REVIEW ARTICLE

RECENT ADVANCES IN COMPOSITE RESTORATIONS: A REVIEW

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ABSTRACT
Dental caries (tooth decay) is a prevalent disease. Resin composites have become the most commonly used materials to restore caries due to their direct-filling capability, tooth-coloredesthetics, and photo cure-on-demand property. Patients' high aesthetic demands drive modern restorative dentistry to move forward toward adhesive, tooth-colored restorations. The limited longevity of dental composite restorations due to the bulk/marginal fracture and secondary caries as well as possible health risks are the critical challenges faced by such materials. Therefore, developments of resin-based dental composites received considerable attention in academic researches for clinical applications. This article provides an insight that paves the way for tailoring and designing resin-based dental composites for clinical applications.
Keywords: Resin composites, esthetics, secondary caries, photo cure.

INTRODUCTION

Among the several resin-based materials used for direct dental restorations, manufacturers offer a wide array of composites suitable for anterior and posterior teeth. These materials greatly differ from each other in terms of characteristics of their inorganic filler, which is known to influence the viscosity and handling of the material,[1] as well as its physical properties.[2,3]The composite strength is maximized when a substantial amount of evenly dispersed filler particles is embedded in the resin matrix.[4] Even if in a manner that lacks consistency in the plethora of dental literature, resin-based composites are usually classified according to their filler characteristics, such as chemical composition, shape, and especially particle size.[5]According to the literature review by Eltahlah et al.[6], resin-based dental composites (44%), amalgams (40.9%), glass ionomers/resin-modified glass ionomers/dental compomers (13.4%), and other types of restoration (e.g., indirect and temporary restorations) (1.7%) have been used as dental restorative materials since 1981. Placement of restorations are divided into two groups: 1) initial restoration placement due to primary caries and non-carious defects and 2) restoration replacement that is reported to be performed for more than half of the initial restorations due to secondary caries, bulk/marginal fracture, poor anatomic form, and bulk/marginal discoloration. The trend of using resin-based dental composites instead of amalgam is increasing in dentistry.

Annual failure rates of up to 3–11% have been reported for dental composite restoration in posterior and anterior teeth. Secondary caries and bulk/margin fracture of the dental composite are the main reasons for restoration failures.[7,8,31] From the material properties perspective, health risks and limited longevity of resin-based dental composite materials have been generally related to the complicated interaction of high surface bacterial biofilm formation tendency, polymerization shrinkage related strain and stress, low fracture toughness (FT), incomplete degree of monomer conversion (DC), high water sorption (WS) and water solubility (WSl), and the possibility of human exposure to bisphenol-A.
Nano/micro-sized fillers with different shapes including particulates, fibers, whiskers, plate-like, and nano-porous structured fillers are discussed, while it is attempted to draw specific trends and mechanisms related to the characteristics of the filler phase, which influence the properties of dental composites.This article reviews the most recent developments of these novel bioactive composites that not only restore the decayed tooth structures but also possess therapeutic and self-healing functions.

ADVANCED LOW-SHRINK MONOMER TECHNOLOGY

1. SPIRO-ORTHO CARBONATES

The use of expanding monomers “spiroortho carbonates” (SOC) was the first attempt for manufacturing a low-shrink composite resin restoration. The double-ring opening polymerization of spiroortho carbonate (SOC) monomers offers a viable route of expansion during polymerization. Due to its relatively complex monomer synthesis pathways, and the low modulus of elasticity and low molecular weight of ring-opened SOC polymers obtained by a cationic polymerization mechanism, these materials have not been widely used in the dental market. The addition of epoxy resins (cured by cationic polymerization) to SOC-based composites seemed to be a potential way of reducing of polymerization shrinkage.[9,30]

2. SILORANE

Silorane is one of the recently discovered low-shrinkage dental composites.[10,29] The name silorane is derived from the combination of siloxanes and oxiranes. The siloxane backbone was introduced in order to provide the hydrophobic nature, and consequently, increase long-term success of these composite restorations.

NANO-FILL COMPOSITES

Nano is derived from “νανος” the Greek word for dwarf. Nanotechnology involves the production and use of materials that have at least the dimensions of a hundred nanometers. A nanometer is 10–9 m, or one billionth of a meter. By comparison, a human hair is about 80,000 nm width. In 2003, Mitra et al.[11,28]used an aqueous colloidal silica sols to synthesize dry powders of nano-sized silica particles (20 and 75 nm in diameter). They treated the silica particles with 3-methacryloxypropyltrimethoxysilane (MPTS) using a proprietary method. This organic component is a bi-functional material, and well-known as a “silane coupling” agent. Hence, they developed novel nanofiller composites using an advanced methacrylate resin matrix and curing technologies. The superior aesthetic of nanofill composites is attributed to its ultra-small filler size, which allows minimal scatter of the light, resulting in the inability of the human eye to distinguish the particles. Also, the application of nanoparticles to composite resin increases the wear resistance of these restorative materials. In summary, incorporation of nanofillers into resin-based composites can reduce the polymerization shrinkage and improve the mechanical properties, as well as significantly enhance the aesthetics.[12,22]

FLOWABLE COMPOSITES

A class of low-viscosity resin composites referred to as “flowable composites” were introduced in dental markets. The flowability of these restorative materials aids in improving handling characteristics and simplifying placement techniques. It is well known that the lower the Young’s modulus of elasticity, the greater the flexibility of the material. The application of flowable composite as an intermediate layer at the internal cavity line angles may decrease the polymerization contraction stresses. In 1998, Bayne et al. [13,23]evaluated the effect of flowable composite applicationson polymerization contraction stresses generated within resin-based restorations.Many authors, including Bayne et al., revealed that this approach can reduce the polymerizationcontraction stresses. However, the author expressed a major concernabout the research outcome, due to the inferior mechanical properties of flowablecomposites compared with traditional hybrid composites.

BULK-FILL COMPOSITES

As the result of contentious development of low-shrink monomers, a novel categoryof resin composite restorations was recently introduced .[14,24] Bulk-fill compositescan be placed in relatively thick layers (approximately 4 mm in thickness), whichmay save the clinician’s time and simplify the application technique. The recenttechnology mainly depends on novel improvements of the resinous components ofbulk-fillcomposites, as well as, a significant enhancement in the photo-initiatorsystems. The first generation of bulk-fill composites was available in flowableform, and required a capping layer of conventional resin-based composite material.Nowadays, bulk-fill composites are provided in body form, and the whole restorationcan be built-up by a bulk-filling technique.

SONICATED BULK-FILL COMPOSITES

The latest generation of bulk-fill composite systems is based on the application ofsonic-power during the insertion of the materials inside the cavities.[15,25] The manufacturerof these systems claimed that incorporation of sonic power increases theflowability of the material without compromising the resin/filler ratio. Also, as a bulkfillcomposite, the photo-initiator systems were significantly improved. Although thiscategory of restorative materials requires special delivery instruments, it can be consideredas a promising restorative alternative to the current conventional systems. Themajor concern about this category of restorative materials is the adverse effect of sonicpower “vibrations” on the mechanical properties of the early-gel stage of cured resin.Also, the survival rate of these restorations is still a questionable/controversial topic.

SHORT FIBER-REINFORCED COMPOSITE RESTORATIONS

Throughout its well-documented history in industry application, fiber-reinforced composite (FRC) technology is constantly evolving as a result of innovative treatment solutions. Utilizing different types of fibers with various orientations and lengths is quite an old idea in engineering and in architectural applications to construct devices with high strength and fracture toughness. The use of FRC in dental applications has been discussed in the literature since the early 1960s.[16] Today, fiber reinforcement has become an effective material of choice within restorative dentistry. In 2013, short fiber-reinforced composite (SFRC) (everX Posterior; GC, Tokyo, Japan) was introduced to the market with the goal to mimic the stress absorbing properties of dentine. The SFRC material is intended to be used as bulk base in high stress-bearing areas for restoring vital and non-vital teeth. It consists of a combination of a resin matrix, randomly-orientated E-glass fibers, and inorganic particulate fillers. The resin matrix contains bisphenol-A-diglycidyl-dimethacrylate (bis-GMA), triethylene glycol dimethacrylate, and polymethylmethacrylate, forming a matrix called semi-interpenetrating polymer network (semi-IPN), which provides enhanced bonding properties for repairs and improves the toughness of the polymer matrix.[17,26]

ANTI-BIOFILM POLYMERIC COMPOSITES

Currently-available dental polymeric composites lack antibacterial properties.[18] Efforts have been devoted to produce novel anti-biofilm polymeric composites.[19] Leachable antibacterial agents, such as chlorhexidine (CHX), silver, and fluoride were integrated into dental polymers .[20] Among them, silver or silver ion-implanted fillers showed a strong antimicrobial activity. Ag ions can lead to cell death by inactivating the vital enzymes of bacteria and cause bacterial DNA to fail in its replication property. Compared with traditional large particles, metal oxide nanoparticles (NPs) were more effective to both gram-positive and gram-negative bacteria due to their small sizes and high surface areas. However, the efficacy of releasable agents was short-lived due to the initial burst releaseand the diminished release in the long-term.[21,27,31]

CONCLUSION

In light of the aforementioned discussions, it is evident that dental composite materials are a complex system due to material related factors affecting their physical, mechanical, and chemical properties to satisfy the clinical expectations inside the harsh oral environment conditions. desired properties for their applications. However, the enhancement of different properties may contrast each other adversely, which add to the complexity of the design of optimized dental composites formulations. Based on the scope of study of this review article, it is suggested that modification of organic resin matrix of a dental composite play a more significant role regarding the reduction of polymerization shrinkage-related strain and stress compared with the modification of the filler phase characteristics. Filler phase characteristics play a more significant role regarding the development of the mechanical properties of dental composites such as modulus, strength, fracture toughness, fatigue life, hardness, and wear resistance compared to the modification of organic resin matrix. It was comprehended that content, size, distribution, shape, porosity, and surface modification of filler particles are very important for designing a filler phase with efficient packing and enhanced filler-matrix interactions in order to provide exceeding improvement into the mechanical properties of dental composites as well as maintaining acceptable DC and depth of cure. Multifunctional composites achieved antibacterial, remineralization and self-healing functions by incorporating antibacterial agents, remineralizing materials and self-healing microcapsules. The combination of novel bioactive and therapeutic agents and nanoparticles is a promising strategy to overcome the existing problems, increase the servicetime of dental polymeric composites, regenerate minerals and protect tooth structures.

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