MECHANICAL PROPERTIES OF PROVISIONAL
RESTORATIVE MATERIALS

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DEDICATION

To my husband, Enrique L. Olavarria

ACKNOWLEDGMENTS

Finally, I dedicate this thesis to my husband, Enrique L. Olavarria. Thank you for your unconditional support, love and encouragement to pursue my dreams and move forward in my career.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

Provisional restorations are used during the interval between tooth preparation and the placement of the definitive restoration. The provisional restoration should provide the following requirements: (1) patient comfort and function, (2) maintenance of periodontal health, (3) stability of maxillomandibular relationships, (4) acceptable aesthetics and phonetics, (5) establishment of proper occlusion and (6) continual evaluation during treatment. These characteristics are essential to ensure positive predictive results in the definitive restoration.[1-2]

From a processing perspective, provisional restorations have been divided into the following categories based on how they are converted from plastic to solid masses: (1) chemically activated acrylic resins, (2) heat activated acrylic resins, (3) light activated composite resins, and (4) dual (or light and chemically) activated composite resins. In terms of chemistry, there are two main groups: (1) Methacrylate Resin (Methylmethacrylate, Ethylmetacrylate, Vinylmethacrylate, Butylmethacrylate) and (2) Composite Resin (bis-GMA, bis-acryl, UDMA / Urethane Dimethacrylate).[1]

Clinicians select a product based on factors that include ease of manipulation, cost effectiveness, esthetics, strength, and marginal accuracy. Because a provisional restoration is subjected to masticatory forces in an oral environment, understanding its mechanical properties is necessary to evaluate products that are coming into the market and verify the manufacturers' claims are warranted. Among mechanical properties, the flexural strength, fracture toughness and hardness of the interim prosthesis are important, particularly in a long span interim prosthesis with short pontic height and connectors and

when the patient presents parafunctional habits such as bruxism and/or clenching. The

flexural strength is also important if the patient is expected to wear the restoration for a

long period of time (e.g. full mouth reconstruction).[3]

Two important factors contributing to the mechanical properties of these materials

are the monomer chemistry and the use of fillers. The bis-acrylic resin contains more

rigid monomers, such as bis-GMA. Furthermore, inorganic fillers are added to the

material.[4] Conventional methacrylate based materials use monomers that are less rigid

and contain little or no fillers.

PURPOSE OF THE STUDY

The purpose of the study is to compare the mechanical properties of provisional

restorations made from composite resins (Protemp Plus, Luxatemp Solar, Radica,

Protemp Crown) to those made of the traditional methacrylate resins (Jet, Snap).

HYPOTHESIS

The hypothesis of this study is that the samples based on composites (Protemp

Plus, Radica, Protemp Crown, and Luxatemp solar) will have higher flexural strength,

flexural modulus, fracture toughness, and microhardness compared to methacrylate based

samples (Jet and Snap)

NULL HYPOTHESIS

There will not be any differences in the mechanical properties between composite

provisional materials and traditional methacrylate resins.

REVIEW OF LITERATURE

Provisional restorations are those placed between the time of tooth preparation and placement of the definitive prosthesis. To be successful, they must fulfill biologic, mechanical, and esthetic requirements. These restorations should provide pulpal protection, patient comfort, positional stability, occlusal function, hygiene access, esthetics, strength and retention.[5, 2, 6-7]

Numerous techniques for fabrication of single unit or multiple-unit provisional restoration materials have been described in the literature. Interim restorations are generally fabricated using one of two techniques: (1) custom fabrication or (2) fabrication with pre-formed materials. Additionally, both of these procedures can be accomplished with direct clinical, indirect laboratory, or direct/indirect combination techniques.[2, 8] The direct clinical method uses some form of intra-oral matrix after finishing with tooth preparation. This matrix can be made of silicone putty, hard wax or heat preformed resin sheets.[9] The indirect technique permits the provisional to be constructed on a stone cast. Different materials have been incorporated to reinforce the provisional restoration (gold, cast metal substructure, orthodontic wire etc).[8, 10]

One of the main applications of polymeric biomaterials in dentistry is the fabrication of provisional restorations. The oldest group of polymer-based direct temporary materials is PMMA resins. In 1932 Imperial Chemical Industries developed poly(methyl methacrylate) as a clearer and more durable form of safety glass in cast sheet form. By 1937 this material was also available in granules and molding powders. The

popularity of this material increased so fast that, by 1946, 95% of the denture bases were fabricated with it. [11] [12]

The biggest improvement of polymer base restorative materials came in the late 1950s and early 1960s. First, Dr. Rafael Bowen started fundamental work on the use of high molecular weight epoxy and methacrylate derivates that incorporated inorganic filler loading. The introduction of a high molecular weight, difunctional monomer (known as bis-GMA or Bowen's Resin) greatly facilitated the commercial development of materials containing inorganic fillers: composites. Bis-acrylic resins are hydrophobic materials similar to bis-GMA.[12]

The visible light polymerized resins were introduced in the 1980s. These materials require the addition of urethane dimethacrylate. Visible light energy and a comphoroquinone / amine photoinitiator initiate the polymerization of the urethane dimethacrylate material. The incorporation of filler materal (microsilica) reduces the polymerization shrinkage. [1]

PMMA and PEMA possesses an acceptable color stability and esthetics.[5, 13-14] It is easy to handle and repair and is inexpensive. However, it is reported to have multiple deficiencies. These deficiencies include polymerization shrinkage, pulpal damage associated with exothermic polymerization reaction and marginal discrepancies. Also, it is susceptible to fracture.[2, 5, 15]

Autopolymerizing acrylic resins provide adequate short term interim prostheses but heat processed acrylic resins are better long term interim restorations because of their increased strength. However, their fabrication is more time consuming. Compared to PMMA materials, composite based provisionals present higher flexural strength and

flexural modulus, due to the bulky bis-GMA monomer. Bis-GMA modifications improve

the properties of the material. For instance, additional monomer groups may add

toughness while some composites have additional fillers (silane treated amorphous silica)

that increase their strength. Moreover, some brands provide more flexible chains than the

other synthetic resins which allow more balance between mechanical strength and the

limited elasticity of the composite material. [4, 12, 16]

Ewoldsen et al. performed a clinical evaluation of visible light cured indirect

composite (Radica). They judged that the clinical performance of the Radica VLC system

for provisionalization and esthetic diagnostic restorations was acceptable. The system

offers esthetics that are superior to conventional provisional restorations, and should be a

valuable option to practitioners considering longer-term provisionalization in complex

cases.[17]

TABLE I shows the clinical advantages and disadvantages of all provisional material types and examples of brands.

FLEXURAL STRENGTH

Strength is the stress that is necessary to cause fracture or a specific amount of plastic deformation. One method to evaluate the ability to withstand the functional loads is to evaluate the material's flexural strength, also known as transverse strength, which is the strength of a material under a static load. This measurement is a combination of tensile and compressive strength tests with elements of proportional limit and elastic measurements.[18]

Young et al. compared the quality of provisional restorations fabricated by dental students from 2 different materials (bis-acryl composite resin and PMMA) and identified the advantages and disadvantages associated with each material. They concluded that the bis-acryl composite resin was superior in several aspects, including a convenient delivery method, which accounted for an accurate and consistent mix.

Lang et al. compared the fracture strength of twenty identical three unit FPDs of PMMA materials Trim and Cronsin and composite-based materials Protemp 3 Garant, Protemp Garant, Luxatemp, and Tempofit. Samples were cemented on Co-Cr alloy dies. Ten FPDs of each material were stored for 14 days in distilled water and artificially aged. Ten FPDs of each material were stored for 24 hours in distilled water as a control group. Fracture resistance was determined using a testing machine. The PMMA FPDs and the composite Tempo fit FPDs showed poor stability during artificial aging, whereas the

highest strength values in combination with low fracture rates were found for the

Protemp 3 Garant composite FPDs.[19]

Koumjiam and Nimmo evaluated the flexural strength immediately following

polymerization, seven days of dry storage and 7 days of wet storage. They found that

water storage absortion resulted in a slight but insignificant decrease in the transverse

strength. Transverse strength varied widely in the repaired group, and all materials

showed a statistically significant reduction compared with the seven day wet storage

group.[20]

Yilmaz et al. compared the fracture resistance of polycarbonate crowns, protemp

II, Bisico Temp S and heat polymerized PMMA resin. The results showed that

polycarbonate crowns were significantly different from the BISCO Temp S, Protemp II,

and PMMA.[21]

Osman et al. evaluated the flexural strengths of specimens prepared with PMMA,

PEMA, bis-acrylic composite and epimin resin materials. PEMA resin was determined

to have the highest value followed by PMMA resin.[22]

Nejatidanesh et al. found that the lowest flexural strengths were found for Trim

(ethyl methacrylate resins) and the highest flexural strengths were found for TempSpan

and Protemp 3 Garant (bis-acryl resins). They concluded that bis-acryl interim materials

exhibited higher flexural strength than the methacrylate resins tested in this study.[3]

Hernandez et al. concluded that Acralon (heat cure) has an advantage for long-

term fixed provisional restorations, because it is significantly stronger and tougher than

the rest. It was at the top in hardness together with TiO2-filled Acralon and two other

IPN groups.[23]

Haselton et al. compared the flexural strength of methacrylate base resins and bis-acrylic resins after immersing samples in artificial saliva for 10 days. Results showed that bis-acryl resins demonstrated significantly superior flexural strength over traditional methacrylate resins.[4]

Balkenhol et al. studied the flexural strength and flexural modulus of interim resin materials at different storage times and concluded that the mechanical properties of composite resin-based materials are superior to methacrylate resins and recommended a dual-curing interim resin material if a high mechanical strength is indispensable directly after fabrication.[24]

Wang et al. compared 6 resins in their study and found that Protemp had the same transverse strength as the other four resins tested. However, Snap presented an extreme plastic deformation and failed within the study.[5]

Ireland et al. evaluated the flexural elastic moduli and moduli of rupture of Povipont DC resin, Triad, Jet acrylic and a 50:50 mixture of jet acrylic resin and orthodontic resin. Provipont DC resin (dual-polymerizing resin) exhibited significantly higher flexural elastic moduli and moduli of rupture values at the 24 hour test time. However, Provitpont DC resin exhibited the greatest decrease in these values over time.[25]

Rosentritt and Lang et al. compared the flexural strength of five resin based provisional materials after repair. The result showed that high flexural strength and fracture resistance would favor Protemp 3 and Provipont for long term clinical application.[26]

FRACTURE TOUGHNESS

Fracture toughness is considered an appropriate parameter for predicting the clinical performance of dental biomaterials. Clinical experience shows that interim restorations often fail suddenly, very likely due to crack propagation beginning on the surface of the restoration.   The failure begins submicroscopically when defects are loaded.[27]

Fracture toughness has been shown to be the highest for PMMA, followed by bis-GMA resin and lastly PEMA. Bis-GMA composite resin materials seem to be more brittle than PMMA, and more likely to fracture in long span FPDs.[28]

In 1987 Gegauff et al. found that among epimine, two poly(methyl methacrylate), one composite and two poly (R' methacrylate) resins, the epimine and two poly(methyl methacrylate) ones demonstrated the greatest fracture toughness. The poly (R' methacrylate) resin had the lowest and the composite resin presented intermediate fracture toughness.[29]

In 1995 Gegauff studied the fracture toughness of four classes of resins using wet and dry test environments, following 48 hours of wet storage. No significant difference in fracture toughness was detected for the wet and dry test environments using miniature compact tension specimens. The light-initiated urethane dimethacrylate resin demonstrated significantly higher fracture toughness than the poly(methyl methacrylate) resin.[30]

Balkenhol et al. investigated the fracture toughness of cross-linked and non cross-linked temporary materials and found that the highest K(IC) was observed for Protemp 3

Garant. Fracture toughness was significantly affected by thermocycling for all dimethacrylates (p<0.05), except for Structur Premium. All dimethacrylates showed a linear-elastic fracture mechanism, whereas the monomethacrylate showed an elasto-plastic fracture mechanism.[27]

MICROHARDNESS

Diaz- Arnold et al. evaluated the microhardness of the samples prepared with bis-acryl composite resin and PMMA resin material after they were kept in artificial saliva at 37°C for 14 days following the preparation. They found that the microhardness of many materials decreases over time, and all samples prepared with bis-acryl composite rersin had a higher microhardness than PMMA resin samples.[31]

Hernandez et al. concluded that Acralon (heat cure) has an advantage for long term fixed provisional restorations. It was at the top in hardness together with TiO2-filled Acralon and two other IPN groups.[23]

MATERIALS AND METHODS

MATERIALS

The following materials were tested in this study:

- Jet (Lang)

- Snap (Parkell)

- Protemp Plus (3M)

- Luxatemp AM Plus Solar (DMG)

- Protemp Crown (3M)

- Radica (Dentsply)

TABLE II shows their general chemical composition. The materials were processed according to the instructions provided by the respective manufacturers.

METHODS

- Specimen Geometry

Flexural Strength and Flexural Modulus: 20 rectangular bar shaped specimens of each material were fabricated using split machine aluminum molds sandwiched between 2

glass slabs with the following dimensions: 25 mm x 2 mm x 2 mm (ISO 4049 American National Standards Institute / American Dental Association specification no 27).

Fracture Toughness: 20 rectangular bar shaped specimens of each material were fabricated using split machine aluminum molds sandwiched between 2 glass slabs with dimensions of 25 mm x 5 mm x 2 mm (ISO 13586).

Microhardness: 10 specimens of each provisional resin material were made within aluminum rings, 20 mm in diameter and 1.5 mm in height. Both planar surfaces of all specimens were cured against glass plates.

- Specimen Fabrication

For sample preparation, the methacrylate resins (Jet) and ethyl metacrylates (Snap) were measured, hand mixed and autopolymerized. The powder was weighed using an electronic balance (model SC-2000, Ainsworth Co., Denver, CO), and the liquid was measured by volume. For each material, manufacturer recommended power / liquid ratios were used (3:1). The liquid was dispensed in a resin mix bowl and hand mixed using a stainless steel spatula. The mixed paste was then poured into a Ramitex syringe (3M) and immediately dispensed into the molds. The samples were polymerized in a pressure pot (DensAir pneumatic curing unit, Nevin Laboratories, Inc., Chicago, IL) under 40°C water at 20 psi for 8 minutes.

For Protemp Plus, the material was mixed using the amount of each component that was delivered by three turns of the dispensing syringes. The material was dispensed into the mold and allowed to autopolymerize.

Protemp crowns were hand molded, placed into the aluminum molds and required application of visible light curing (hand lamp) for polymerization (20 seconds per section).

The Radica resin syringe was heated in the syringe heater unit (60-64°C) allowing it to warm up for about 30 minutes. After that, the warm resin was placed on the rectangular mold and left for 2 minutes for hardening. Then the resin was light polymerized using an Entera VLC curing unit for 5 minutes.

- Mechanical Testing

a) Three Point Bending Test

This test was used to measure flexural strength and flexural modulus. The 120 bar shaped specimens (in groups of 20 for each material) were polished with SiC paper (600 grit.) to standardize thickness. Each specimen was then measured 3 times using a screw micrometer and the mean values recorded. Ten of the specimens in each group were stored in destilled water at 37°C for 24 hours. The other ten samples from each group were stored in distilled water solution at 37°C for seven days. The samples were then subjected to thermal cycling (2500 cycles, 5-55°C; 45 s dwell time). After the

storage period, a plastic guide was used to align the strips in the three point loading

apparatus. Specimens were loaded on a universal testing machine at a crosshead speed of

1.0 mm per minute. Load and crosshead displacement was graphically displayed.

The flexural strength (S) was calculated using the following formula:

$$S = 3FL / 2db^2$$

Where:
S   Flexural strength (MPa)
F   Load at break or yield (N)
L   Distance between supports (25mm)
b   Width of the strip (mm)
d   Thickness of the strip (mm)

The flexural modulus was calculated using the following formula:

$$E = 3F_1 L^3 / 4bd^3 D_1$$

Where:
E   Flexural modulus (MPa)
F_1 Force at deflection (N)
L   Distance between supports (25mm)
b   Width of the strip (mm)
d   Thickness of the strip (mm)
D_1 Deflection at linear region of load deflection curve

b) Fracture Toughness Test

The 120 bar shaped specimens (in groups of 20 for each material) were polished

with SiC paper (600 grit.) to standardize thickness. Each specimen was then measured 3

times using a screw micrometer and the mean values recorded. Ten samples of each

group were stored in a distilled water solution at 37°C for 24 hours. Another ten samples

from each group were stored in a distilled water solution at 37°C for seven days. The

samples were then subjected to thermal cycling (2500 cycles, 5-55°C; 45 s. dwell time).

After the storage period, a plastic guide was used to align the trips in the three point

loading apparatus. Specimens were loaded on a universal testing machine at a crosshead

speed of 0.2 mm per minute.

Fracture toughness was calculated from the following equation:

$$K_{IC} = f(a/w)(F/h\sqrt{w})$$

Where:
K_{IC} Fracture toughness (MPa m$^{0.5}$)
$f(a/w)$ Fracture geometry factor
       $6\alpha^{1/2} [1.99 - \alpha(1-\alpha)(2.15 - 3.93\alpha + 2.7\alpha^2)] / [(1+2\alpha)(1-\alpha)^{3/2}]$
F   Force at begin of crack propagation (N)
a   Crack length (mm)
h   Specimen thickness
S   Supporting span (mm)
W   Specimen width (mm)

c) Microhardness Test

Knoop hardness measurements were employed. Five of the ten specimens of each

provisional resin material made within aluminum rings were stored in dry conditions at

37°C for 24 hours. The other five samples from each group were stored in a distilled

water solution at 37°C for seven days. The latter set of samples was then subjected to

thermal cycling (2500 cycles, 5-55°C; 45 s dwell time). After the storage period,

hardness measurements were taken for all samples using Knoop's microhardness testing

(M-400 Hardness Tester, Computing Printer ACP-94, LECO®, Knoop Diamond Indenter

860-538) set for a 100 g load and a 20 second dwell time.

The resulting impressions were observed under a microscope and measured. Five readings were taken per specimen. These measurements were then converted into a hardness number. The Knoop hardness number (KHN) is the ratio of the load applied to the area of the indentation calculated with the following formula:

$$KHN = L/l^2 C_p$$

Where:

KHN   Knoop hardness number (Kg/mm^2)
L   Load applied (Kgf)
L   Length of the long diagonal of the indentation (mm)
C_p Constant relating l to the projected area of the indentation

STATISTICAL METHODS

The results were analyzed by two-way ANOVA with material type and aging conditions as the main variables. Significance level was set at $p = 0.05$.

RESULTS

A summary of the mean values obtained in testing for each material and group of samples can be seen in TABLE III.

FLEXURAL STRENGTH

Mean flexural strength values are compared in TABLE IV. Radica exhibited the highest value in flexural strength (149 MPa) followed by Protemp Crown (93.2 MPa), Protemp Plus (73.1 MPa), Luxatemp Solar (65.0 MPa) and Jet Acrylic (68.3 MPa) at 24 hour testing. Stored for 7 days, Radica presented the highest value in flexural strength (113.5 MPa) followed by Protemp Crown (83.2 MPa), Protemp Plus (80.9 MPa), Luxamtep Solar (75.4 MPa) and Jet Acrylic (64.0 MPa) in decreasing order. Snap underwent severe plastic deformation without fracture in both 24 hour and 7 day group testing. The value presented here for Snap is the highest stress value during testing and not the stress at break.

A two way ANOVA indicated that the effect of different levels of materials depends on what level of time point is present. There is a statistically significant interaction between material and time point ($p<0.001$). A pairwise multiple comparison using the Holm-Sidak method shows that there was a significant increase from 24 hours to 7 days in Luxatemp and a significant decrease in the Protemp Crown and Radica groups from 24 hours to 7 days.   At both 24 hours and 7 days, Radica is significantly

higher than all other materials. Protemp Crown is significantly higher than all other

materials except Radica.

FLEXURAL MODULUS

The mean flexural modulus values are compared in TABLE V. Radica presented

the the highest value in flexural modulus (7,888.36 MPa), followed by Protemp Crown

(6,220.45 MPa), Protemp Plus (2,029.97 MPa), Luxatemp Solar (1,597.68 MPa) and Jet

Acrylic (1,698.32 MPa) at 24 hour testing. Stored for 7 days, Radica exhibited the

highest value in flexural modulus (6,795.26 MPa), followed by Protemp Crown

(5,249.52 MPa), Protemp Plus (2,351.52 MPa), Luxamtep Solar (1,850.44 MPa) and Jet

Acrylic (1,710.14 MPa) in decreasing order.

A two way ANOVA indicated that the effect of different levels of materials

depends on what level of time point is present. There is a statistically significant

interaction between material and time point ($p<0.001$). A pairwise multiple comparison

using the Holm-Sidak method shows that there was a significant increase from 24 hours

to 7 days in the Luxatemp and a significant decrease in the Protemp Crown and Radica

groups from 24 hours to 7 days.   At both 24 hours and 7 days, Radica is significantly

higher than all other materials. Protemp Crown is significantly higher than all other

materials except Radica.

FRACTURE TOUGHNESS

The mean values of fracture toughness are compared in TABLE VI. Radica exhibited the highest value in fracture toughness (2.0 MPa-m$^{1/2}$), followed by Protemp Plus (1.5 MPa-m$^{1/2}$) , Protemp Crown (1.4 MPa-m$^{1/2}$), Jet Acrylic (1.4 MPa-m$^{1/2}$), Luxatemp Solar (1.2 MPa-m$^{1/2}$) and Snap Acrylic (0.9 MPa-m$^{1/2}$) under 24 hour testing. Stored for 7 days, Protemp Plus exhibited the highest value in fracture toughness (1.9 MPa-m$^{1/2}$) followed by Radica (1.7 MPa-m$^{1/2}$), Luxatemp Solar (1.6 MPa-m$^{1/2}$), Jet Acrylic (1.4 MPa-m$^{1/2}$), Protemp Crown (1.2 MPa-m$^{1/2}$) and Snap Acrylic (0.8 MPa-m$^{1/2}$) in decreasing order.

A two way ANOVA indicated that the effect of different levels of materials depends on what level of time point is present. There is a statistically significant interaction between material and time point ($p < 0.001$). A pairwise multiple comparison using the Holm-Sidak method shows that there was a significant increase from 24 hours to 7 days in the Luxatemp and Protemp Plus and a significant decrease in the Protemp Crown, and Radica groups from 24 hours to 7 days. At 24 hours, Radica is significantly higher than all other materials. At 7 days, Protemp Plus is significantly higher than all other materials.

MICROHARDNESS

The mean surface hardness values of the various resins are shown in TABLE VII. Protemp Crown exhibited the highest microhardness value (39.60 KHN) followed by

Radica (32.36 KHN), Protemp Plus (14.97 KHN), Luxatemp Solar (13.75 KHN), Jet

Acrylic (10.17 KHN) and Snap Acrylic (6.27 KHN) at 24 hour testing. Stored for 7 days,

Protemp Crown exhibited the highest microhardness value (37.90 KHN) followed by

Luxatemp solar (37.74 KHN) , Radica (36.15 KHN), Protemp Plus (15.74 KHN), Jet

Acrylic (11.47 KHN) and Snap Acrylic (7.48 KHN) in decreasing order.

A two way ANOVA indicated that the effect of different levels of materials

depends on what level of time point is present. There is a statistically significant

interaction between material and time point ($p < 0.001$). A pairwise multiple comparison

using the Holm-Sidak method shows that there was a significant increase from 24 hours

to 7 days in the Luxatemp and Radica groups. At 24 hours, Protemp Crown is

significantly higher than all other materials. At 7 days, Luxatemp is significantly higher

than all other materials.

TABLES AND FIGURES

TABLE I

Types of provisional materials, advantages and disadvantages

Material Type	Clinical Advantages	Clinical Disadvantages	Brands
Methyl methacrylate	- Color stability and esthetics - Good marginal adaptation - Capable of high polish - Relatively inexpensive - Easily repaired	- Exothermic polymerization - Polymerization shrinkage - Poor wear resistance - Pulpal irritation associated with excess monomer	- Jet acrylic
Ethyl methacrylate	- Lower exothermic reaction - Low polymerization shrinkage - Good handling characteristics - Good polishability - Good toughness	- Low tensile strength - Poor surface hardness - Poor wear resistance - Poor durability - Poorer color stability - Difficult to repair	- Snap
Bis-acrylic composite Resins	- Good surface hardness - Good Transverse strength - Easy to use - Low exothermic reaction - Low polymerization shrinkage - Good marginal fit - Good abrasion resistance - Minimal pulpal irritation	- Limited shades - Expensive - Brittle - Alteration and repair are difficult - Poor stain resistance - Poor color stability	- Protemp plus - Luxatemp solar - Luxatemp
Bis-GMA composite Resins	- Good Transverse strength - Good Marginal fit - Lower shrinkage - Lower exothermic setting - Good polishability - Easily repaired	- Expensive - Limited shades - Single unit (protemp crown). - Brittle.	- TempSpan - Protemp Crown
Urethane Dimethacrylate resins	- Good marginal fit - Good polishability - Low shrinkage - No exothermic setting reaction. - Easy repaired - Good Transverse strength - Good abrasion resistant	- Indirect technique fabrication. - Expensive - Light cure unit needed (Entera) - Brittle	- Revotec LC - Radica

1-2, 14, 32

TABLE II

Materials tested and their composition

Resin Group	Resin Subgroup	Type	Materials Tested	Composition
Methacrylate Resin	Methyl methacrylates	Chemically activated	Jet (Lang)	*Power :* Polymer < 99% Diethyl Phthalate <22% *Liquid:* Methyl Methacrylate > 95% N-dimethyl-p-toluidine.
	Ethyl methacrylates	Chemically activated	Snap (Parkell)	*Power:* Particulates not otherwise classified 10mg/m^3 Polyethyl methacrylate 10mg/m$^{3\ TLV}$ Benzoyl Peroxide 5mg/m$^{3\ TLV}$ Titanium Dioxide 10mg/m$^{3\ TLV}$ Iron Oxides 10mg/m$^{3\ TLV}$ Mineral pigment blend 10mg/m$^{3\ TLV}$ *Liquid:* Isobuthyl Methacrylates Monomer Ethylene glycol Dimethacrylate Monomer N,N – Dimethyl-p-Toluidine Benzophenone-3 p-Hydroxyanisole 5mg/m$^{3\ TLV}$
Composite Resin	Bis- Acryl- Composites	Chemically activated	-Protemp Plus (3M)	*Base paste*: Dimethacrylate 50- 60 % Silane treated Amorphous silica 20-30% Polyurethane methacrylate 10-20% Silane treated silica 5-10. *Catalyst paste*: Ethanol 2,2 70-80% Diacetate Benzyl-phenyl-Barbituric acid <10% Silane- treated silica < 10%

(continued)

(continued)

TABLE II

Materials tested and their composition

Resin Group	Resin Subgroup	Type	Examples	Composition
Composite Resin	Bis- Acryl- Composites	Dual Cure	-Luxatemp AM Plus Solar (DMG)	*Base Paste:* Acrylic resin glass powder silica. *Catalyst past:* Urethane dimethacrylate Aromatic dimethacrylate Glycol methacrylate.
	Bis- GMA composites	Light Activated	Protemp Crown (3M)	Silane treated ceramic 70 - 80% Bisphenol a diglycidyl ether dimethacrylate (BISGMA) 5-15% Functionalized dimethacrylate polymer 1-10% Synthetic Amorphous silica, fumed , crystalline free 1-10% Water <5 % Thiethylene glycol dimethacrylate (TEGDMA) <1%
	Urethane dimetacrylate Composites	Light Activated	Radica (Dentsply)	Barium Fluoroalumino Borosilicate 50-70% Urethane Methacrylate 10-20% Aliphatic Urethane Diacrylate 1-5% Aliphatic Urethane Acrylate 5-10% Methacrylate Ester 5-10%

TABLE III

General results obtained for all samples (mean values)

	Flexural Strength (MPa)		Flexural Modulus (MPa)		Fracture Toughness (MPa-m$^{1/2}$)		Microhardness (KHN)	
	24h	7d,TC	24h	7d,TC	24h	7d,TC	24h	7d,TC
Jet Acrylic	68.3	64.0	1,698.32	1,710.14	1.37	1.42	10.17	11.47
Snap Acrylic	40.7	42.2	1,031.68	1,002.53	0.94	0.83	6.27	7.48
Luxatemp Solar	65.0	75.4	1,597.68	1,850.44	1.18	1.55	13.75	37.74
Protemp Plus	73.1	80.9	2,029.97	2,351.52	1.52	1.90	14.97	15.74
Protemp Crown	93.2	83.2	6,220.45	5,249.52	1.38	1.18	39.60	37.90
Radica	149.3	113.5	7,888.36	6,795.26	1.98	1.66	32.36	36.15

TABLE IV

Mean Values for flexural strength, comparison between the groups
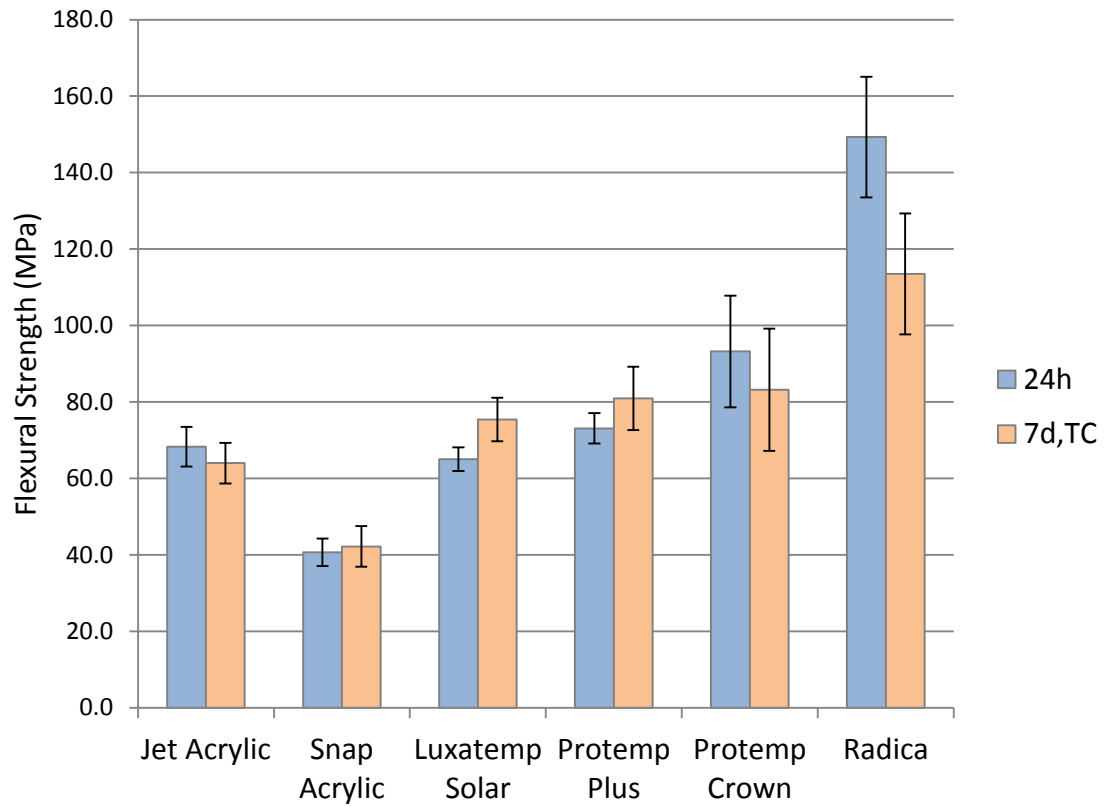
TABLE V

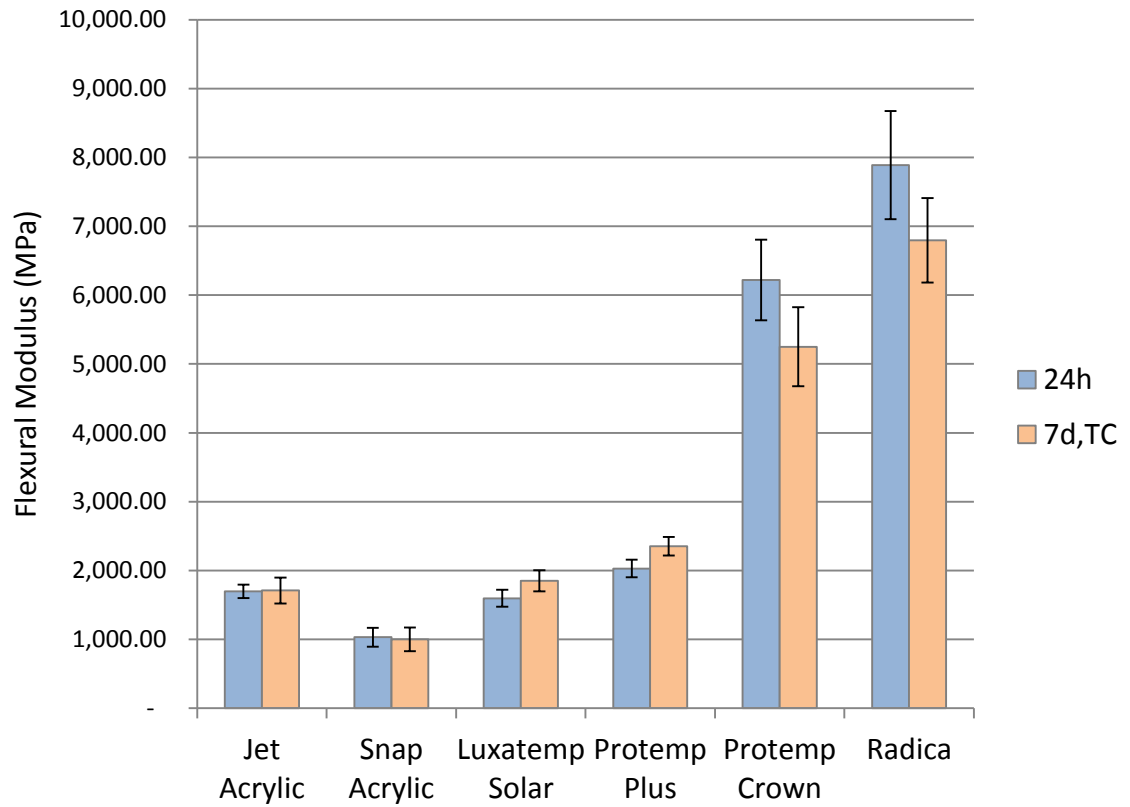Mean values for flexural modulus, comparison between the groups

TABLE VI

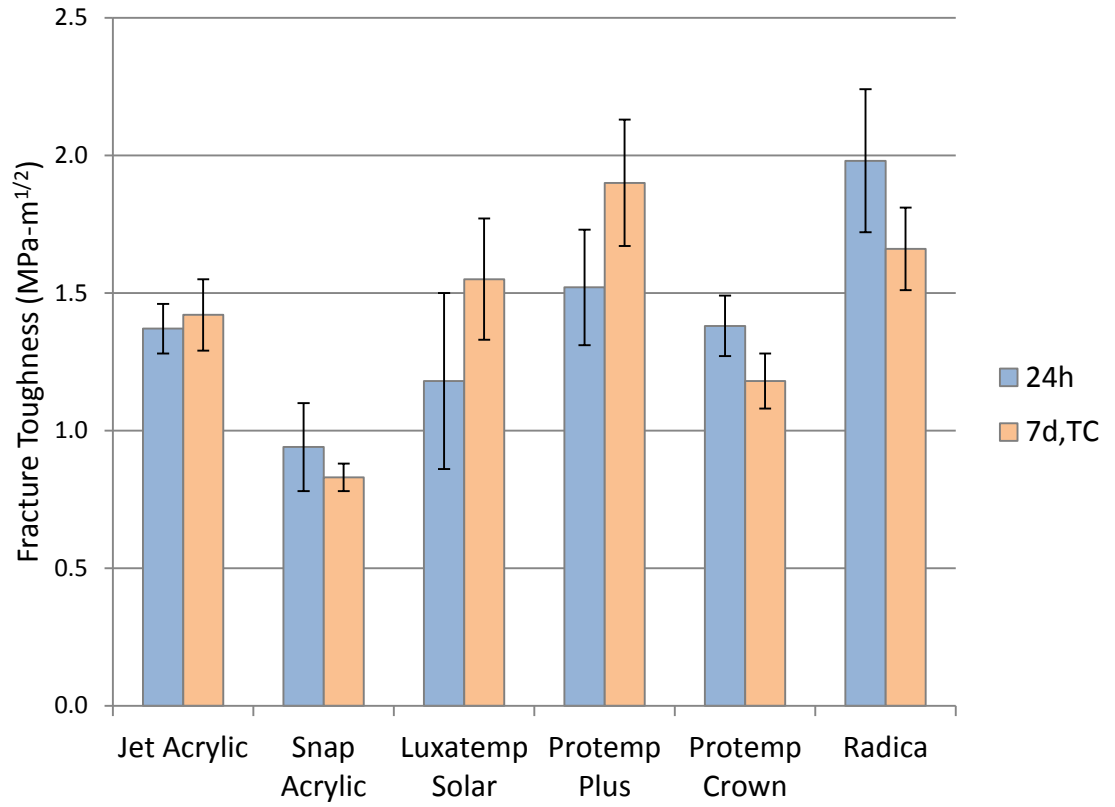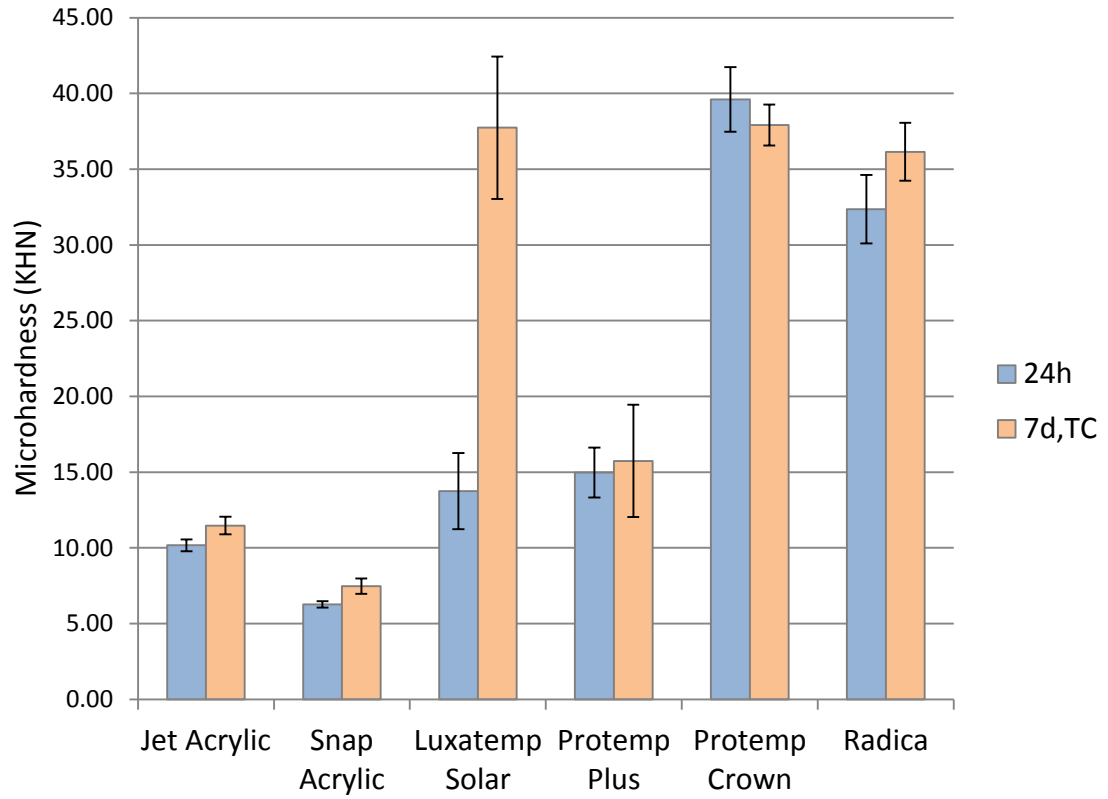Mean values for fracture toughness, comparison between the groups

TABLE VII

Mean values for microhardness, comparison between the groups
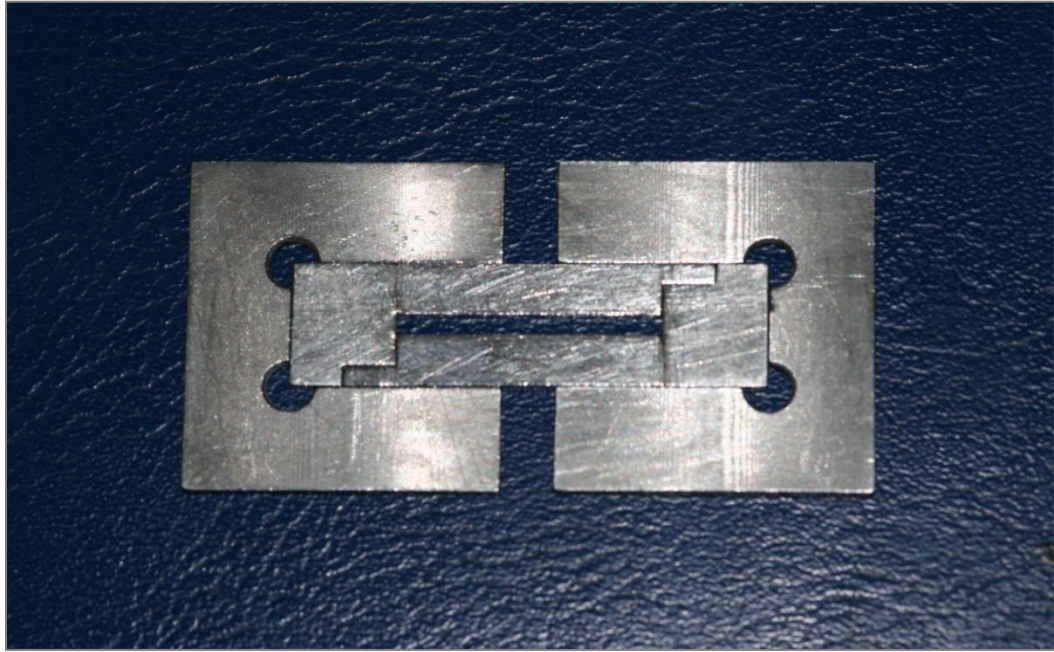
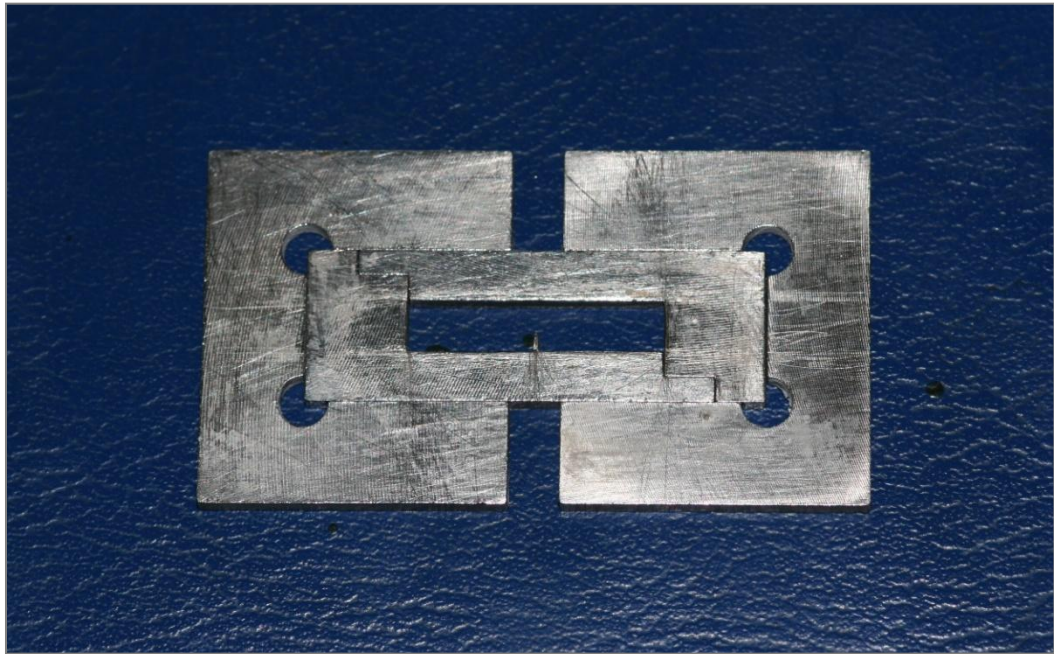FIGURE 1   Flexural strength metal mold

FIGURE 2   Fracture toughness metal mold

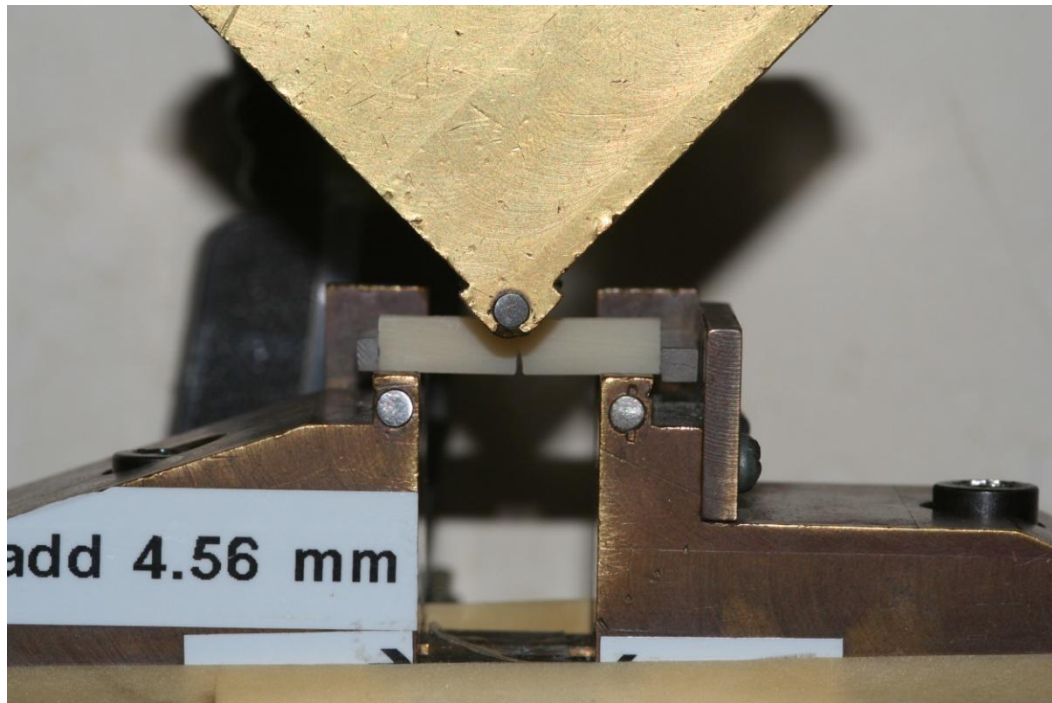FIGURE 3   Microhardness metal mold

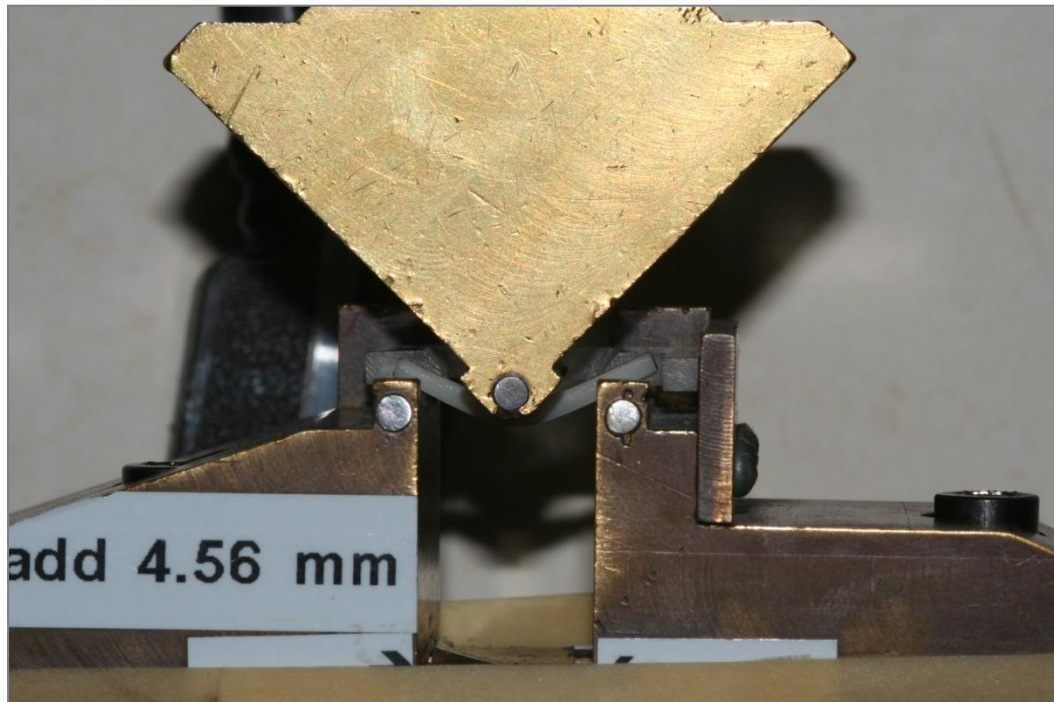FIGURE 4   Fracture toughness test

FIGURE 5   Three point bend test at a crosshead
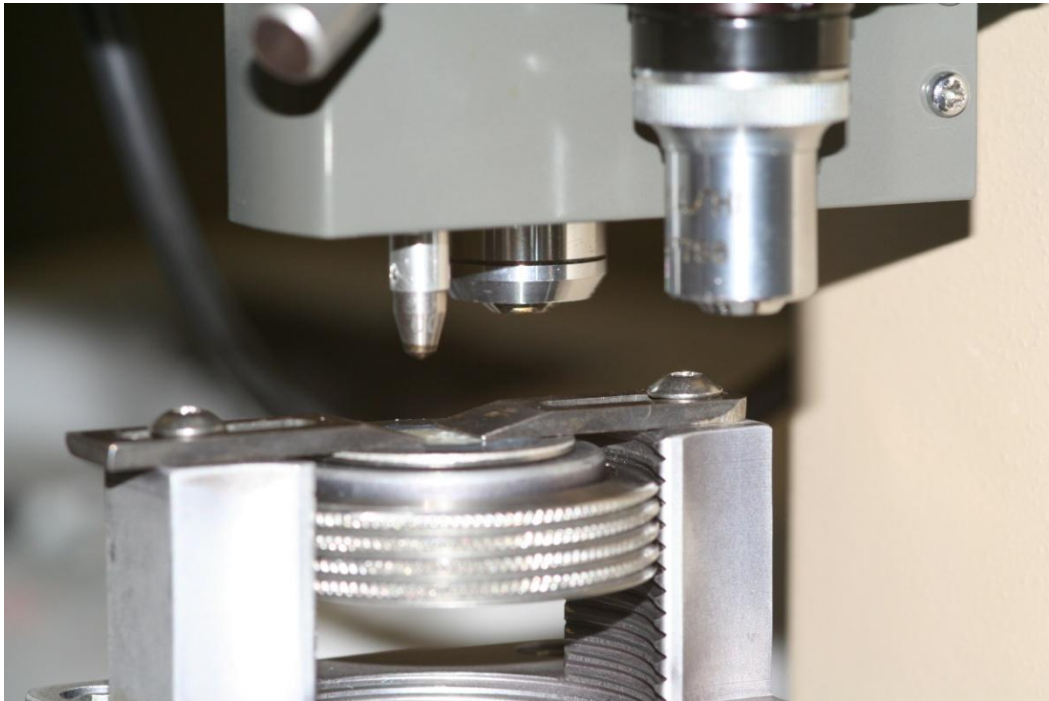
FIGURE 6   Microhardness test

DISCUSSION

Overall, Radica shows high values in all four biomechanical properties: flexural modulus, flexural strength, fracture toughness and microhardness.

FRACTURE RESISTANCE

Radica shows high values in flexural modulus and flexural strength. Compared to the other materials tested, Radica is the most suitable for application with high biomechanical demands, like in long span temporary bridges.

Both Luxatemp Solar (dual cure) and Protemp Plus (chemically activated) present less than 50% fillers in their composition while Protemp Crown and Radica (which are light cured) present more than 50% fillers. The filler contents may have contributed to the significantly higher value in flexural strength and flexural modulus in the Radica and Protemp Crown group.

The chief clinical implication of the transverse strength test results for Snap is that a provisional bridge made from this material might severely deform rather than fracture under excessive occlusal forces.

Lang, Balkenhol, Ireland, Haselton conducted a three point bending test for flexural strength to compare acrylic resins and composites and reached the same conclusion: composite resin provisional materials present higher values in flexural strength than methacrylic acrylic resins.

FRACTURE TOUGHNESS

Geauff and Wikedons investigated the fracture toughness of four provisional restorative materials. Triad (urethane dimethacrylate) exhibited a significantly higher fracture toughness value compared to Jet Acrylic. In the same way, Radica (urethane dimethacrylate) presented the highest values in fracture toughness compared with the others.

Protemp Crown is high in flexural strength, modulus, and hardness, but shows an intermediate value in fracture toughness. The material is well suited for its intended purpose of a single crown temporary restoration.

Protemp Plus shows similar values to Jet Acrylic in flexural strength, modulus, and hardness but it showed significantly higher toughness values at 7 days, indicating a superior crack-resistance. The material may be recommended for multiple unit applications.

SURFACE HARDNESS

Surface hardness is a good indicator of resistance to wear and surface deterioration.

Diaz-Arnold found that all bis-acrylic resin composite materials exhibit superior microhardness over the traditional methyl methacrylate resins throughout a 14 day interval of investigation. In our study, we found that Protemp Crown presented the

highest microhardness values followed by Radica, Protemp Plus and Luxatemp Solar. The lowest values were found in Jet Acrylic and Snap.

SEVEN DAY STORAGE

Interestingly, Luxatemp shows significant increase in flexural strength, modulus, toughness and hardness from 24 hours to 7 days. The same trend was observed for Protemp Plus, though only statistically significant in fracture toughness. The opposite was observed in Radica and Protemp Crown in flexural strength, flexural modulus and fracture toughness. The dual cure nature may have allowed more continual cross linking to take place between 24 hours and 7days and contribute to the significant increase in flexural strength, modulus, toughness and hardness from 24 hours to 7 days in Luxatemp Solar. The limited continual cross linking in the light cured Protemp Crown and Radica may not have been able to counter the degradation effect from soaking between 24 hours and 7 days and thus showed a significant decrease in flexural strength, flexural modulus and fracture toughness from 24 hours to 7 days.

It is important to note that although Radica responded with the best mechanical properties in the experiment this does not necessarily mean that Radica is the best interim fixed prosthetic material. There are multiple requirements for an ideal interim fixed prosthesis material.

CONCLUSIONS

Groups of two chemically activated acrylic resins (Jet Acrylic and Snap) and 4 composite, one dual cure (Luxatemp Solar), one chemically activated (Protemp Plus) and two light activated (Protemp Crown and Radica), were evaluated based on the four mechanical properties considered to be pertinent to their clinical performance: flexural strength, flexural modulus, fracture toughness and microhardness.

Radica showed high values in all four biomechanical properties. It showed the highest values of all materials for flexural modulus, flexural strength and fracture toughness. Protemp Crown presented the highest microhardness values followed by Radica. Although Radica responded with the best mechanical properties in the experiment this does not necessarily mean that Radica is the best interim fixed prosthetic material. There are multiple requirements for an ideal interim fixed prosthesis material.

The filler contents may have contributed to the significantly higher value in flexural strength and flexural modulus in the Radica and Protemp Crown groups. These materials present more than 50% of filler in their composition.

The chief clinical implication of the transverse strength test results for Snap is that a provisional bridge made from this material might severely deform rather than fracture under excessive occlusal forces.

The results of this study indicate that the mechanical properties of the four composite resin provisional materials tested here were superior than the methacrylate groups (Snap and Jet).

Future studies need to be done in order to compare the quality of these materials. I suggest comparing the marginal fit of the material in dies, repaired bond strengths, color stability and wear resistance.

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ABSTRACT

A provisional restoration must fulfill biologic, mechanical and esthetic requirements. These prostheses should provide comfort, pulp protection, positional stability, occlusal function, hygiene access, esthetics, strength and retention.

The purpose of the study is to compare the mechanical properties of provisional restorations made from composite resins (Protemp Plus, Luxatemp Solar, Radica, Protemp Crown) to those made of the traditional methacrylate resins (Jet, Snap).

Six groups of samples, 2 groups from methacrylate based and 4 groups from composite based materials were fabricated. Samples from each group were evaluated for microhardness (n=10), flexural strength and flexural modulus (n=20) according to ISO 4049, and fracture toughness (n=20) according to ISO 13586. Ten samples for flexural strength, flexural modulus and fracture toughness and five samples for microhardness from each group were tested after storing at 37°C in a distilled water solution for 7 days followed by thermal cycling (2500 cycles, 5-55°C, 45 s. dwell). Ten samples for flexural strength, flexural modulus and fracture toughness and five samples for microhardness from each group stored in distilled water solution at 37°C for 24 hours were used as controls. The results were analyzed by two-way ANOVA with material type and aging conditions as the two main variables. Significance level was set at p=0.05. Higher flexural strength and flexural modulus values were obtained for Radica. Protemp Plus (7 days) and Radica (24h) had the highest fracture toughness value. Protemp Crown showed the highest surface hardness. The mechanical properties of compositve resin provisional materials with a composition made up of more than 50% fillers were superior.

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