

What Is a “Compomer”?

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A b s t r a c t

“Compomers” are recently introduced products marketed as a new class of dental materials. These materials are said to provide the combined benefits of composites (the “comp” in their name) and glass ionomers (“omer”). Based on an critical review of the literature, the author argues that “compomers” do not represent a new class of dental materials but are merely a marketing name given to a dental composite.

MeSH Key Words: composite resins; dental cements; glass ionomer cements.

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Dental materials science, to paraphrase a definition of materials science,¹ is primarily concerned with the search for basic knowledge about internal structure, properties and processing of dental materials. The aim of this paper is to analyze from a dental materials science point of view a recently introduced dental material marketed as “compomer”. To facilitate the discussion, a brief review of dental composites and polyalkenoate cements, in particular glass-polyalkenoate cements or glass ionomer cements (GICs), is necessary.

Dental Composites

A composite is “a material system composed of a mixture or combination of two or more micro- or macro-constituents that differ in form and chemical composition and [that] are essentially insoluble in each other.”¹ To generalize and simplify, composites have two main constituents: the matrix and the filler. The matrix forms a network that provides the structural skeleton of the composite, and the filler imparts its mechanical properties onto those of the composite.

The filler has to be intimately bonded to the matrix to fulfil its role. Based on their dominant dimension (length, width, thickness), fillers can be classified as spherical (no dominant dimension), fibres (length is dominant) or flakes (length and width are dominant). The percentage of volume occupied by the filler (V_f [volume fraction filler]), the orientation of fibre-type fillers and the aspect ratio of flake-type fillers are crucial in determining the properties of a composite. The effect of V_f of spherical fillers on the modulus, for instance, follows an exponential curve, which becomes significant beyond 60% (Figure 1).² This relationship has been used as the rationale in

a proposal for the classification of dental composites.³ Metals, ceramics and polymers can form either the matrix or the filler. Pigments, antioxidants, inhibitors, preservatives and antimicrobials are some other possible minor constituents of composites.

Dental composites are polymer-ceramic materials in which methacrylate and dimethacrylate monomers polymerize to form the matrix and glasses, ceramics or glass-ceramics are incorporated as spherical fillers. Among the most commonly used dimethacrylate monomers are 2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy)phenyl]propane (BIS-GMA), 1,6-bis(urethane-ethyglycol-methacrylate)2,4,4-trimethylhexane (UEDMA) and triethyleneglycol dimethacrylate (TEGDMA). To ensure bonding between the filler and the matrix, the filler particles are coated with silane-coupling agents that contain a

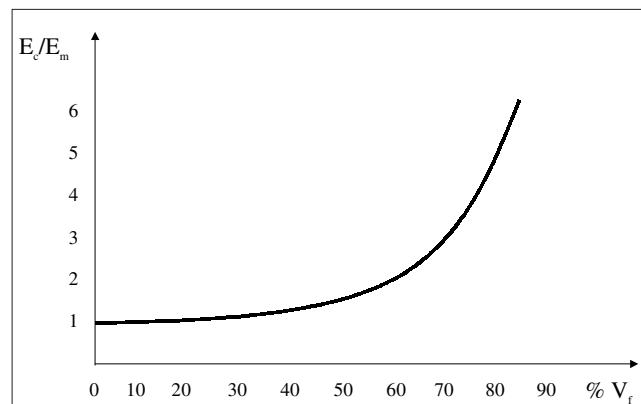


Figure 1: The effect of volume fraction filler (V_f) on the modulus of elasticity of composite (E_c) in relation to the modulus of elasticity of the unfilled resin matrix (E_m).

methacrylic group able to co-polymerize with the matrix-forming dimethacrylate monomers and functional groups able to interact with the filler. The quality and extent of the silane coating significantly affect the properties of composites.⁴

The best available hybrid composites have mechanical properties that are far from ideal for a restorative material. An ideal restorative material should have properties that match those of the hard tissue that it is supposed to replace. From a structural point of view, matching the modulus of elasticity is the most important consideration. Matching the compressive strength, fracture toughness, coefficient of thermal expansion and other properties are secondary considerations. The modulus of dentin is approximately 18 GPa and that of enamel is approximately 80 GPa; the modulus of hybrid and posterior composites (including laboratory-processed ones) ranges from 15 to 25 GPa. Hybrid and posterior composites have adequate stiffness to replace dentin but are far from approaching the stiffness required to replace enamel. The stiffest dental composite has the ability to "flex" three times more than enamel, a fact that clearly contradicts the arguments of those who advocate the use of more flexible composites.

Polyalkenoate Cements

The developments of zinc polycarboxylate cement (ZPCC) by Smith⁵ and of GICs by Wilson and Kent⁶ are considered important milestones in the history of dental materials. ZPCC and GICs have two common features: (1) they set via an acid-base reaction in an aqueous environment, thereby complying with the general definition of dental cements; and (2) the acid component is an alkenoic acids polymer (Figure 2). The ratio of carboxylic groups to backbone carbon atoms is approximately 1.5:2. The "base" in ZPCC is zinc oxide, and in GICs it is an ion-leachable (sodium) calcium fluoroaluminosilicate glass. Zinc crosslinks the poly(acrylic acid) chains leading to the setting of ZPCC. Calcium and aluminium from the ion-leachable glass crosslink the acrylic-maleic-itaconic copolymer chains (Figure 3), leading to the setting of GICs.^{7,8} The carboxylic groups of the polyalkenoic chains can chelate

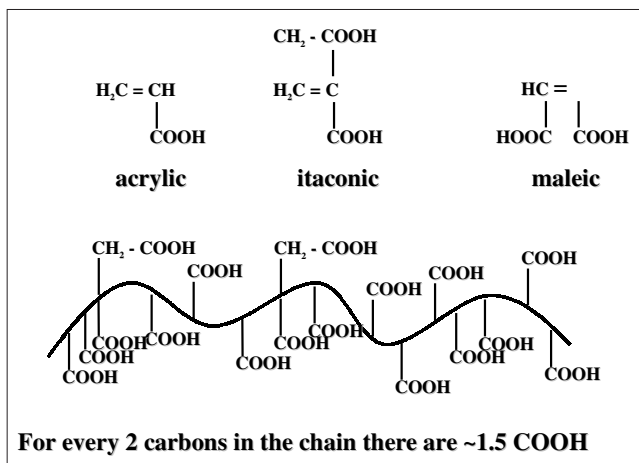


Figure 2: Three alkenoic acid monomers and a schematic representation of a polyalkenoic acid present in GICs.

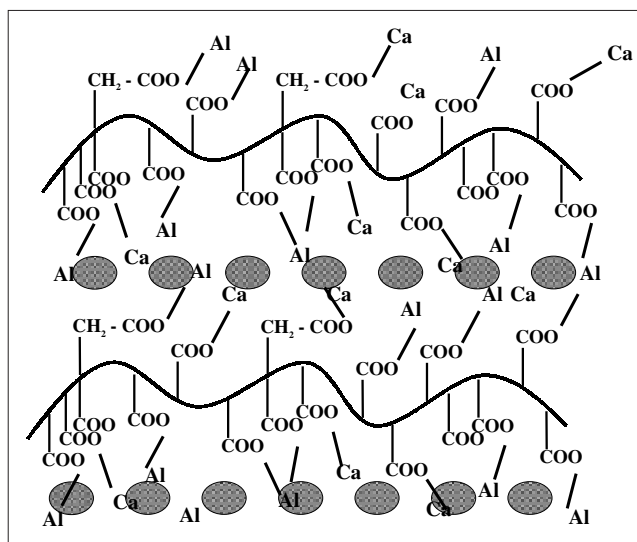


Figure 3: Schematic structure of set GICs.

the calcium of the hydroxyapatite to bond the cement to mineralized hard-tooth tissues.^{9,10} The ability to bond to mineralized hard-tooth tissues represents a major benefit of both ZPCC and GICs.

The acid-base reaction that leads to the setting of GICs results in calcium, aluminium, sodium, fluoride and silicate ions being released from the acid-soluble glass. A silicagel layer rich in fluoride surrounds the unreacted glass particles. Water sorption-desorption facilitates an ion exchange between hydroxyl (OH⁻) and fluoride (F⁻) ions — ions that have similar radii. As a result of this exchange, fluoride can be released from a set GIC into the surrounding environment. It has been suggested that the release of fluoride from GICs has beneficial effects in overall caries control,¹¹ but this suggestion is still under debate.¹² Nevertheless, the release of fluoride is considered to be the second major benefit associated with GICs.

From a structural point of view, a set GIC is a composite in which the unreacted glass particles are the filler and the calcium-aluminium crosslinked polyalkenoate chains form the matrix. The reaction products surrounding the glass particles mediate an intimate bonding between the filler and the matrix. Ionic bonds are responsible for the crosslinking of the polymeric chains and the setting of the cement; however, a large number of secondary bonds are present and play a significant role in determining the mechanical properties of the cements. GICs are brittle, have a low modulus of elasticity, are weak in tension and have low fracture toughness. Their relatively poor mechanical properties limit their usage as a restorative material.¹³ A significant effort has been made over the years to improve the mechanical properties of GICs while maintaining their two major benefits: adhesion to hard-tooth tissues and fluoride release. These efforts have followed two approaches, one focused on the filler and the other focused on the matrix.

There have been two major attempts to improve the mechanical properties of GICs by modifying the filler (ion-leachable glass). One approach was to substitute some of the

glass with silver-tin-copper amalgam-alloy particles¹⁴ under the erroneous hypothesis that the presence of metal filler would impart some of its properties onto the set material. Both in vitro and in vivo results were disappointing, and the approach was abandoned. A second approach was to change the properties of the acid-soluble glass by incorporating in its structure a metal constituent (silver), thus creating a “cermet” (ceramic-metal) filler.¹⁵ Cermet-ionomer cements are still on the market, although their usage is limited to just a few applications. This approach has proven more successful than the one previously described; however, the resulting slight improvements in some mechanical properties were offset by decreases in others,¹⁶ by the release of silver ions and by a decreased release of fluoride.^{17,18}

Resin-Modified GICs

The second approach to improving the mechanical properties of GICs focused on the matrix. Improvement has been achieved by grafting unsaturated carbon-carbon bonds onto the polyalkenoate backbone, by incorporating (di)methacrylate monomer(s) into the composition or by doing both.^{7,19-21} The presence of unsaturated carbon-carbon bonds enables the covalent crosslinking of the matrix via free radical polymerization reactions (chemically or light activated). A covalently crosslinked matrix significantly improves the mechanical properties of the set cements.²²⁻²⁶ These cements are well tolerated by the pulp,^{27,28} although some biocompatibility concerns have been raised because of the release of resin components (i.e., hydroxyethyl methacrylate, or HEMA).²⁹ It has been proposed that these types of GICs be called resin-modified glass ionomer cements (RMGICs),³⁰ although “resin-modified glass polyalkenoate cements” might have better described their structure. RMGICs are water based, an acid-base reaction is the main setting mechanism, they maintain the ability to bond to hard-tooth tissues via the carboxylic groups of the polyalkenoate component,^{24,31-34} and they have levels of fluoride release similar to GICs.³⁵

“Compomers”

Shortly after the introduction of RMGICs, “compomers” were introduced to the market. They were marketed as a new class of dental materials that would provide the combined benefits of composites (the “comp” in their name) and glass ionomers (“omer”). These materials have two main constituents: dimethacrylate monomer(s) with two carboxylic groups present in their structure (Figure 4), and filler that is similar to the ion-leachable glass present in GICs. The ratio of carboxylic groups to backbone carbon atoms is approximately 1:8. There is no water in the composition of these materials, and the ion-leachable glass is partially silanized to ensure some bonding with the matrix. These materials set via a free radical polymerization reaction, do not have the ability to bond to hard tooth tissues,³⁶ and have significantly lower levels of fluoride release than GICs.³⁷⁻⁴⁵ Although low, the level of fluoride release has been reported to last at least 300 days.⁴⁶ The delayed (post-cure and post-water-sorption) acid-base

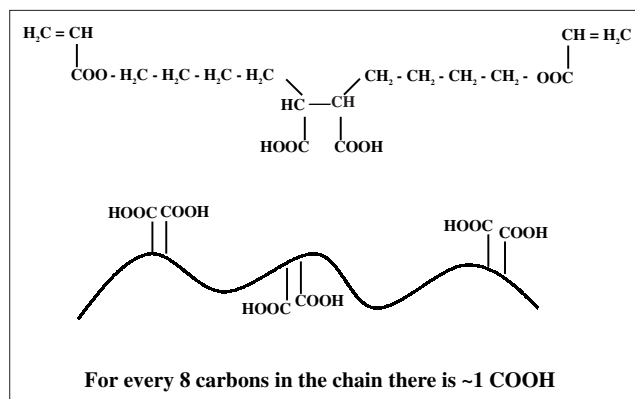


Figure 4: Schematic structure of a dicarboxylic monomer used in “compomers”.

reaction between sparse carboxylic groups and areas of filler not contaminated by the silane coupling agents is speculative⁴⁷ and is probably insignificant to the overall properties of these materials.

Based on their structure and properties, these materials belong to the class of dental composites.⁴⁸ Often, they have been erroneously referred to as “hybrid glass ionomers”,^{49,50} “light-cured GICs”,⁵¹ or “resin-modified glass ionomers”,^{25,38,52-54} along with the “genuine” resin-modified GICs. The proposed nomenclature for these materials as polyacid-modified composite resins,³⁰ a nomenclature that is widely used in the literature, may over-emphasize a structural characteristic of no or little consequence. Considering the low volume fraction filler and the incomplete silanization of the filler, it could be postulated that they are inferior composites. Both in vitro and in vivo investigations have confirmed this expectation. Lower flexural modulus of elasticity,^{48,55-57} compressive strength,^{48,55,57} flexural strength,^{48,56,57} fracture toughness and hardness,⁵⁸⁻⁶⁰ along with significantly higher wear rates^{58,61-64} compared to clinically proven hybrid composites, have been reported for these materials. Their clinical performance received mixed reviews in in vivo clinical trials.^{42,62-66} With the exception of concerns about the release of HEMA from these materials,²⁹ no other biocompatibility issues have been associated with their usage.^{67,68} Their applicability as orthodontic adhesives,^{69,70} amalgam bonding systems⁷¹ and veterinary restorative materials⁷² has also been reported.

Constant re-formulations of these types of materials may eventually lead to them being comparable or even superior to existing composites, but, as long as they do not set via an acid-base reaction and do not bond to hard-tooth tissues, they cannot and should not be classified with GICs. They are, after all, just another dental composite.

Dental practitioners should have a good understanding of basic dental materials science principles to enable them to critically assess the plethora of new materials that are constantly being introduced and aggressively marketed. By knowing the structure of a material, practitioners can predict its properties and assess its suitability for particular applications. It is important, therefore, that the classification and the nomenclature of dental materials be based on their structure to maximize the

conveyance of relevant structural information. The concept of a continuum that encompasses glass-polyalkenoates, resin-modified glass-polyalkenoates and composites (including "compomers")^{43,57} could only exacerbate the existing confusion and misunderstanding about these materials.

It is also advisable for practitioners to request long-term *in vitro* and *in vivo* independently acquired evidence of the performance of a material before deciding to use it. Unfortunately, many of these materials have market lives shorter than the time required to adequately assess their performance. Avoiding such short-lived materials may well be beneficial for both practitioners and patients. ♦

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