ACP
AMERICAN COLLEGE OF PROSTHODONTISTS®

Flexural Strength of Interim Resin Materials for Fixed Prosthodontics

Farahnaz Nejatidanesh, DDS, MS,[1] Glareh Momeni, DDS,[2] & Omid Savabi, DDS, MS[1]

[1] Associate Professor, Department of Prosthodontics and Torabinejad Dental Research Center, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran
[2] Graduate Student, Department of Prosthodontics, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

Keywords
Bisphenol A-glycidyl methacrylate; methyl methacrylate; interim fixed prostheses; composite resins; interim restorative materials.

Correspondence
Omid Savabi, #400-Sheikhsadoogh Shomali St., Sheikhsadoogh Cross Rd., Isfahan, 81648-13315, Iran. E-mail: savabi@hotmail.com

This study was supported by Isfahan University of Medical Sciences Research Grant #385042.

Based on a thesis submitted to the School of Dentistry, Isfahan University of Medical Sciences, in partial fulfillment of the requirement for the DDS degree.

Accepted July 28, 2008

doi: 10.1111/j.1532-849X.2009.00473.x

Abstract

Purpose: Flexural strength of interim materials is of particular concern with long-span fixed partial dentures (FPDs) or in areas of heavy contact. The purpose of this study was to compare the flexural strength of seven resins used to fabricate interim fixed prostheses.

Materials and Methods: Ten identical 25 × 2 × 2 mm specimens were made from seven interim materials (N = 70) (Trim, Acropars, Protemp 3 Garant, Unifast LC, TempSpan, Tempron, Duralay) according to ADA specification #27. After 14 days' storage in artificial saliva and thermocycling for 2500 cycles (5°C to 55°C), a standard three-point bending test was conducted on the specimens with a universal testing machine at a crosshead speed of 0.75 mm/min. The mean values of flexural strength of each interim material were calculated. Data were analyzed using the Kruskal-Wallis and Mann-Whitney U-test, and the significance level was set at $\alpha = 0.05$.

Results: The lowest and highest flexural strengths were found for Trim from ethyl methacrylate resins and TempSpan from bis-acryl resins, respectively. The mean rank of flexural strength of the studied materials was TempSpan = 66.3, Protemp 3 Garant = 53.4, Tempron = 47.5, Duralay = 38.3, Unifast LC = 24.1, Acropars = 17.9, and Trim = 5.9. There was no significant difference between Tempron and Protemp 3 Garant, but the other resins were significantly different.

Conclusions: Bis-acryl interim materials exhibited higher flexural strength than the methacrylate resins tested in this study. These higher values should be considered in making interim fixed prostheses, especially when long-term use or long-span FPDs are planned.

Interim prostheses are essential components of fixed prosthodontic treatment.[1,2] These restorations should fulfill biological, mechanical, and esthetic requirements to be considered successful.[3] Achieving these requirements depends on important properties of resins, including polymerization shrinkage, wear resistance, color stability, and strength.[4,5] Resistance to functional loads and removal forces are mechanical factors that must be considered when choosing an interim restorative material for clinical use.[3]

The flexural strength of interim prostheses is a critical property, particularly in long-span interim prostheses with short height pontics and connectors[3] and when the patient exhibits parafunctional habits such as bruxism and clenching. Flexural strength is also important when these restorations are worn over a long period of time to assess the results of periodontal, endodontic, and temporomandibular joint dysfunction therapies and during the restorative phase of implant reconstructive procedures.[6-11] The maintenance of these interim prostheses can present considerable difficulty for both the patient and the dentist. Not only can repair procedures be time consuming, but also breakage of these restorations can lead to tooth movement and functional and esthetic problems.[6]

Interim fixed restorative materials can be divided into four groups according to composition: polymethyl methacrylate (PMMA), polyethyl or butyl methacrylate, microfilled bisphenol A-glycidyl dimethacrylate (Bis-GMA) composite resin, and urethane dimethacrylate (light-polymerizing resins).[3,12] The primary monomer determines many of the material characteristics such as polymerization shrinkage, strength, and exothermic heat of reaction.[3] There is no interim material that meets optimal requirements for all situations.[13,14] Clinicians select a product based on factors that include ease of manipulation, cost effectiveness, esthetics, strength, and marginal accuracy.

Table 1 Materials tested

Product name	Manufacturer	Lot number	Resin type
Acropars	Marlic Medical Co., Tehran, Iran	UCB 4067	Ethyl methacrylate
Duralay	Duralay Corp., Worth, IL	DTX002	Methyl methacrylate
Protemp 3 Garant	3M ESPE, St. Paul, MN	NR.FA02204	Bis-acryl
Tempron	GC, Aichi, Japan	0519151	Ethyl methacrylate
TempSpan	Pentron, Wallingford, CT	140105	Bis-acryl (dual-cured)
Trim	Bosworth Co. Skokie, IL	105-308-X	Vinylethyl methacrylate
Unifast LC	GC America, Alsip, IL	0506081	Methyl methacrylate (light-cured)

Previous studies have evaluated the marginal accuracy, polymerization shrinkage, temperature rise, and mechanical properties of interim resin materials, and in these studies, valuable information has been presented regarding various materials.[1,15-25] Because interim restorative materials are subject to masticatory forces, an understanding of the mechanical properties of these materials is important in determining whether the restoration will be able to survive repeated functional forces in the oral environment. In addition, the mechanical properties of the interim resin materials can be influenced by saliva, food components, beverages, and interactions among these materials in the oral environment.[26-29] The purpose of this study was to compare the flexural strength of seven interim fixed restorative materials with different compositions. The null hypothesis was that there was no difference between flexural strength of these interim restorative materials.

Materials and methods

A Plexiglas split mold was used to make specimens with dimensions of 25 × 2 × 2 mm (ADA specification no. 27).[30] The design of the assembled mold provided five rectangular specimens for each pour of the resin materials.

Ten specimens were made from the interim restorative materials according to the manufacturers' instructions (N = 70 specimens). To extrude excess resin from the mold and to apply needed pressure during polymerization, the material was set under a glass slab and a weight of 1.5 kg was applied to the surface of the mold.

The interim restorative materials compared in this study were seven tooth-colored resin materials currently used for making interim fixed prostheses (Table 1). These tested materials are representative of all four types of interim restorative materials. Trim, Acropars, Duralay, Tempron, and Unifast LC were mixed manually, but Protemp 3 Garant and TempSpan were mixed automatically by dispenser tip.

The specimens were stored in artificial saliva[31] at 37°C for 14 days and then were thermocycled for 2500 cycles between 5°C and 55°C. Dwell time was 6 seconds in each water bath. The specimens were then placed on a universal testing machine (H 100, Dartec, Surrey, UK) for three-point bending test with a crosshead speed of 0.75 mm/min. The force at fracture was recorded in Newtons and calculated in MPa using the following formula:[32]

$$S = 3PI/2bd^2$$

where S = flexural strength, P = fracture load, I = distance between the supports, b = width of the specimen, and d = thickness of the specimen.

Data were analyzed using the Kruskal-Wallis test, and materials were ranked with the Mann-Whitney U-test, because the homogeneity of variance assumption was not satisfied for both row and log-transformed data. A significance level of $\alpha = 0.05$ was used for all statistical analysis.

Results

The mean, standard deviations, and mean ranks of the flexural strength of the materials tested are shown in Table 2. The Kruskal-Wallis test indicated a significant difference between the interim materials ($p < 0.001$). In particular, the Mann-Whitney U-test indicated no significant difference between Tempron and Protemp 3 Garant ($p = 0.063$). There were significant differences between the other materials tested ($p < 0.05$) (Table 2). The greatest flexural strength belonged to bis-acryl resins, and TempSpan was statistically superior to the other resins tested. Trim showed significantly lower flexural strength compared to other materials.

Discussion

Seven interim resin materials were evaluated for flexural strength in this study. Although laboratory flexural strength values under static loading may not reflect intraoral conditions, these values are nevertheless helpful in comparing materials under controlled situations and may be a useful predictor of clinical performance.[15] The fracture resistance of interim materials is subject to the geometry of the restoration and aging processes that occur in clinical application. Intraorally, a mean chewing force of 35 to 70 N with a frequency of 1066 Hz can be expected. Mouth temperatures range between −8°C and +81°C, and the resulting temperatures on the surfaces of a construction between 5°C and 55°C.[15] The flexural strength of interim resin materials may be influenced by saliva, food components, beverages, and interactions among these materials.[26-29] To partially simulate the oral environment, specimens were stored for 14 days in artificial saliva and thermocycled for 2500 cycles (5 to 55°C). Then standard three-point bending tests were conducted on the specimens.

The results of this study showed that TempSpan and Protemp 3 Garant bis-acryl composite resins had the highest flexural strength, and Trim vinylethyl methacrylate resin exhibited the

Table 2 The mean (standard deviation) of flexural strength of studied resins (MPa) and Mann-Whitney groups

	Mean (SD)	95% confidence interval for mean		Mean rank	Mann -Whitney group*
		Lower bound	Upper bound		
TempSpan	94.69 (12.06)	86.06	103.32	66.3	A
Protemp 3 Garant	70.50 (6.74)	65.68	75.32	53.4	B
Tempron	64.31 (7.29)	59.10	69.53	47.5	B
Duralay	55.13 (6.91)	50.18	60.07	38.3	C
Unifast LC	40.90 (5.16)	37.44	44.37	24.1	D
Acropars	35.63 (6.43)	31.02	40.23	17.9	E
Trim	21.81 (4.83)	18.35	25.26	5.9	F

*There is a significant difference between the means with different letters ($p < 0.05$).

lowest. This result is consistent with those of past studies in which the flexural strength of bis-acryl resins was higher than other conventional interim restorative materials.[6,11,15,18,26]

The differences between flexural strength of methacrylate resins and bis-acryl resins are a result of the different monomer composition. The bis-acryl resins contain multifunctional monomers (such as Bis-GMA or TEGDMA), which increase the strength due to cross-linking with other monomers.[11] Additional inorganic fillers further improve strength and microhardness.[18]

Conventional methacrylate resins are monofunctional, low-molecular-weight, linear molecules that exhibit decreased strength and rigidity. In addition, if they are not polymerized under pressure, the air bubbles will be trapped and decrease their strength.[6,11,20]

One way to enhance the mechanical properties of a material is to create a composite material. A composite material is a system composed of a mixture or combination of two or more micro-constituents differing in form or composition, which are essentially insoluble in each other. The reason materials are made tougher and stronger by incorporation with other materials is that cracks are stopped or deflected by the presence of these additions, probably at the interface, so that fracture resistance increases dramatically.[21,22]

In this study, mixing of composites was performed in a cartridge delivery system, and this dispensary method may allow for a more accurate and consistent mix; however, the working and resultant biophysical properties of set methacrylates can be influenced by the monomer-powder ratio, which can vary from mix to mix and from dentist to dentist.[23]

Direct comparison to other studies is not possible due to differences in materials, methodology, and specimen configuration. Haselton et al[11] compared flexural strength of methacrylate base resins and bis-acryl resins after immersing in artificial saliva for 10 days. Results showed that some, but not all, bis-acryl resins demonstrated significant superior flexural strength than traditional methacrylate resins. They concluded that the differences in flexural strength can be partly attributed to differences in chemical compositions; however, they deemed this property to be material specific.[11] Lang et al[15] investigated fracture resistance of interim fixed partial denture (FPD) materials after storage for 14 days in distilled water and artificial aging and found low mechanical fracture behavior and total failure of PMMA materials tested because of deformation during oral simulation. They also found that PMMA materials showed water absorption up to 32 μg/mm, primarily because of the polar properties of the resin molecules, which may act as a plasticizer and thus reduce the fracture strength of the material.[15] There was no significant difference between methyl methacrylate and composite interim materials in some of the studies.[4,14,24] This can be explained by the difference in the test method and materials. In these studies, the size of specimens was different, and an early generation of composites was used.[14,24] Manufacturers of these interim restorative materials have made efforts to improve the mechanical properties of their products.

TempSpan, which showed the highest flexural strength ($p < 0.001$), is a dual-polymerizing material that has both auto- and light-polymerizing components that may increase the degree of polymerization, whereas Protemp 3 Garant is an autopolymerizing material. The polymerization process invokes chemical, mechanical, dimensional, and thermal changes that affect the properties of resin materials.[3] The type of matrix and the degree of conversion influence the properties, especially when aging occurs in the oral environment.[25] In addition, the type and concentration of cross-linking agents may vary between these products. This information is proprietary and is not readily available; nevertheless, an increased degree of conversion and a high concentration of cross-linking agents will result in a harder material with increased flexural strength.[16]

Balkenhol et al[33] 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. They explained that in dual-curing materials a large amount of polymerization takes place at the beginning because of the light curing initiation of the reaction.[33]

Protemp Garant has been modified and marketed as Protemp 3 Garant. The modifications include a newly developed monomer system, not with the rigid intermediate chain characteristic of some bis-acryl homologues, but with a somewhat more flexible chain than other synthetic resins. This attribute allows a balance between high mechanical strength and limited elasticity of the composite material. According to the manufacturer, the result is a material that withstands high stresses until fracture and that can tolerate brief deformation.[11]

During the bending test, all Trim specimens were deflected without breakage, and the maximum force recorded by the universal testing machine was measured. Others have also similarly found that after different storage conditions, Trim specimens failed because of extreme plastic deformation without fracture.[14,15,33]

One of the limitations of this study was that there is a weak correlation between monotonic flexural strength and resistance to fatigue loading. The fatigue tests are more pertinent than monotonic flexural strength, so flexural strength data alone may be insufficient to provide relevant information for long-term clinical performance.[17]

Finally, it should be mentioned that flexural strength is only one of a number of factors influencing the success of an interim prosthesis. A strong material may possess other less desirable characteristics. For example, a restorative material may be difficult to manipulate, have tendency to stain easily, lack polishability, or not be esthetically pleasing.[11] The clinician must be aware of all attributes of various materials and choose the interim material appropriate for each patient.

Conclusion

Within the limitations of this study, it can be concluded that bis-acryl interim materials exhibit higher flexural strength than the monomethacrylate resins for interim prostheses, and these higher values should be considered when making interim fixed prostheses, especially when planning long-term use or long-span FPDs. There are many other properties, not tested in this experiment, which are equally important in determining the choice of material to use.

References

1. Kim SH, Watts DC: Exotherm behavior of the polymer-based provisional crown and fixed partial denture materials. Dent Mater 2004;20:383-387
2. Hamza TA, Rosenstiel SF, Elhosary MM, et al: The effect of fiber reinforcement on the fracture toughness and flexural strength of provisional restorative resins. J Prosthet Dent 2004;91:258-264
3. Rosenstiel SF, Land MF, Fujimoto J: Contemporary Fixed Prosthodontics (ed 4). St. Louis, Mosby, 2006, pp. 96, 466-479
4. Koumjian JH, Nimmo A: Evaluation of fracture resistance of resins used for provisional restorations. J Prosthet Dent 1990;64:654-657
5. Haselton DR, Diaz-Arnold AM, Dawson DV: Color stability of provisional crown and fixed partial denture resins. J Prosthet Dent 2005;93:70-75
6. Ireland MF, Dixon DL, Breeding LC, et al: In vitro mechanical property comparison of four resins used for fabrication of provisional fixed restorations. J Prosthet Dent 1998;80:158-162
7. Bichacho N, Landsberg CJ: Single implant restorations: prosthetically induced soft tissue topography. Pract Periodontics Aesthet Dent 1997;9:745-752
8. Stein JM, Nevins M: The relationship of the guided gingival frame to the provisional crown for a single-implant restoration. Compend Contin Educ Dent 1996;17:1175-1182
9. Jemt T: Restoring the gingival contour by means of provisional resin crowns after single-implant treatment. Int J Periodontics Restorative Dent 1999;19:20-29
10. Savabi O, Nejatidanesh F: A method for fabrication of temporary restoration on solid abutment of ITI implants. J Prosthet Dent 2003;89:419
11. Haselton DR, Diaz-Arnold AM, Vargas MA: Flexural strength of provisional crown and fixed partial denture resins. J Prosthet Dent 2002;87:225-228
12. Nejatidanesh F, Lotfi HR, Savabi O: Marginal accuracy of interim restorations fabricated from four interim autopolymerizing resins. J Prosthet Dent 2006;95: 364-367
13. Robinson FB, Hovijitra S: Marginal fit of direct temporary crowns. J Prosthet Dent 1982;47:390-392
14. Wang RL, Moore BK, Goodacre CJ, et al: A comparison of resins for fabricating provisional fixed restorations. Int J Prosthodont 1989;2:173-184
15. Lang R, Rosentritt M, Behr M, et al: Fracture resistance of PMMA and resin matrix composite-based interim FPD materials. Int J Prosthodont 2003;16:381-384
16. Atsuta M, Turner DT: Strength and structure of glassy networks formed from dimethacrylates. Polym Eng Sci 1982;22: 438-443
17. Scherrer SS, Wiskott AH, Coto-Hunziker V, et al: Monotonic flexure and fatigue strength of composites for provisional and definitive restorations. J Prosthet Dent 2003;89: 579-588
18. Rosentritt M, Behr M, Lang R, et al: Flexural properties of prosthetic provisional polymers. Eur J Prosthodont Restor Dent 2004;12:75-79
19. Hernandez EP, Oshida Y, Platt JA, et al: Mechanical properties of four methylmethacrylate-based resins for provisional fixed restorations. Biomed Mater Eng 2004;14:107-122
20. Diaz-Arnold AM, Dunne JT, Jones AH: Microhardness of provisional fixed prosthodontic materials. J Prosthet Dent 1999;82:525-528
21. Powell DB, Nicholls JI, Yuodelis RA, et al: A comparison of wire- and Kevlar-reinforced provisional restorations. Int J Prosthodont 1994;7:81-89
22. Mullarky RH: Aramid fiber reinforcement of acrylic appliances. J Clin Orthod 1985;19:655-658
23. Young HM, Smith CT, Morton D: Comparative in vitro evaluation of two provisional restorative materials. J Prosthet Dent 2001;85:129-132
24. Osman YI, Owen CP: Flexural strength of provisional restorative materials. J Prosthet Dent 1993;70:94-96
25. Condon JR, Ferracane JL: In vitro wear of composite with varied cure, filler level, and filler treatment. J Dent Res 1997;76:1405-1411
26. Akova T, Ozkomur A, Uysal H: Effect of food-simulating liquids on the mechanical properties of provisional restorative materials. Dent Mater 2006;22:1130-1134
27. Söderholm KJ, Roberts MJ: Influence of water exposure on the tensile strength of composites. J Dent Res 1990;69:1812-1816
28. Lee SY, Greener EH, Mueller HJ, et al: Effect of food and oral simulating fluids on dentine bond and composite strength. J Dent 1994;22:352-359
29. Oshida Y, Hashem A, elSalawy R: Some mechanistic observation on water-deteriorated dental composite resins. Biomed Mater Eng 1995;5:93-115

30. ANSI/ADA Specification No. 27: Direct filling resins. American National Standards Institute, American Dental Association. Revised 1993
31. ten Cate JM, Arends J: Remineralization of artificial enamel lesions in vitro. II. Determination of activation energy and reaction order. Caries Res 1978;12:213-222
32. Powers JM, Sakaguchi RL: Craig's Restorative Dental Materials (ed 12). St Louis, Mosby Elsevier, 2006, pp. 68
33. Balkenhol M, Mautner MC, Ferger P, et al: Mechanical properties of provisional crown and bridge materials: chemical-curing versus dual-curing systems. J Dent 2008;36:15-20