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THERMAL, MECHANICAL, AND BIOCOMPATIBILITY PROPERTIES OF CURED MULTI-METHACRYLATES DERIVED FROM PROPOXYLATED, ENZYME OLIGOMERIZED BPA NEAT RESINS

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Key Words: Multi-Methacrylates, Visible Light-Curing; Glass Transition Temperature (T_g), Thermal Expansion Coefficient (α), Mechanical Properties, Biocompatibility

ABSTRACT

In a previous study, we showed that the methacrylate derivatives of propoxylated bisphenol-A oligomers (EPBPA) have potential application for formulating visible light-curable (VLC) composites for dental restoratives. The purpose of this study was to evaluate the thermal, mechanical and biocompatibility properties of the EPBPA oligomers. The EPBPA oligomer multi-methacrylate: triethylene glycol dimethacrylate (TEGDMA) (50:50/wt:wt) blends were combined with 0.5 wt% camphorquinone (CQ) and 1.0 wt% N,N-di-methyl-aminoethyl methacrylate (DMAEMA). The control was 2,2-bis[4-(2-hydroxy-3-methacryloyloxpoxy) phenyl] propane (BisGMA:TEGDMA) (50:50/wt:wt) blends having the same levels of CQ/DMAEMA. The glass transition temperature (T_g) and the thermal expansion coefficient (α) were

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obtained for all materials studies, using a thermomechanical analyzer (TMA, TA Instruments 2940 with an expansion probe (heating rate 10°C/min, N_2). The compressive (CS) and diametral tensile strength (DTS) tests were carried out using a screw-driven mechanical testing machine (Model 4204 screw-driven mechanical testing machine (Model 4204, Instron Corp., Canton, MA) at 25°C, with a constant crosshead speed of 0.5 mm/min. The biocompatibility test of the polymerized oligomers (EPBPA) was done, and compared with the conventional BisGMA/TEGDMA neat resins and blank controls, using cellculture techniques. Human gingival fibroblasts were used for the initial evaluation of the biocompatibility of the EPBPA based resins.

One-way ANOVA and Tukey multiple comparison ($p < 0.05$) results show that the cured EPBPA neat resins have better thermal and mechanical properties than the BisGMA/TEGDMA neat resin control. The results also revealed that the EPBPA oligomer significantly favored the cell growth of the human gingival fibroblasts, compared to the control. Thus, the conclusion is reached that EPBPA oligomers have potential application in formulating dental composites as direct esthetic restorative materials with improved properties.

INTRODUCTION

Composite Chemistry

A composite material is defined as a "three-dimensional combination of at least two chemically different materials with a distinct interface separating the components" [1]. Dental resin composites comprise a blend of hard, inorganic particles bound together by a soft, resin matrix, consisting mainly of three main components: (1) the resin matrix comprising: (i) a monomer system, (ii) an initiator system for free radical polymerization and (iii) stabilizers for maximizing the storage stability of the uncured resin composite and the chemical stability of the cured resin composite; (2) the inorganic filler consisting of particles such as glass, quartz, and/or fused silica; and (3) the coupling agent, usually an organosilane, that chemically bonds the reinforcing filler to the resin matrix.

The properties, and hence the performance of resin composites, are dependent upon the three basic components of the material. The first group of properties, which are mainly related to the filler and the coupling agent, includes strength, stiffness, abrasion resistance, and coefficient of thermal expansion. Color stability and softening tendency mainly stem from the resin matrix [2-5].

A third group of properties may be identified that, to a higher degree, depends on both filler and matrix. Such properties are polymerization shrinkage and water sorption [6-8]. However, most properties are derived from all three basic constituents of the material; e.g., mechanical properties are, as stated, highly influenced by the filler and the coupling agent, but also the organic matrix plays a significant role for strength, stiffness, and abrasion resistance [9-11].

Bisphenol-A, employed as a building block to make polycarbonates, is the major building block used to produce dimethacrylates for use in dental composites. To achieve proper working viscosities and allow for good mixing with large quantities of filler, low viscosity, reactive, diluent dimethacrylates must also be employed. As described previously, the main monomer derived from bisphenol-A to produce VLC composites is BisGMA. The often-used reactive diluent is triethylene glycol dimethacrylate (TEGDMA). BisGMA and TEGDMA (Figure 1) based formulations or a urethane dimethacrylate modified BisGMA and TEGDMA system are not truly adequate to the task for production of the required or desired polymeric matrix for superior dental composites. Combinations of the BisGMA type monomers and reactive diluents, such as TEGDMA, are too hydrophilic, shrink too much on curing, have poor adhesion to tooth structure, and have too low water saturated (wet) T_g values, establishing a clear need for new monomers and oligomers.

New building blocks are required to produce new dimethacrylates which, in turn, can be used to formulate dental composites with superior performance profiles, i.e., acceptable for replacement of amalgams and closer matching of actual tooth properties.

Biocompatibility of Dental Composite Resins

The biocompatibility of modern dental composite resins, in general, is not as good as ceramics and glass-ionomers [12], unless they are highly filled composite resins. A brief review of the dental composite resins developmental history is available [13]. Unfilled resins are actually the origin of the modern composite resins. They have a very high thermal expansion coefficient, high polymerization shrinkage, high marginal leakage (microleakage), and are not biocompatible. After self-cured, filled resins were introduced, the problems with thermal expansion coefficient, shrinkage and marginal leakage were partially solved. Development of UV light-cured composite resin systems eliminate the concerns but revealed the dangers associated with using UV light, having incomplete polymerization, higher porosity, and insufficient depth of cure. Until visi-

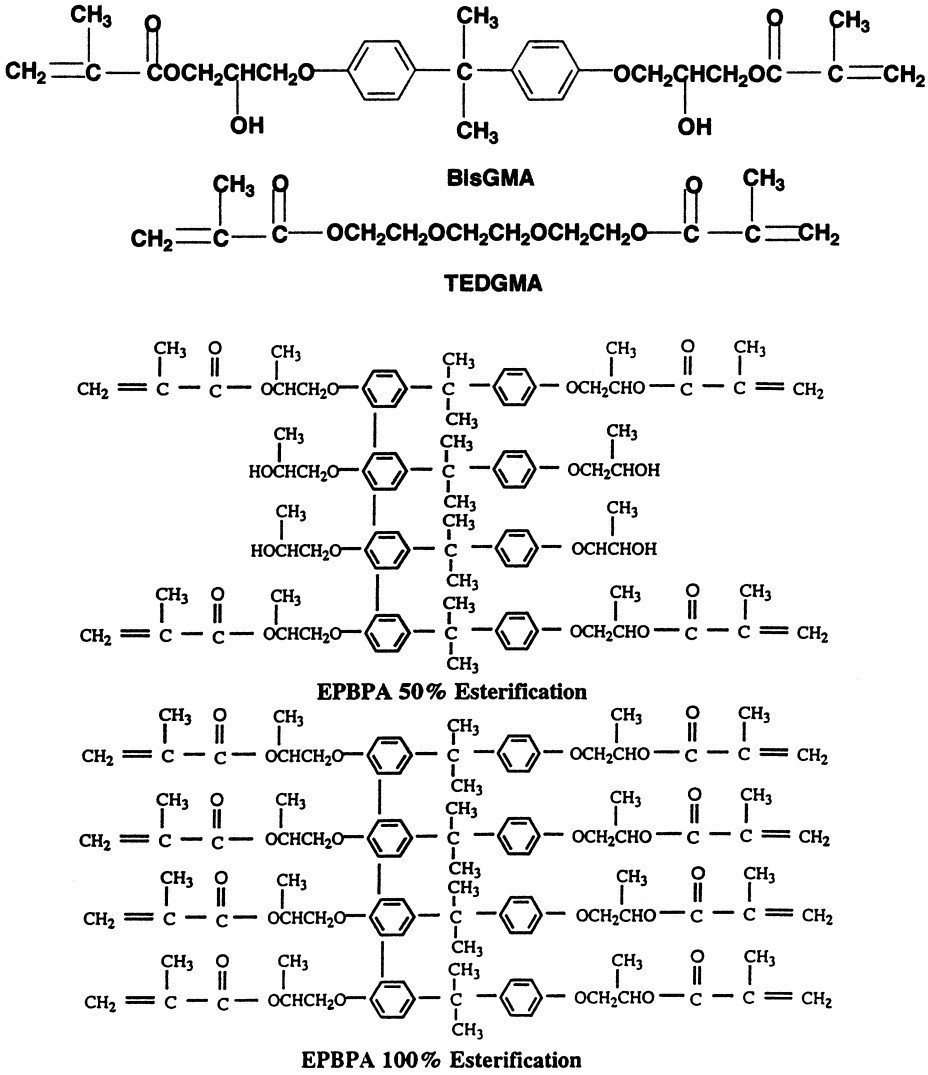

Figure 1. Structures of BisGMA, TEGDMA and hypothetical EPBPA multimethacrylate oligomers, having 50 and 100% esterification.

ble light-cured (VLC) composite resin system was introduced to restorative dentistry, having better depth of cure, achieving a higher degree of polymerization with less shrinkage, and development of incremental curing layers and less porosity, were gradually achieved to some extent. These factors directly or indirectly cause the release of unreacted monomers or components and hence lead to tissue inflammation and microleakage.

In several tissue culture systems [14], composite resins have been shown to be cytotoxic, containing several cytotoxic components [15]. Hanks, *et al.* [14] tested 11 components toward Balb/c 3T3 mouse fibroblasts and reported that the most cytotoxic component was E-BPA, where BisGMA, UDMA, TEGDMA and BPA were cytotoxic in the range between the E-BPA and initiators/activators such as camphorquinone and 2-N,N-dimethyl-aminoethyl meth-acrylate. The latter evaluation was based on the study of determining the inhibitory effects of these resin components on DNA and protein synthesis. However, Wataha, *et al.* [15], commented that the cytoxicity of the resin materials depends on their ability to diffuse through the dentin and accumulate in the pulp. Another study [16] compared the effects of the composite resin and glass-ionomer cements on oral gingival fibroblasts and oral epithelial cells and found that resins showed severe toxicity and glass-ionomer showed no morphological cell damage except for inhibition of macromolecular synthesis in gingival fibroblasts. The reason may still be attributed to the release of unreacted monomers.

Recent highly filled composite resins are more biocompatible since they have higher conversion, higher degree of cure and less shrinkage. However, the systems still need to be improved because other weakness such as water sorption, biodegradation, shrinkage, etc., will still allow leached monomer residues, degradation products, and microleakage to occur. Both short and long-term biocompatibility and cytoxicity tests need to be made on all new materials before clinical acceptance.

MATERIALS AND METHODS

Materials

The starting material, poly(isopropylidenediphenol) resin (trade name Enzo*BPA 1300), was provided by Enzymol International, Inc. (Columbus, OH). It is reported that the Enzo*BPA is made from enzymatic oligomerization of bisphenol A. Enzymol claims Enzo*BPA 1300 has a number average molecular weight (Mn) of 1300. BisGMA, TEGDMA, camphorquinone (CQ), N,N-dimethylaminoethyl methacrylate (DMAEM) and propylene carbonate, obtained from Aldrich Chemical Co. (Milwaukee, WI), were used as received. Methacryloyl chloride (Aldrich Chemical) was distilled (b.p. = 95-96°C) before use.

Synthesis of EPBPA Oligomers

The synthesis and purification of the various EPBPA type oligomers, where two hypothetical structures are shown in Figure 1 for the 50 and 100% esterification levels, was previously described [17]. A general description would be as follows: Under bulk reaction conditions, oligomerized BPA was treated with excess propylene carbonate at 160-180°C, using an amine [N(n-butyl)3] catalyst. After 4-5 hours reaction time, the viscous product was washed with a methanol/water (50/50) mixture, collected and dried, to obtain an excellent yield of PBPA, as a slightly yellow colored solid. Under a nitrogen sparge, the hydroxyl groups on the PBPA were esterified with methacryloyl chloride at 0-10°C, using a tetrahydrofuran/triethylamine solvent mixture. Using this technique and increasing levels of methacryloyl chloride, four EPBPA (multi-meth-acrylate) oligomers, EPBPA #1-#4 were prepared, with esterification of the 1-4 oligomers being approximately 25-100%. Structures of the EPBPA oligomers were confirmed by FT IR and ^{13}C NMR, as previously reported [17].

Formulation and Photo-Polymerization

The visible light-cured (VLC) formulations consisted of EPBPA (#1-#4)/TEGDMA (50/50, wt/wt), 0.5 wt% CQ and 1.0 wt% DMAEMA. The control consisted of BisGMA/TEGDMA (50/50, wt/wt), with the same level of CQ and DMAEM. The various formulations were VLC using an Elipar light source (wavelength 468 nm, ESPE Corp., Seefeld, Germany) photo-curing lamp.

Characterization of Thermal Mechanical Properties

The thermal characteristics of the neat VLC resins were evaluated by employing a thermomechanical analyzer (TMA 2940, TA Instruments, Wilmington, DE), equipped with an expansion probe. The glass transition temperatures (T_g) were determined from the thermograms by using the TMA Standard Data Analysis V5.1 program. The disk samples (6 mm in diameter x 1.6 mm in thickness) used in the study were visible light-cured for 3 minutes, followed by conditioning for one week in distilled water at 37°C. Four samples of each VLC neat resin were tested.

Preparation of VLC Resin Specimens

The neat resin samples for mechanical properties and water sorption were prepared as follows. The cylindrical resin specimens (3.3 mm in diameter

x 6.6 mm in height) were made by putting the VLC oligomer blends into transparent glass molds, followed by photo-curing with an Elipar light source, as previously described, for a total of 5 minutes. After removal from the glass mold, the sample surface was polished by using silicon carbide paper (FEPA P# 400). All specimens were conditioned in distilled water at 37°C for one week, prior to testing.

Compressive and Diametral Tensile Strength Tests

The compressive (CS) and diametral tensile strength (DTS) tests were carried out using a screw-driven mechanical testing machine (Model 4204, Instron Corp., Canton, MA) at 25°C, with a constant crosshead speed of 0.5 mm/min. For each resin, five samples were tested.

Cell Growth

Polymer Disc Preparation

The experimental dental neat resins investigated in this study were made of EPBPA in the concentration of 50, 75, and 100%. Polystyrene discs cut from well bottoms of the 12 well cell culture plates (Corning, Corning, NY) were used as a control. All neat resin formulations were cast into glass molds 14 mm in diameter and 2 mm thick. Polymer discs were prepared by exposing the molds to a COE-Lite (Model 4000, Imperial Chemical Industries PLC, Macclesfield, Cheshire, UK) light source for about 2 minutes on each side. Twelve discs of each material were formed. The smooth disc surface, which faced the glass bottom of the mold, was used to grow gingival fibroblast cells, since the smooth surface facilitates release of attached cells. The discs were gently rinsed with running tap water and cleaned ultrasonically with trypsin (0.05% and 0.53 mm EDTA 4 Na, Life Technologies, USA) for 60 minutes, to remove any possible cell or protein debris that might be on the surface. They were then placed in distilled water and ultrasonically cleaned for another 60 minutes. The cleaned discs were sterilized overnight by ultraviolet radiation.

Isolation and Culture of Human Gingival Fibroblasts

Fibroblasts derived from human gingival were isolated from explants derived from different gingival locations of two medically healthy individuals. The clinically healthy gingival tissues (firm, non-edematous, pink tissue that does not bleed upon probing) were minced with scissors and explant fragments

placed into a 25 cm^2 culture flask containing the media (described below). Incubation of explants was at 37°C in a humidified atmosphere of 5% CO_2. The media were changed every 5 to 6 days by removing 1 ml old media and adding 1 ml fresh media. When emigrating fibroblast-like cells became confluent around most of the tissue fragments, the media were removed and the attached cells released with trypsin. The cells were then resuspended in media in a 25 cm^2 culture flask. Upon confluence, cells were harvested and distributed to a 75 cm^2 flask.

Medium

Minimal essential medium (MEM, Mediatech, Inc., Herndon, VA) was supplemented with 10% (v/v) fetal bovine serum (FBS, Life Technologies, USA) and 2 mM L-glutamine (Life Technologies, USA). In addition, 100 μg of penicillin (Biowhittaker, USA) per ml of solution were added to the culture medium. MEM alone was also used as a wash medium.

Test Procedure

Two different human gingival fibroblast cell lines from twin individuals were tested in this study. For each patient, 12 discs of each material (3 discs for each cell counting day) were used. The discs were placed in wells of 24 well plastic issue culture plates (Corning, Corning, NY). Silicon rubber O-rings (McMaster-Carr, Cleveland, Ohio, USA), which had received the same cleaning protocol as the discs, were placed on top of the polymeric discs to keep the discs from floating to the surface of the medium. Empty wells without polymer discs were used as blank control. The fibroblasts were plated onto the polymer discs at a density of 20,000 cells in 1 ml Medium (above) per well. The cultures were incubated in a Medium (above) at 37°C in humidified air containing 5%, CO_2. The Medium was changed at day 3 and day 5. At days 1, 3, 5, and 7, the media were removed from the wells and the discs rinsed once with the wash medium. Cells on each disc were then trypsinized with 1ml of trypsin, diluted one to ten with hematol (Fisher Scientific, USA), an azide-free isotonic diluent, and counted by a Coulter Counter ZM (Coulter Corp.).

Statistical Analyses

All statistical analyses were performed by using analysis of variance (ANOVA) with the subsequent Tukey multiple comparisons test at a level of $\alpha =$ 005 ($p < 0.05$).

RESULTS AND DISCUSSION

Glass Transition Temperature and Thermal Expansion Coefficient

The coefficient of thermal expansion and the glass transition temperature are important properties influencing the performance of dental restoratives or composites. The second order transition from the rigid glassy state to the elastic rubbery state is an important feature of polymer behavior, marking a region where dramatic changes in the physical properties are observed. This transition is accompanied by abrupt changes in the specific volume, hardness, modulus of elasticity, heat capacity, coefficient of thermal expansion, and other physical properties of polymeric materials, with all these being important variable in dental restoratives.

Several methods exist for the determination of T_g, which include differential thermal analysis (DTA), differential scanning calorimetry (DSC), thermomechanical analysis (TMA) and others. The TMA procedure is a convenient method for measuring the expansion or contraction of a specimen due to temperature changes, where a sudden change in the slope of the thermal expansion curve (α) is used to determine T_g. From a single TMA experiment, both T_g and a values for the resin are readily determined, as shown in Figure 2.

In the present study, the thermal expansion coefficient (α) and T_g of the wet (water saturated) VLC experimental and Bis GMA control neat resins were determined by TMA, with the α and T_g values determined from the curves for these multi-methacrylate resins given in Table 1.

It can be seen from Table 1, the thermal expansion coefficient (α) increased when temperatures are higher than the T_g, and the α of the BisGMA before and after the glasstransition temperature is significantly lower than that of each experimental resins. The glass transition temperatures of all the experimental systems are significantly higher than that of the BisGMA control, especially for the highest esterification monomer (EPBPA #4). This is mainly due to the differences in monomer compositions and in sorption of water by the resins. The cured experimental EPBPA resins have more rigid structures and lower sorption of water than the BisGMA based control. The two to five phenyl rings connected by covalent bonds on EPBPA oligomers impose a strong stereo restriction on the segmental motion of the polymerized oligomer chains. The cured EPBPA resins have lower sorption of water than the BisGMA monomers due to their more hydrophobic structures. Water molecules in the resin act as a plasticizer, promoting the segmental movement of the crosslinked polymer chains and low-

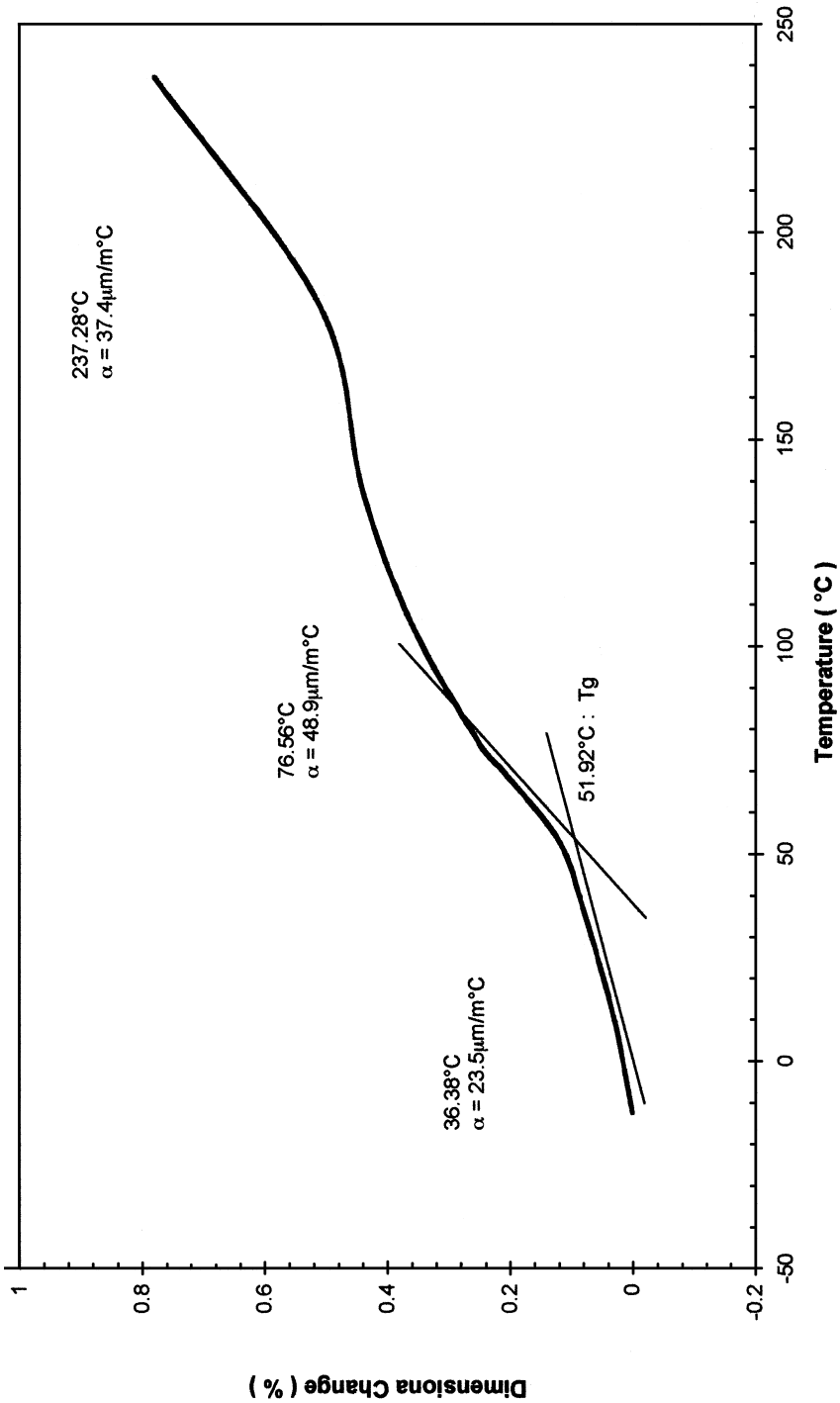

Figure 2. TMA curve of the wet, VLC BisGMA unfilled resin at 10°C/min.

TABLE 1. The Thermal Expansion Coefficient (α) and Glass Transition Temperature (T_g) of the Water Saturated, VLC Resins

Oligomer / TEGDMA*	Thermal expansion coefficient (α)** (10^{-6}/ °C)		T_g (°C)**
	$< T_g$	$> T_g$	
BisGMA	69.1 (1.0) A	84.1 (2.4) A	51.4 (0.8) A
EPBPA #1	82.7 (2.4) B	100.2 (1.9) B	54.9 (1.2) B
EPBPA #2	88.1 (2.7) B	101.7 (1.8) B	55.1 (1.4) B
EPBPA #3	85.1 (2.1) B	104.1 (2.7) B	56.8 (1.6) B
EPBPA #4	84.2 (2.2) B	99.1 (4.3) B	60.1 (1.8) B

* EPBPA Oligomer / TEGDMA (50/50 , wt/wt) with 0.5 wt. % initiator (CQ) and 1.0 wt. % co-initiator (DMAEMA).

** Resin specimens (6.0 x 1.6 mm) were conditioned in distilled water for one week at 37 °C prior to characterization by TMA. Each entry is the mean value (standard deviation) for a group of four specimens (N = 4) The means with the same letter, i.e., A, B, and C, for a specific mechanical property, are not significantly different at the $\alpha = 0.05$ level ($P > 0.05$).

ering the T_g. However, since the cured EPBPA based formulations have less C=C double bond conversion after exposure to the visible light-curing condition, there are more unreacted methacrylate type C=C pendent groups in the polymer network, increasing the segmental movement and plasticization. As a result, the magnitude of the increase in T_g of the experimental resins is not as large as expected.

Compressive and Diametral Tensile Strength

Compressive strength (CS) and diametral tensile strength (DTS) are important properties for restorative dental materials. The CS is considered relevant because the restorative materials must withstand biting forces under *in vivo* condition. Because the resins fail by crack propagation, the material is generally much weaker in tension than in compression, which may contribute to failure

of the material in service. Therefore, measurement of tensile strength is considered necessary. For relatively brittle dental resins, the DTS is generally measured, rather than using the uniaxial tension test, since it is difficult to prepare samples and to obtain uniform results. However, if the specimen deforms before failure or fractures into more than two equal pieces, the data may not be valid. In this study, the neat resins failed with somewhat permanent deformation under the diametral tensile test. Hence, the DTS data were only used for relative comparison. The measured values of CS and DTS for the water saturated or wet VLC experimental and BisGMA neat resins are shown in Table 2. Experimental neat resins with esterification degrees of 76, 57, and 44% have higher compressive strength than experimental neat resin EPBPA #4 and the BisGMA control. The diametral tensile strength of BisGMA is significantly higher than those of EPBPA #1 and #4, but not significantly different from those of EPBPA #2 and #3. These results show that three of the experimental neat resins, i. e., EPBPA #1-#3, have compressive strength better than the BisGMA control.

TABLE 2. Compressive Strength and Diametral Tensile Strength of the Wet, VLC Experimental and BisGMA Neat Resin

Oligomer/TEGDMA Resin*	Compressive Strength (S.D.) (MPa)**	Diametral Tensile Strength (S.D.) (MPa)**
Bis GMA	373.2 (29.8) A	33.1 (4.9) A
EPBPA #1	458.4 (21.2) B	25.8 (1.0) B
EPBPA #2	480.1 (35.2) B	28.7 (3.1) A
EPBPA #3	475.1 (31.4) B	26.3 (2.9) A
EPBPA #4	361.8 (22.9) A	24.1 (1.9) B

* Oligomer / TEDGMA (50/50,wt/wt) with 0.5 wt. % initiator (CQ) and 1.0 wt. % co-inititiator (DMAEMA).

** Resin specimens (3.3 x 6.6 mm) were conditioned in distilled water for one week at 37 ^{o}C prior to testing. Each entry is the mean value (standard deviation) for a group of five specimens (N = 5). The means with the same letter, i.e., A and B, for a specific mechanical property, are not significantly different at the $\alpha = 0.05$ level ($P > 0.05$).

Effect of EPBPA-TEGDMA on Growth of Human Gingival Fibroblasts

Even though the cured EPBPA-TEGDMA neat resins show good promise for increasing the longevity of dental composites, nothing is known about the biocompatibility of these type materials with vital tissues. Biocompatibility is perhaps the most critical requirement of dental materials. If these materials adversely affect the oral environment, then all the attempts to treat the tooth decay are, at best, questionable. It is apparent that restorative materials must satisfy the need to be both functional as well as be biologically tolerated. The stability of polymeric materials in biological environments is crucial to their long term success.

Dental restorative material surfaces often come into intimate contact with periodontal tissue. The attachment and proliferation of gingival fibroblasts to material surfaces is of general interest in the design of materials that might be used for applications in the oral cavity. *In vitro* cell culture techniques have been used to evaluate the cytotoxicity of various dental materials, including dental composites [18-20]. The technique of measuring the growth rate of cells in direct contact with a material surface is a very useful procedure for estimating possible cytotoxicity. The objectives of the present study were: (1) to compare the effects of EPBPA-TEGDMA and the control system of BisGMA-TEGDMA upon human gingival fibroblasts; (2) to compare the responses of two different human gingival fibroblast cell lines to these materials. Cell growth curves (cell counts versus time) of two different cell lines on a number of polymer discs and controls, as shown in Table 3, are presented in Figures 3 and 4, respectively. The means and standard deviations for the counts of day 1, 3, 5, and 7 are depicted

TABLE 3. Material Surfaces Examined in the Study of Cell Growths

Material	Description
Model Resin	BisGMA-TEGDMA (50:50, mol:mol)
Control disc	Polystyrene disc cut from tissue culture plates
Control well	Blank control, well without disc
EPBPA #2	EPBPA #2 (50 %)-TEGDMA (50:50, mol:mol)
EPBPA #3	EPBPA #3 (75 %)-TEGDMA (50:50, mol:mol)
EPBPA #4	EPBPA #4 (100 %)-TEGDMA (50:50, mol:mol)

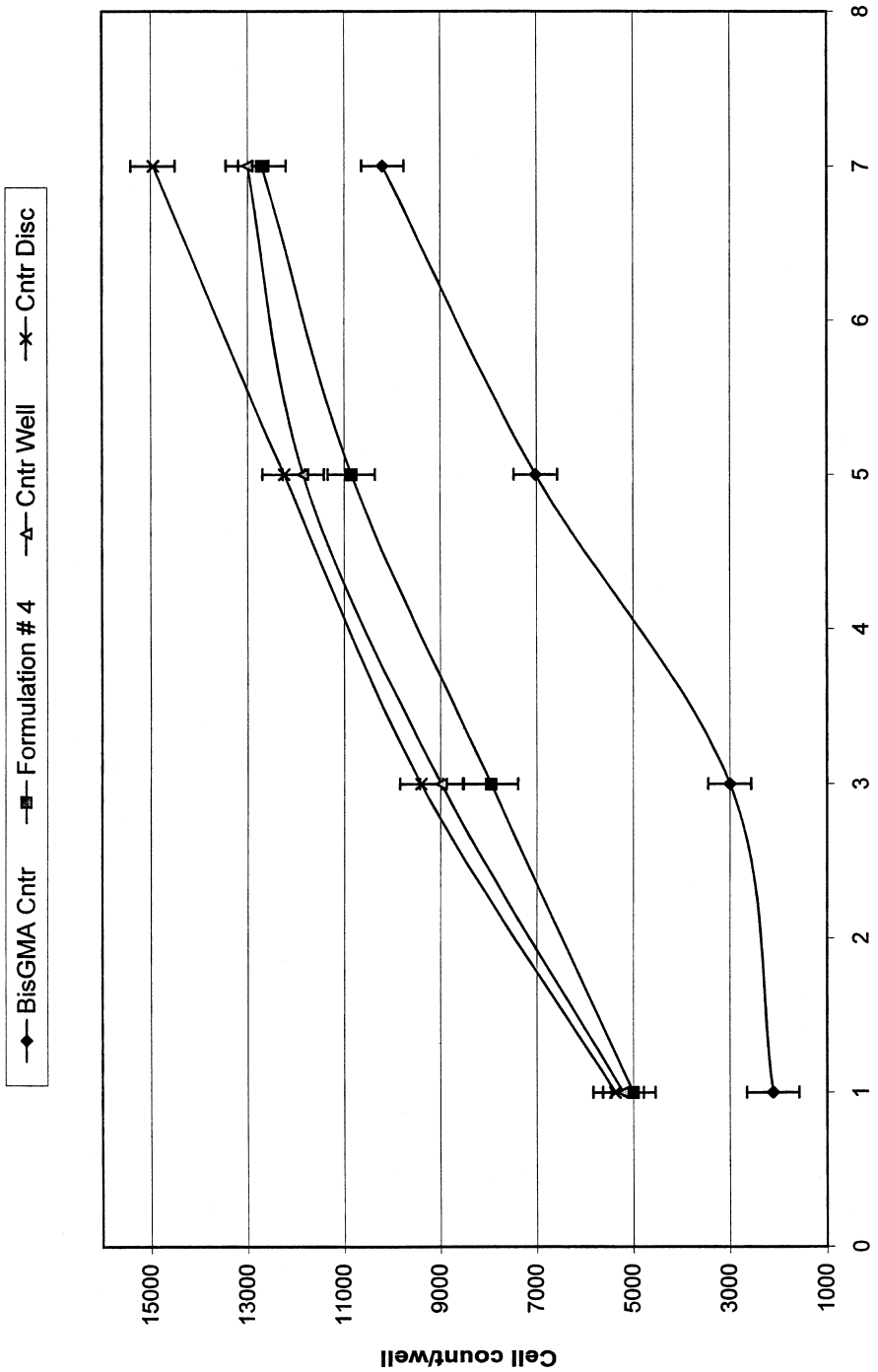

Figure 3. Seven-day growth pattern on different polymer discs for patient one.

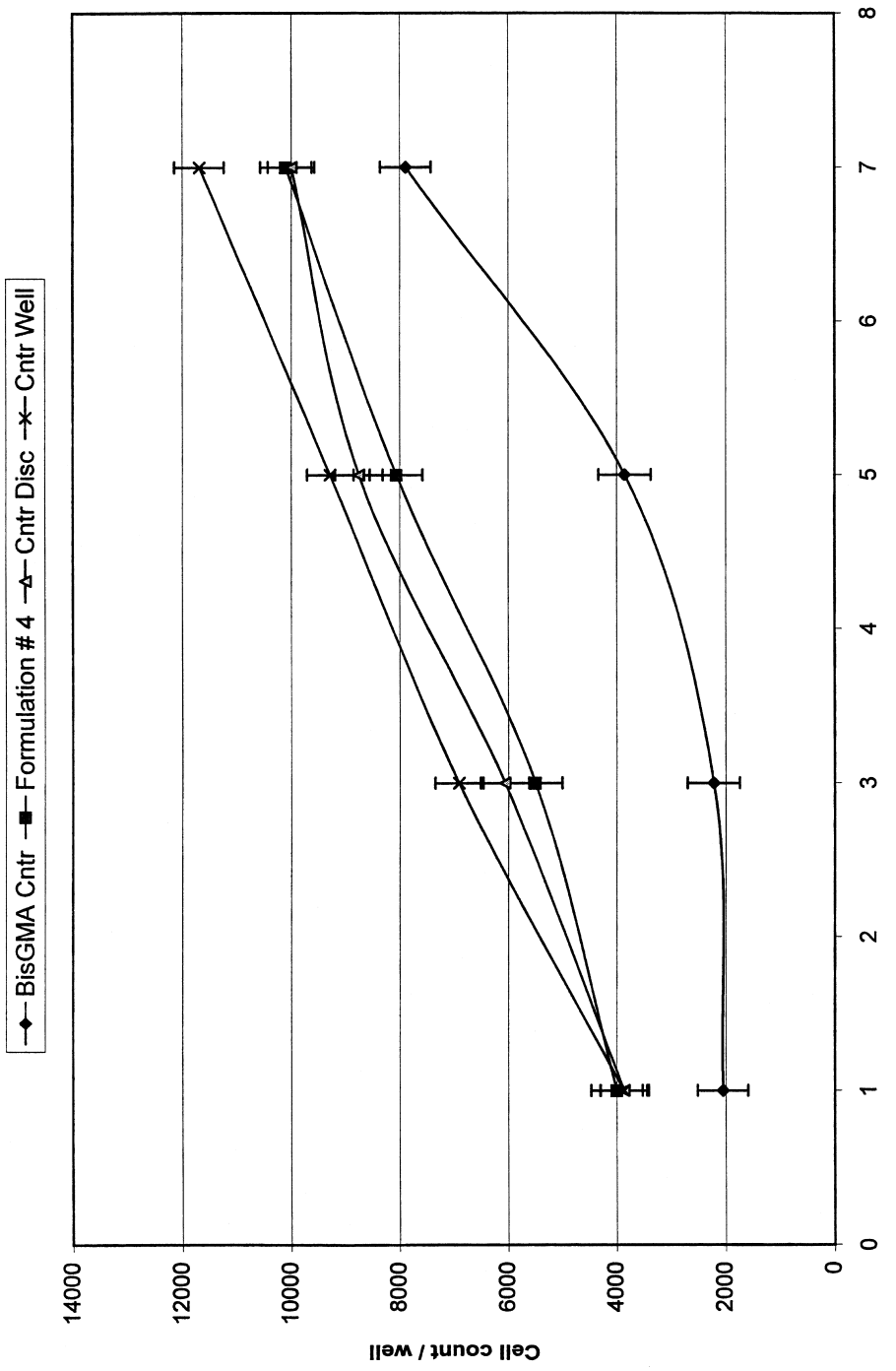

Figure 4. Seven-day growth pattern on different polymer discs for patient two.

in the figures. The absolute cell counts of the same material vary from one cell line to the other. The first cell line gave a higher cell count. For both patients, the cured BisGMA-TEGDMA surface always demonstrated the lowest cell counts among all the materials tested. The control well showed the highest cell counts among all the materials. Of all the cured, experiment polymeric materials evaluated, the EPBPA #4 (ca. 100% esterified product) formulation always resulted in the highest cell counts, which means the surface of this material allowed the best cell proliferation.

At first, the cell counts for all the materials were within the same range for both patients, which means the same initial seeding of the cells on the discs were accomplished. At days 1, 3, 5 and 7, the cell count patterns were evaluated for all the materials. For each patient cell count, the EPBPA based materials always exhibited the highest cell counts compared to the BisGMA-TEGDMA based material, with ranking for the experimental materials cell counts being EPBPA 100% > EPBPA 75% > EPBPA 50%. In summary, the cured BisGMA-TEGDMA model or control formulation gave the lowest cell counts and the cured EPBPA 100% based formulation gave the highest cell counts, among all the experimental surfaces examined. The results of the two-way ANOVA indicate that both material and patient cells significantly affect the resulting cell counts, with $p < 0.01$.

Discussion

This study shows that human gingival fibroblasts proliferate better on the EPBPA copolymer discs than on the BisGMA-TEGDMA Model or control system discs. Specifically, EPBPA 100% gave very high cell counts compared to the BisGMA-TEGDMA System. Previous studies have not disclosed any information on how the EPBPA copolymer would interact with the cells proliferating on them. Cell-substrate adhesion has been suggested to involve at least two measurable steps: the first involves initial contact between cell and substrate governed by van der Waals and electrostatic interactions. This type of interaction is sometimes referred to as non-specific. When proteins are adsorbed on the surface, cells can establish receptor-ligand bonds, which is the second stage of adhesion. This stage requires metabolic energy and is governed by specific interactions. Although adhesion is influenced by both specific and non-specific interactions, it can be expected that the specific, high-affinity interactions between cell receptors and their ligands are much stronger than the non-specific interactions [21, 22].

It has been reported that small molecules, such as the TEGDMA monomer, can easily leach out from dental composites and diffuse through dentin [23]. It has also been believed that the dental resin component monomers BisGMA and TEGDMA show certain degrees of cytotoxicity towards cultured mammalian fibroblasts. Further studies will need to be done to ascertain why the EPBPA based system allows for better cell proliferation than the commonly used BisGMA-TEGDMA system. However, we may hypothesize that the higher molecular weight and enhanced hydrophobicity of the EPBPA type oligomer, compared to BisGMA and TEGDMA plays a major role in making it more difficult for the EPBPA oligomer(s) to have any biological effect on vital cells. What ever the actual case, one can assume that the low toxicity of EPBPA is one of the reasons why gingival fibroblast cells proliferated better on EPBPA containing discs. The toxicity of monomers may affect either the vitality of the cells or the specific stage of the cell attachment process. It is also recognized, the observed cell counts on the EPBPA 100 % discs being higher than on the BisGMA-TEGDMA system (control) discs might be attributed, in some measure, to the disc surface conditions.

CONCLUSION

This effort is part of a continuing study to obtain a better understanding of the structure-property relations needed to obtain improved composites and to develop new and improved resin matrix systems for dental composite applications. These EPBPA type polyfunctional oligomers, neat resins, possess comparable visible light-curing characteristics to the BisGMA based control, along with having higher compressive strength, lower polymerization shrinkage and lower absorption of water and other liquids. Initial biocompatibility test on these oligomers revealed that the cured EPBPA type oligomer significantly favored the cell growth of the human gingival fibroblast, compared to the BisGMA/TEGMA based control. This new family of polyfunctional methacrylate oligomers have potential application in formulating dental composites with improved properties, as well as formulating composites for a variety of other applications, including such things as bone cements.

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