Dental composite materials: highlighting the problem of wear for posterior restorations

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SUMMARY

Manufacturers of dental composites promote their products as having ideal wear resistant characteristics. Evaluation of the problems that persist with wear of dental composites is made. Recommendations for further research involving wear resistance of dental composite materials are provided. This article provides a review of English, peer-reviewed literature involving wear resistance of dental composite materials conducted through ScienceDirect and hand searched data bases between 1994 and 2006.

INTRODUCTION

Evaluating wear resistant properties of dental composite materials highlights factors that have influenced the success of dental composite materials in dentistry.[1-4,6] Dental ceramic materials produce excessive wear to the opposing dentition.[5,8] In the past, manufacturers of dental composites promoted their products on the grounds that these products were the ideal wear resistant materials - in spite of views that the ideal composite material to resist wear for posterior restorations still needed to be developed.[1,5-7] Nevertheless, the use of dental composite materials has increased while improvements are continually being sought.[1,43] Due to improvements in wear resistance of dental composites, Farracane[4] questions whether the wear of dental composites is still of clinical concern. This article provides recommendations pertaining to whether further research involving wear resistance of dental composite materials for posterior restorations is needed.

Attempts to improve wear resistance of dental composites

Historically dental composite materials did not provide the wear resistant properties sought for posterior stress-bearing areas.[1,2,6] Excessive force exerted on the dental composite material over time may produce fatigue that is related to the amount of wear.[42,43] Although the initial use of dental composite materials was extensive in the anterior region where the biting force is reduced, dental composite materials were used with limited success for posterior restorations.[6,8] Even with new improvements and developments in dental composite materials continually taking place, it is difficult to determine whether the ideal wear resistant characteristics for these materials have been produced for all composites.[1,3,4,6,12,20,24-28,37-43]

More recently dental composite materials have been reported to provide acceptable wear resistance in posterior stress-bearing areas for small restorations.[4] Insufficient evidence to support acceptable wear resistance from the same dental composite materials for larger restorations suggests that wear for small restorations is less significant since it was found that the material in these cases need not resist wear in functional cusp areas.[4] Although in vitro tests have been used extensively in order to speed up the assessment of wear of dental composites, the need for their continued use has also been questioned.[4] The literature contains conflicting reports on the ability to predict the wear-resistant properties of composites since the *in vivo* wear resistance of resin based dental restorative materials is complex in nature.[9] In a comparison of the wear resistance of 10 indirect dental restorative materials in five wear simulators it was found that relative ranks of the materials varied tremendously between the test centres.[12] Failure of large dental composite restorations due to wear or fracture, however, still occurs and justifies the need to continue with accurate, reproducible *in vitro* wear testing of dental composite restorations.[4]

Dental composites consist of a compound of two or more distinctly different materials. Filler particles with more desirable physical properties are incorporated into the resin. These filler particles significantly improve the matrix material if they are bonded well to the resin matrix.[6-8,10,14-17,23] Bis-phenol-glycidal-methacrylate (bis-GMA) developed in the 1960s was the first successful resin material used for dental composites[ma-ter]. Most research and development of dental composite materials has only been done since 1965 with short chain polymers like urethane-dimethacrylate (UDMA), triethylene glycol dimethacrylate (TEGDMA) or decandiol-di-methacrylate added to the matrix in order to improve cross linking chains and physical properties.[7,38] The success of dental composite materials depends largely on silane bonding that allows for good adhesion between the filler material and the matrix. Without adequate adhesion being provided by silane bonding the filler particles act as stress concentrators that weaken the mechanical properties of the material[8]. The need for adequate silane bonding was further seen because as the silane bond deteriorates with time and with water absorption, the composite material became weaker.[44,54] Such a reaction would influence the wear since it was also found that there is a positive correlation between wear resistance and impact strength.[52].

Initially filler particles were produced from grinding quartz or glasses, to produce a range of particles from 0,1 to 100 μm. Filler particles less than 0,1 μm were used to fill in spaces between larger particles and provide improved wear-resistant characteristics.[8,40] There appeared to be a critical value of filler particle size between 1,3-1,5 μm that reduced wear of these early dental composites because the food fibres are unable to penetrate the inter- particle spaces.[40] Establishing these initial trends resulted in composites that use filler particles in the nanometer range in order to further improve wear resistance.[52]

Problems with wear resistance of dental composites

Wear patterns and an understanding of the resistance of restorative materials to wear, have become more complex. Previous theories that wear resistance was directly proportional to hardness of dental materials have been discarded.[9] The property of wear resistance is complex, with no direct relationship between hardness and wear resistance except in limited materials of similar composition.[5, 8,10] Mandikos *et al*,[9] and Callaghan *et al*,[43] did establish that significant relationships were observed between depth of wear and hardness in a comparison of wear resistance and hardness of dental composites. Dental composite materials, therefore, fall within the limited range of materials that provide a relationship between hardness and wear resistance. This relationship, however, needs to be tested to establish trends within a wider selection of dental composite materials.

Rough surfaces, high loads, high sliding speeds and the type of apposing surface - as well as three body wear with saliva and food particles as the third body - have been reported to influence the wear-resistant properties of the materials due to an increase in the coefficient of friction.[4,5,11,20,27,39-43] Acidic and or alkali chemical environments are detrimental to wear resistance of enamel and dental ceramics and the pH must remain as neutral as possible.[5] Since the literature did not supply desired information regarding the influence of pH changes on wear of dental composite materials, the authors recommend that investigations be done to determine whether dental composite materials provide more favorable wear resistance during pH changes compared to enamel and ceramic. It has been reported that abrasion due to tooth-brushing of dental composites is undesirable and varies in accordance with the material.[11]

Adhesive bonding

Success in dental composites is due to the silane adhesive bonding agent. There is sufficient evidence to show that fillers would weaken the composite material without silane adhesive bonding.[8,44,52,54] The particles would act like stress concentrators that initiate separation of the different types of material[8]. Resin materials will not normally bond to glass since the surface of glass readily adsorbs water. This reduces the wettability of resin to glass resulting in a poor bond. Pioneer work in dental composite materials involved overcoming this weak link with silane, a bipolar molecule consisting of a methacrylate group at one end and a silanol group at the other[13]. This permitted the methacrylate group to bond to the resin while the silanol group bonded to the glass as a result of the condensation reaction as the silane dried.[13] Although this formed a strong chemical bond between the glass and the bis-GMA, more recently multifunctional urethane and thioether(meth) acrylate alkoxysilanes have been developed as dental restorative materials for the synthesis of inorganic–organic copolymer ormocer composites. The methacrylate groups are available for photochemically induced organic polymerization while the alkoxysilyl groups of the silane allow the formation of an inorganic SiOSi network by hydrolysis and polycondensation reactions.[55]

The literature to enable an understanding of the silane bonding mechanism for bonding resins to non-etchable filler materials such as zirconia and alumina, is limited. For successful silanization with non-etchable filler materials, different combinations of conditioners and silanes are recommended for different materials and further research is required to improve these bonding mechanisms.[49]

Research in dental composites

To date, studies[7,21,22,23,43] in wear resistance have been directed mainly at comparing and evaluating wear-resistant patterns of existing dental composite materials, improving wear resistance by changing the filler content, introducing changes to the resin matrix to improve physical properties, or improving the adhesive bond between filler and matrix. A study using electron beam irradiation was shown to improve wear resistance of dental composites by reducing chain entanglement. However, the resultant colour effects were found to be detrimental.[38]

Applequist and Meiers[19] suggested that glass/ceramic inserts be placed in composite restorations in order to improve the wear resistant properties of posterior restorations, but fractures or flaking of restorations as well as rough or pitted surfaces between the composite and insert reduced the success of such restorations.[19] More desirable results were initially achieved with micro-filler composites than with macro filler.[20,40] In recent years nanoparticles and hybrid nanoparticles–microparticles as fillers have been reported to increase wear resistance.[52,56,57] The shape of filler was also found to be of significant interest with regard to the properties of dental composite materials. The strengthening mechanism due to fibre reinforcement through the incorporation of whiskers or fibres appears to be effective as a result of their desirable shape and orientation.[22-24] The advantages of whiskers on their own as composite filler material have been shown with regard to physical properties only.[22] Fibre reinforcement depends on additional variables such as type of fibres, percentage of fibres in the matrix, modulus and distribution of the fibres, fibre length, and form.

Irregularly shaped particles provided better wear resistance than smooth round fillers.[39,40,43] The importance of filler shape for dental composites may be understood better by considering a study in which Jagger *et al*[21] eliminated the bonding and modulus variables that may exists as a result of different materials (in dental composite materials) and replaced poly(methylmethacrylate) (PMMA) fibres with PMMA beads (in PMMA acrylic). Jagger *et al* discovered that the beads were not as effective as the fibres.

Different sized particles have resulted in a smoother polished finish, and greater strength benefits have been achieved by producing more compaction between filler particles[55]. Hybrid composite fillers that are formed by combining two types of filler materials, fall into a category of composites that are superior to those containing only one type of filler material[8]. The advantages of hybrid composites are the close compaction of filler particles combined with an improved strengthening mechanism. Further advantage is gained by reducing the filler particle size[52,56,57] and including organic filler particles. Ormocer composites (organic modified ceramics) combine inorganic constituents such as glass with organic (polymer) constituents to provide a packable composite material with handling properties of a hybrid composite material.[55] Influence of the flexibility of composites on marginal leakage due to the plasticity of resin should be studied. Marginal leakage may occur as a result of stress and wear that causes deformation to the bonded composite around the margins.[26,27] The problem with composite restorations is the occurrence of secondary caries as the composite material breaks down around the margins.[19,28-37] When a restoration fractures it is simply replaced to prevent further clinical problems. However, when the composite material breaks down around the margins, it is difficult to detect clinical problems such as secondary caries. The health of a tooth may also be jeopardized as a result of delayed treatment.[30] As a result, factors that prevent flexure and improve wear-resistant properties should be tested with regard to preventing clinical problems, thereby preventing marginal leakage, marginal breakdown, and chipping of dental composite restorations.

SUMMARY

Dental composite materials are constantly being tested and developed in order to produce the desirable properties of wear resistance, strength, resistance to shrinkage, colour stability, aesthetics, surface finish and cementation. Based on the literature review, it is recommended that factors that decrease flexibility while increasing flexural strength and wear-resistant properties should be tested in order to prevent marginal leakage and chipping of dental composite restorations while preserving tooth structures as far as possible. Silane bonding agents should also be improved since they deteriorate with time. Further investigation is required regarding silane bonding between non-etchable fillers and resin materials. In addition, further studies to determine the influence of pH on the wear of dental composites and the time related silane deterioration within the composite material are necessary. Accurate reproducible *in vitro* wear tests on dental composite materials still need to be performed for large cusp bearing restorations.

CONCLUSION

Improvements in dental composite materials between 1990 and 2006 have resulted in wear-resistant properties that are more suitable for posterior restorations than the early composite materials. The complex nature and continued problems of wear of composite restorations require further solutions for large composite restorations before they can be considered to possess the ideal wear-resistant properties.

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