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Effects of Filler Content on Mechanical and Optical Properties of Dental Composite Resins

Seyed Mostafa Mousavinasab

*Department of restorative dentistry, Dental school
Isfahn university of medical sciences, Isfahan
Iran*

1. Introduction

Filler -matrix coupling determines, to a large extent, the mechanical strength and clinical longevity of dental composites. Incorporation of filler into resin matrix greatly influences and improves material properties provided that filler particles are bonded to polymer matrix or otherwise it may actually weaken the resin.

Benefits of filler content presence are increased hardness, strength, radiopacity and decrease in polymerization shrinkage, thermal expansion and contraction, water sorption, softening, staining and finally improved workability.

Formulation of the monomer and filler, shear rate and temperature greatly influence characteristics of resin composite.(1)

There are significant differences in number of filler particles, size and area occupied for the fine particle composite resins of different brands.(2)

2. Physical and mechanical properties

There is a correlation between physical and mechanical properties and filler content weight and size in composite resins. Following increasing filler particle size an increase in stress concentration and decrease in flexural strength is observed.(3)

In addition to correlation existed between elastic moduli and filler content fraction of composite resin, the shape and size seem to be fine-tuning factors for young's modulus.(4-7)

Flexural strength and modulus, hardness as well as fracture toughness are influenced by both filler morphology and filler loading.(8)

flexural strength and modulus of elasticity values are different among different universal hybrid composites whereas the microfine composite resins present lowest filler weight and mechanical properties compared to universal hybrid and the nanofilled resins present intermediary results .(9)

Mechanical properties of microfilled composite resins as well as polyacid- modified resin composites are dependent on the inorganic filler content and properties of matrix resin and whether matrix resin is hydriphilic or hydriphobic.(10-12)

Significant exponential relations are found between filler content of the resins and their flexural moduli and flexural strength .(13)Although some studies demonstrate that there is no correlation between fracture toughness and filler content by volume of flowable composites but hardness and fracture toughness tend to be linearly proportional to filler

content in the composite resin and resin composites demonstrate a range of fracture toughness values.(14-16)

There is a linear relationship between elastic module and filler loading but correlation of fracture strength and fatigue data to filler fraction could not be proved, therefore materials providing high initial strengths don't obviously reveal the best fatigue resistance.(17)

Condensable composite and hybrid composite resins with similar concentration of inorganic particles may show different flexural strength.(18)

Presence of spherically- shaped filler particles affect the microfracture mechanisms of dental resin composites and increase the bending strength and fracture toughness with a much higher rate for elastic modulus.(19-20)

Percent of submicron silica level in hybrid resin composites has direct effect on physical strength.(21)

The particle size of the filler appear to have a moderate influence on the properties of resin composite.(22)

Presence of nano-filler particles in resin -based restorative materials produce superior performance compared to micro-particles.(23)It also greatly influences grindability of composite resin adhesives.(24)

The flexural strength of metal -resin composite restorative materials containing 4-META treated particles is mainly affected by filler content and immersion time(25)and is increased by the particle size and content of Ag-Sn and Ag-In alloy particles as filler and 4-META as coupling agent.(26-30)

An experimentally prepared metal -resin composite using Ag-Cu particles as filler in which metal particles are involved in the polymerization initiation system has the potential to be used as a dental restorative material,(31)

The bending properties: such as maximum stress and bending modulus, increase with filler content.(32)

Uncontrolled aggregation of amorphous calcium phosphate particulate fillers and their uneven distribution within polymer matrices can have adverse effects on the properties of composite containing this kind of fillers.(33)

Adding apatite and titanium nanotubes to resin based cements will increase the fracture toughness, flexural and compressive strength, hardness and modulus without changing radiopacity and biocompatibility.(34-35)

Beside degree of cure other factors like filler content and monomer type affect the color stability, hardness, compressive strength, stiffness and flexural strength of composites.(36-37)

Coefficient of linear thermal expansion and water absorption of glass-fiber reinforced resins depends on the inorganic filler content or glass-fiber content.(38)

There is an underlying relationship among the composition, component stability and post polymerization properties of flowable composites.(39)

Discrepancy between filler and matrix, filler content, particle size and the ability of the polishing systems to abrade filler may contribute to polished surface characteristics of resin composite.(40)

Decrease in filler particle size to less than 1 micrometer and a lower filler loading permit the clinical development and maintenance of smooth surface with microfilled compared to conventional composite restorative resins.(41)

Fluoride release from filled resins containing CaF₂ particles as filler in the range of 9.09 mass% concentration is independent of PH solution and may help to reduce the occurrence of both secondary caries and restoration fracture.(42-44)

3. Wear resistance and polymerization shrinkage

Wear resistance is a major concern about composite resins. In general it is suggested that composite resins with smaller particles wear less and filler components characterize the wear patterns especially in the occlusal contact area. (45-47)

Wear resistance of composite resins is enhanced due to presence of higher filler volume and functional silane treated microfiller particles. (48)

The abrasion resistance of heat curing composites is also controlled by the filler size and filler content.(49)

The effect of filler content on toothbrush wear resistance may vary with different resin matrices.(50)

Increasing the filler content offers characteristics like bulk curing with less polymerization shrinkage, decreased wear and packability to the composite resin.(51)

Polymerization shrinkage:

Filler loading reduces polymerization contraction and reaction inhibition under atmospheric oxygen at the composite resin surface. (52)

Low shrinkage composites including Ormocers and cationic ring -opening systems despite their higher filler mass show no difference regarding mechanical properties compared to highly filled methacrylate-based materials.(53)

There is an inverse linear relationship between filler content and polymerization shrinkage (54)

Higher inorganic content is associated with lower polymerization stress values which is in direct relation with reduced shrinkage.(55)

Increased filler content in packable composite resins assures of improved wear-resistance, strength, longevity, postoperative sensitivity and esthetics.(56)

Compositional interactions between the filler and matrix influence viscosity and flow characteristics of resin composite.(57)

Higher filler loaded flowable composites are preferred to flowable composites with lower filler content when incremental technique is used in conjunction with conventional hybrid composites for 2-mm deep cavities to achieve better marginal integrity.(58)

Marginal adaptation is significantly related to the amount of inorganic component and also to the volume of the prepolymerized inorganic filler content.(59)

Both organic and inorganic composition of the composite resin influence its rate of cure .The rate of polymerization is increased with the level of HEMA and TEDDMA in the monomer composition.(60-61)

Substitution of Bis-GMA , UDMA and TTEGDMA with alternative monomers results in increased flexural strength. Increased hygroscopic expansion and reduced shrinkage are achieved using a very hydrophilic monomer.(62)

Optical properties:

One interesting aspect of filler content effect is on optical properties of the resin. When a ray of light interacts with composite surface, some of the light may be partly reflected and some partly refracted. The density of the filler determines how strongly the light is scattered within the material. The low filler proportion regions show lower scattering than denser filler regions. With the addition of filler to unfilled resin matrices (UDMA and TEGDMA based composite resins) a significantly higher transmittance value will be seen and there is a linear correlation between percentage of Bis-GMA in the resin matrix and the total and diffuse translucency.

Higher transmittance of Bis-GMA compared to UDMA and TEGDMA with the addition of filler positively influence translucency of composite resin. (63)

Improvement of surface treatment material of filler and composition of filler makes it harder to absorb the microwave energy which is dependent on the size of filler.(64)

There is a linear relation between optical scattering and filler concentration of resin composite and also efficiency of optical scattering is related to size and shape of the filler.(65)

Higher translucency is achieved by decontamination of the added fillers to the matrix of composite resins.(66)

Filler type influences the color difference values and translucency of composite resin artificial teeth.(67) The pigments are usually metal oxides. Certain fluorescent agents are added to resin composite in order to give the materials a natural -looking, tooth like structure. Metal oxides such as titanium oxide are added to composite to produce opaque composite. The volume fraction of the filler and matrix in composite resins influence scattering and absorption as a result the color of composite resin.(68)

Adding fillers such as TiO₂ particles to resin matrix will lead to increasing opalescence of resin composite, decrease in translucency parameter but no effect on fluorescence. Presence of TiO₂ nanoparticles produce human enamel like appearance.(69)

The orientation of fillers affects the absorption and scattering coefficient differences in fiber reinforced composite resins.(70)

Some of particulate filled composite resins that can be fabricated into metal-free crowns are stable in both translucency and color during storage period in a media such as water.(71)

Darker shades of resin composite contain darker pigments that absorb more light. Refraction index of resin composite is an important factor in attaining a color matching between composite and dental tissues. To prevent light scattering at the resin-filler interface, the refractive indices of the different components (filler-matrix-coupling agent) shouldn't vary too much, otherwise resulting in a material that looks opaque with reduced transparency for light. Opalescence parameter varies by the size and amount of filler and translucency parameter decreases as the amount of same filler size increases.(72)

Refractive index match between resin/filler linearly rises with the conversion of composite resin and increase in light transmission during conversion is greater for increasing filler levels.(73)

It has been shown by researchers; light scattering is related to filler particle size in the resin composite, that is maximized when the filler Particle size is one half the wavelength of activation light, resulting in a lower transmission coefficient and smaller depth of cure. Transmission Coefficient is influenced by the wavelength of light, refractive indices of the resin and fillers, and type and amount of filler particles.

The depth of cure of a composite resin is affected by the amount of light that reaches the photo initiator.

Light intensity decreases as it passes through the material. Fillers and pigments strongly influence the intensity of the incident light, limiting the depth of cure. Both intensity of the light source and attenuating power of the material influence the degree of conversion. Filler/resin refractive index has significant interaction on cure depth and color matching of composite resin.(74)

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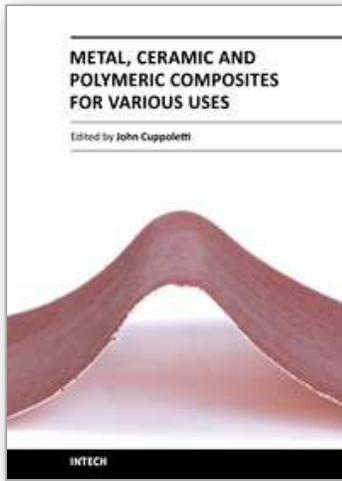
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Composite materials, often shortened to composites, are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure. The aim of this book is to provide comprehensive reference and text on composite materials and structures. This book will cover aspects of design, production, manufacturing, exploitation and maintenance of composite materials. The scope of the book covers scientific, technological and practical concepts concerning research, development and realization of composites.

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