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Optical characteristics of contemporary dental composite resin materials☆

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ABSTRACT

Objectives: Optical and physical properties of dental restorative composite materials are affected by composition. Basic optical absorption and scattering properties have been derived through the use of a corrected reflectance model, but practical and important optical properties are not easily derived from these basic spectral characteristics. The purposes of this study are to derive and compare colour and translucency characteristics of two cured contemporary nanohybrid composites being marketed as universal composites, and to evaluate colour difference between each composite material and published shade guide data.

Methods: Previously derived optical scattering and absorption coefficients for five diverse shades of these composite materials were used to calculate the CIE colour parameters of L^*, a^* and b^* at infinite thickness under various illuminants and to derive ideal translucency parameters at various thicknesses using two colour difference formulae.

Results: Differences were found in the inherent colour parameters and in the translucency parameters between the brands for some of the shades studied. The colour differences of the inherent colours from published shade guide data were always higher than the perceptibility limit, and often higher than the acceptability limit.

Conclusions: Inherent colours and ideal translucency parameters may be calculated from optical coefficients for a variety of illuminants. Different inherent colour parameters of composite materials marked for the same shade indicate the influence of compositional differences between these materials.

Clinical significance: Since patients are seen under various illuminations, the ability to assess appearance matching characteristics under diverse illuminants will help assure an optimum match for the patient.

1. Introduction

Important attributes of contemporary composite dental restorative materials include handling characteristics, aesthetic appearance and clinical durability. Composite resin materials have been improved in many ways over the years to provide superior optical properties while at least maintaining, often improving, resistance to degradation during service.

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Currently available products vary in colour,[1] translucency,[1,2] fluorescence,[3] opalescence,[4] and many clinically important mechanical properties.[5] A challenge to the clinician is to select the material which will best satisfy the requirements of the restoration and which will remain in service to the satisfaction of the patient. Inherent in this challenge is the adequate characterization of the optical properties of the many available restorative dental materials.

Dental restorative composite resins are generally classified according to their filler shape,[6] size,[7] location of use,[8] and more recently, according to their resin matrix.[9,10] The filler size classification, however, remains the most widely used. Advances in the filler loading, type and size have tremendously aided in achieving a more natural appearance for composite resin restorations.[11] With the evolution of nanotechnology, nanosized (submicron) fillers have been incorporated into the dental composite resin systems by several manufacturers. Optical[12] polishing and wear characteristics[13] were improved while mechanical properties remained at least comparable to conventional composites.[14–18]

Nanosized fillers approximately 0.04 μm (40 nm) in size were incorporated into microfill composites[19] and in some hybrids and acted as the predecessors to newer nanocomposites. Recently, filler particles of sizes between 5 and 100 nm are being manufactured.[20] Because these filler sizes are below the wavelengths (380–780 nm) of visible light, nanofilled composites provide favourable translucency, as well as polishability, and surface-gloss retention.[21,22,13] It has also been reported that nanomeric particles with average sizes between 20 and 75 nm which are below the wavelengths of visible light, allow these materials to exhibit high translucency.[23] More conventional hybrid composites often contain filler particles which range in size from 8000 to 30,000 nm and which exhibit a mismatch in the refractive index when compared to the resin matrix. These large filler particles will scatter the light, resulting in an unavoidable reduction in translucency.

1.1. Nanocomposite technology

Hybrid composites that incorporate a range of particle sizes from nano to micron were developed to take advantage of benefits of nanosized fillers while maintaining a high filler loading. In addition, prepolymerized filler particles that contain nanofiller allow the incorporation of a higher loading of nanoparticles without the problems associated with high surface areas. While these developments addressed the physical properties of composites, nanocomposite technology will have a significant effect on the colour and optical properties.[23]

1.2. Resin matrix

Many commercial dental composites, like Herculite Ultra, utilize Bisphenol A-glycidyl methacrylate (Bis-GMA) as a base monomer in their organic matrix with triethyleneglycol dimethacrylate (TEGDMA) as the reactive diluent monomer. The refractive indices of Bis-GMA, urethane dimethacrylate (UDMA) and TEGDMA are 1.55, 1.48 and 1.46, respectively.[24] Since Bis-GMA has a refractive index very close to silica filler particles, the addition of Bis-GMA to TEGDMA will increase the refractive index of the resin to more closely match that of the filler, thereby enhancing its optical match with the silica filler system.[25] Since the optical scattering[26,27] and therefore the translucency[28] of composite resins have been shown to depend on the filler particle size and filler content, adjustments to the resin composition can also be considered for adjusting the optical properties of aesthetic composites.[24,29]

1.3. Material and colour science developments

Recent developments of dental composite resins are mainly focused on reducing polymerization shrinkage and related polymerization stress,[30,31] together with improving biocompatibility,[32] wear resistance[6,11,33] and optical properties.[26,27,34–36] Achieving this balance requires manufacturers to adjust the amount, size or shape of the filler, or to modify the monomer structure or chemistry,[37] or any combination of these. The composite resin material Kalore (GC America, Alsip, IL, USA) was introduced with claims of a novel monomer technology for low polymerization stress and superior colour-blending effect to the surrounding tooth structure.

It is scientifically known[38] and visually very obvious that the colour of a translucent composite material is influenced by the interaction of the material's basic optical properties, the material's thickness and the colour of the backing. The basic or inherent shade or colour of a resin composite material and its inherent translucency depend on the colorants that are incorporated in the matrix, with the particles of filler and their interaction with the matrix potentially having a significant effect.[26–28] The inherent colour and translucency are largely determined by the visible spectra of absorption and scattering of light within the material in combination with the spectra of the illumination.[39] An accurate reflectance theory for translucent materials may be used to calculate the optical absorption (*K*) and scattering (*S*) coefficients that are wavelength-dependent, based on spectral reflectance measurements over ranges of thickness of the material and of reflectance of the backing.[38] Unfortunately, it is not easy to accurately describe the inherent colour under various illuminants and the translucency of a material based directly on optical absorption and scattering coefficients. However, an accurate reflectance theory may be used to predict the spectral reflectance at any thickness and backing, which then permits the calculation of colour for any illuminant at any thickness on any backing using the CIE method of colour calculation.[39] The inherent colour of a translucent material, which is its colour at optical infinite thickness on any backing, and the translucency[40] at one or more clinically important thicknesses may be used to provide basic or inherent optical characterization of an aesthetic dental restorative material.

Since resin formulation influences optical properties of a resin composite,[41] materials containing different monomer formulation might exhibit differences in colour and translucency. Furthermore, differences in the filler size, shape and loading fraction play a major role in optical characterization as described above. Using previously derived optical absorption and scattering coefficients for materials of claimed differing formulations,[38] more clinically applicable aspects of colour