World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

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Recent advances in newer generation composites: An overview

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World Journal of Advanced Research and Reviews, 2022, 14(02), 100–103

Publication history: Received on 01 April 2022; revised on 04 May 2022; accepted on 06 May 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.14.2.0403

Abstract

Composite restorative materials represent a class of unique modern biomaterials since they replace biological tissue in both appearance and function. The early formulations were characterized by problems such as polymerization shrinkage, improper marginal adaptation, inappropriate proximal contact, discoloration or staining and also secondary caries. The need to improve said properties and achieve adequate contact is necessary for dental composites and numerous attempts have been made to accomplish these aims. Newer generation composites have been produced in order to protect the healthy tooth structure, to reduce microleakage and secondary caries formation, increase fracture toughness and to reduce marginal pigmentation and postoperative sensitivity together with developments in technology. This article discusses the advances in resin restorative materials.

Keywords: Words: Antimicrobial; Self- Healing; Self-Adhesive; Nano-Composites

1. Introduction

Composite resins have been introduced into the field of conservative dentistry so as to reduce the drawbacks of the acrylic resins that had replaced silicate cements in the 1940s. Composite restorative materials are successful in modern biomaterials research, since they replace biological tissue in both appearance and function. The advantages of resin based restorative materials include tooth-like appearance, simplistic material manipulation and relative insolubility in oral fluids. The development and implementation of newer composite materials rely on a comprehensive understanding of the individual components of the composite and methodical considerations for changing each component. The purpose of this article is to discuss newer resin systems exhibiting substantial improvements in clinical performance [1].

2. Antimicrobial Composite

Silver and titanium particles were introduced into dental composites, respectively, to introduce antimicrobial properties and enhance biocompatibility of the composites [2]. Microbes are subsequently killed on contact with the materials or through leaching of the antimicrobial agents into the environment [3]. Dental composites comprised of 1% (w/w) quaternary ammonium polyethylenimine (PEI) nanoparticles were tested for their antimicrobial activity. The antibacterial properties of these composites were leaching. Introduction of the PEI nanoparticles had not significantly affected the mechanical properties. It was observed that the antimicrobial effect lasted for at least 1 month [4].

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Derivatives of alkylated ammonium chloride [5] and chlorhexidine diacetate [6] have also been presented as antimicrobial agents into dental composites.

3. Nano-composites

Nanotechnology may provide composite resins with a significantly smaller filler particle size which can be dissolved in higher concentrations and polymerized into the resin system [7].

The average particle size of nano-filler ranges from 1-100 nm. The properties of these composites are shape and size determinant [8]. The nano-filled resins are as strong as the hybrid and micro-hybrid resins owing to the fact that they occupy approximately 60% volume filler loading. The nano-fillers contain nanomodifiers such as the nanomers and nanoclusters which lead to an increase in flexural strength and modulus of elasticity, improved wear resistance and hardness, decreased polymerization shrinkage and enhanced polishability of the resin. Inceram X from Dentsply is an example of nanofillers that include colloidal silica or ormocers.

Another feature that is observed is the enhanced fracture toughness and adhesion to tooth tissue [8, 9, 10, 12]. Nanotechnology can improve the continuity between the tooth structure and the nanosized filler particles to provide a more stable and natural interface between the mineralized hard tissues of the tooth and the advanced restorative biomaterials [11].

4. Stimuli Response Composites

These are also known as “smart materials”. Their materialistic properties essentially depend on external stimuli such as pH, temperature, mechanical stress, moisture, etc. [12]. Stimuli responsive composites contain bioactive amorphous calcium phosphate (ACP) filler that responds to environmental pH changes by releasing calcium and phosphate ions and thereby becoming adaptable to the surroundings [13]. In 1998, this class of composite was introduced as the product Ariston pHc. In the presence of active plaque, when the pH drops to less than 5.5 in the area immediately adjacent to the restorative materials, functional ions like fluoride, hydroxyl, and calcium ions are released and therefore provides additional caries protection [14].

5. Self-healing Composites

Microcracks in a material are the precursors to structural failure [15] and the ability to heal them ensures a longer lifetime and less maintenance. Self-healing composites can be categorized into three groups: capsule-based, vascular and intrinsic self-healing materials [16]. In capsule-based self-healing composites, small capsules containing a liquid that can fill and close cracks are embedded under the material surface. Upon material damage, the cracks cause the rupture of some capsules and release the liquid to close the gap. In the epoxy composite material, if a crack occurs, the microcapsules destroyed near the crack release the resin. The crack is then subsequently filled by the resin and reacts with a Grubbs catalyst dispersed in the epoxy composite, which result in polymerization of the resin and a repair of the crack [17]. For vascular self-healing composites, a vascular structure similar to a tunnel network replace the capsules, in which various functional liquids flow. When a crack occur and the vascular network breaks, these functional liquids flow in and fill the gap. The material contained within a capsule or a vascular network is called a healing agent. Intrinsic self-healing materials heal through inherent reversibility of chemical or physical bonding instead of structure design [18] such as the swelling of shape memory polymers[19], the melting and solidification of thermoplastic materials [20], and increasing viscosities of pH-sensitive micro-gels [21, 22].

6. Self-Adhesive Composites

Self-adhering composites are also known as compo-bonds. Self-adhering flowable composite combine the advantages of both dental adhesives and restorative materials technologies (8th generation) into a single product [12, 23]. They eliminate the precursory bonding stage necessary to adhere resin to tooth substrate, and therefore reduce the chances of postoperative sensitivity. Its properties are similar to that of conventional flowable composites. Since compo-bonds also have the properties of 7th generation dentin bonding agents, they act as shock absorbers beneath the resin-based composite restoration. A longer curing time is necessary to ensure its complete polymerization as compo-bonds function both as dentin adhesive and resin restorative material [12].

7. Universal Shade Composites

Shade-matching for anterior composite restorations can be technically challenging for reasons such as the following; composite materials do not match standardized VITA shade guides [24], the material undergoes perceptible color changes after light curing [25] and variation in color based on the lighting source of the room [26]. As a result of which, several manufacturers now offer single-shade universal composites (one shade representing all VITA shades, eg, Omnichroma, Tokuyama, Japan). These universal composites are able to blend with surrounding tooth structure based on increased translucency [27].

Some single-shade universal composites take advantage of structural color, which is the use of filler particles of a certain size (260 nm) to impart a yellowish-red hue to the composite instead of using pigments [28]. The presence of a dark substructure (eg, sclerotic dentin, staining, discoloration) can affect the composite shading due to the increased translucency of single-shade universal composites. Therefore, in such scenarios an opaque blocker composite may be needed [29, 30].

8. Conclusion

There has been a significant increase in the use of composites due to its benefits such as adhesive bonding to tooth structure, improved esthetics and universal clinical usage. However, problems such as postoperative sensitivity still exist for which the development of high performance and improved restorative materials are essential to the success of dental treatment. As the esthetic demands of patient's increase, so will the usage of composite materials for restorations and therefore it is necessary to research, overcome existing limitations and develop newer composites as a restorative material.

Compliance with ethical standards

Acknowledgments

The authors thank Vinayaka Mission's Sankarachariyar Dental College and Vinayaka Mission's Research Foundation for giving the opportunity of doing this review and presenting it in this eminent Journal.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this document.

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