical significance. Although studies have shown that the addition of woven fibers and unidirectional fibers increases the surface toughness of provisional restorations, there is a need to add another form of an easily handled reinforcement material.[3,4,15] Our novel approach was to add silica gel powder to the provisional restoration material. The inherent flaws that occur during fabrication of polymer specimens may have a direct effect on the fracture toughness values obtained during a three-point loading test. Fracture toughness describes the mechanical performance of dental polymers under a load. Fracture toughness provides information on the crack propagation of the material and is described by the critical stress intensity factor (K_{IC}). K_{IC} is an indication of the onset of material failure.[3,15]

Table 1: Descriptive statistics of fracture toughness results for both provisional restoration groups as function of modification concentration

Materials	Concentration (%)	Mean ± SD	Tukey's rank
PMMA	Control	2.013 ± 0.19	B
	0.5	2.690 ± 0.08	A
	1.5	2.504 ± 0.18	AB
	3	2.336 ± 0.17	AB
	5	2.083 ± 0.22	AB
	10	2.006 ± 0.07	B
Bis-acryl resin	Control	1.879 ± 0.19	B
	0.5	2.522 ± 0.27	AB
	1.5	2.316 ± 0.48	AB
	3	2.088 ± 0.26	AB
	5	1.894 ± 0.17	B

PMMA: polymethylmethacrylate; Tukey's rank as function of modification concentration on both groups

All of the specimens were constructed with the same dimensions and under the same conditions. This ensures the same dimensional changes during processing, as well as the same force distribution. Specimens were stored in distilled water at 37 °C for 24 h. It is known that the provisional materials used in this study imbibes the majority of the water during the first 24 h of immersion. The test was performed with a cross-head speed of 1 mm/min. This speed is considered to be within the range used in determining the fracture toughness of dental biomaterials (0.1-6 mm/min).[27]

The results of this study were not uniform; therefore, a correlation between the addition of the silica gel with any concentration and the fracture toughness values could not be established. However by adding 0.5% silica gel to the tested resins demonstrated a statistically significant increase in the fracture toughness values. This would indicate the need for further investigation on the effects of lower concentrations of silica gel. This was not investigated in our study.

Carbon black is one of the materials used for rubber reinforcement. The particle morphology of carbon black is the same as the silica gel. The particle morphology of the silica gel has a poorer affinity for polymers compared to carbon black. This difference in affinity has leaded to the use of silica gel for rubber reinforcement. There has been a limited amount of research on the lack of affinity of silica gel.[25]

The basic purpose of a filler (silica gel) is to reinforce the polymer (PMMA and bis-acryl resin). To obtain this, the mix should be homogenous with good filler/polymer adhesion where the filler starts to improve the mechanical properties of the polymer.[29] Silica gel contains siloxane groups at the surface that are changed into hydroxyl groups. The hydroxyl groups polarize and form hydrogen bonds due to their proximity to each other.[30,31]

Because of the non-crystalline structure of the PMMA, PMMA has a high internal energy. Therefore, molecular diffusion can occur in the PMMA resin due to a lower activation energy. The imbibition process of acrylic resins is partly due to the formation of hydrogen bridges between the polar carboxyl group and water.[32] It has been shown that PMMA adsorbs to the surface of the silica by the formation of hydrogen bonds between the carboxyl group of the PMMA and a silanol group of the silica.[33] Wei *et al*.[34] illustrated that materials produced from MMA with silica and PMMA with silica[35] where the hybrid homogenous materials formed without covalent bonds but with hydrogen bonds as the main interaction between the organic-inorganic phase.

Fracture toughness values obtained in the laboratory under static loads may not simulate the *in vivo* oral conditions. The forces in the oral cavity are cyclic, not static, and there are other factors which may affect the overall performance of a provisional restoration, such as temperature and pH. However, the testing of different materials in a laboratory controlled situation may be a useful predictor of clinical performance.

In this study, temporary luting cement was excluded. Luting cement may increase the fracture strength. This subject should be investigated in future studies. The most important suggestion for future studies is to perform research using lower concentrations of silica gel. Other mechanical properties may also be tested. Factors like wear resistance, surface roughness, and polishability may influence color stability. These characteristics should be considered for future research.

In conclusion, within the limitations of this study, it was concluded that the addition of a 0.5% concentration of silica powder gel by weight would increase the fracture toughness of PMMA.

Authors' contributions

Manuscript's preparation: A.H. Sherif
Manuscript's review: T.A. Hamza
Concept design: T.A. Hamza, E.A. Abdalla
Literature search: T.A. Hamza, A.H. Sherif, E.A. Abdalla

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Conflicts of interest

There are no conflicts of interests.

Patient consent

Not applicable.

Ethics approval

Not applicable.

REFERENCES

1. Kim SH, Watts DC. In vitro study of edge-strength of provisional polymer-based crown and fixed partial denture materials. *Dent Mater* 2007;23:1570-3.
2. Haselton DR, Diaz-Arnold AM, Vargas MA. Flexural strength of provisional crown and fixed partial denture resins. *J Prosthet Dent* 2002;87:225-8.
3. Hamza TA, Rosenstiel SF, El-Hosary MM, Ibraheem RM. Fracture resistance of fiber-reinforced PMMA interim fixed partial dentures. *J Prosthodont* 2006;15:223-8.
4. Pfeiffer P, Grube L. Effect of pontic height on the fracture strength of reinforced interim fixed partial dentures. *Dent Mater* 2006;22:1093-7.
5. Zinner ID, Trachtenberg DI, Miller RD. Provisional restorations in fixed partial prosthodontics. *Dent Clin North Am* 1989;33:355-77.
6. Driscoll CF, Woolsey G, Ferguson WM. Comparison of exothermic release during polymerization of four materials used to fabricate interim restorations. *J Prosthet Dent* 1991;65:504-6.
7. Gegauff AG, Holloway JA. Interim fixed restorations. In: Rosenstiel SF, Land MF, Fujimoto J. Contemporary fixed prosthodontics. 3rd ed. St. Louis: Mosby; 2011. p. 380-6.
8. Doray PG, Wang X, Powers JM, Burgess JO. Accelerated aging affects color stability of provisional restorative materials. *J Prosthodont* 1997;6:183-8.
9. Hernandez EP, Oshida Y, Platt JA, Andres CJ, Barco MT, Brown DT. Mechanical properties of four methyl methacrylate-based resins for provisional fixed restorations. *Biomed Mater Eng* 2004;14:107-22.
10. Craig RG. Craigs restorative dental materials. 12th ed. St. Louis: Mosby Elselvier; 2006.
11. Christensen GJ. Provisional restorations for fixed prosthodontics. *J Am Dent Assoc* 1996;127:249-52.
12. Vallittu PK. The effect of glass fiber reinforcement on the fracture resistance of a provisional fixed partial denture. *J Prosthet Dent* 1998;79:125-30.
13. Vallittu PK. Comparison of the in vitro fatigue resistance of an acrylic resin removable partial denture reinforced with continuous glass fibers or metal wires. *J Prosthodont* 1996;5:115-21.
14. Vallittu PK, Vojtkova H, Lassila VP. Impact strength of denture polymethyl methacrylate reinforced with continuous glass fibers or metal wire. *Acta Odontol Scand* 1995;53:392-6.
15. Hamza TA, Rosenstiel SF, Elhosary MM, Ibraheem RM. The effect of fiber reinforcement on the fracture toughness and flexural strength of provisional restorative resins. *J Prosthet Dent* 2004;91:258-64.
16. Amin AE. The effect of poly-aramide fiber reinforcement on the transverse strength of a provisional crown and bridge resin. *Egypt Dent J* 1995;41:1299-304.
17. Emtiaz S, Tarnow DP. Processed acrylic resin provisional restoration with lingual cast metal framework. *J Prosthet Dent* 1998;79:484-8.
18. Ireland MF, Dixon DL, Breeding LC, Ramp MH. In vitro mechanical property comparison of four resins used for fabrication of provisional fixed restorations. *J Prosthet Dent* 1998;80:158-62.
19. Fahmy NZ, Sharawi A. Effect of two methods of reinforcement on the fracture strength of interim fixed partial dentures. *J Prosthodont* 2009;18:512-20.
20. Hamza TA, Johnston WM, Schricker SR. Effect of polyhedral silsesquioxane (POSS) on the flexural strength and color of interim materials. *J Prosthet Dent* 2014;112:228-34.
21. Iler RK. The chemistry of Silica. New York: Wiley; 1979.
22. Ahmad S, Ahmad S, Agnihotry SA. Nanocomposite electrolytes with fumed silica in poly(methyl methacrylate): thermal, rheological and conductivity studies. *J Power Sources* 2005;140:151-6.
23. Chen F, Ma X, Qu X, Yan H. Structure and properties of an organic rectorite/poly (methyl methacrylate) nanocomposite gel polymer electrolyte by in situ synthesis. *J Applied Polymer Sci* 2009;114:2632-8.
24. Krejza O, Velická J, Sedlaříková M, Vondrák J. The presence of nanostructured Al2O3 in PMMA-based gel electrolytes. *J Power Sources* 2008;178:774-8.
25. Rattanasom N, Saowapark T, Deeprasertkul C. Reinforcement of natural rubber with silica/carbon black hybrid filler. *Polym Test* 2007;26:369-77.
26. Balos S, Pilic B, Markovic D, Pavlicevic J, Luzanin O. Poly(methyl-methacrylate) nanocomposites with low silica addition. *J Prosthet Dent* 2014;111:327-34.
27. Balkenhol M, Köhler H, Orbach K, Wöstmann B. Fracture toughness of cross-linked and non-cross-linked temporary crown and fixed partial denture materials. *Dent Mater* 2009;25:917-28.
28. Gegauff AG, Pryor HG. Fracture toughness of provisional resins for fixed prosthodontics. *J Prosthet Dent* 1987;58:23-9.
29. Murphy J. Additives for plastics handbook. 2nd ed. Oxford: Elsevier Science; 2001. p. 19-20.
30. Hoffman P, Knozinger E. Novel aspects of mid and far IR Fourier spectroscopy applied to surface and adsorption studies on SiO_2. *Surf Sci* 1987;188:181-98.
31. Morrow BA, Cody IA, Lee LSM. Infrared studies of reaction on oxide surfaces. 7. Mechanism of the adsorption of water of dehydroxylated silica. *J Phys Chem* 1976;80:2761-7.
32. Anusavice KJ. Phillips' Science of Dental Materials. 10th ed. Philadelphia: Saunders; 1996.
33. Kobayashi K, Araki K, Imamura Y. Adsorption of poly(methyl methacrylate) on silica surfaces having various silanol densities. *Bull Chem Soc Jpn* 1989;62:3421-5.
34. Wei Y, Yang DC, Bakthavatchalam R. Thermal stability and hardness of new polyacrylate-SiO_2 hybrid sol-gel materials. *Mater Lett* 1992;13:261-6.
35. Novak BM, Davies C. "Inverse" organic-inorganic composite materials. 2. Free-radical routes into nonshrinking sol-gel composites macromolecules. *Macromolecules* 1991;24:5481-3.