GLASS-IONOMER CEMENTS, THE INTERESTING ALTERNATIVE FOR RESIN-BASED COMPOSITES

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Introduction

There is a continuous urge for novelties in dentistry originating from changing professional perceptions, changing demands from the patient and progress in industrial possibilities. The altering professional perceptions come along with raising consciousness that cariestreatment is not merely technique, but requires a bio-medical approach, that less-invasive techniques are possible, that bio-compatibility requires increased interest, that there are challenging new possibilities and that there exist new markets (Davidson, 2003).
The patient has changed as they demand more esthetics, established bio-compatibility and lower costs. Today's dentistry can be characterized by a move away from metal towards non-metal restorations. Motivation is mainly based on concern for esthetics and biocompatibility.
In direct restorative dentistry this means a shift from amalgam to composites. For direct restorations, three essentially different materials are at our disposal: amalgam, resin-based composites and glass-ionomer cements.

Amalgam

Of all direct dental restorations in the Netherlands, in 1993, 30% were performed in tooth colored alternatives for amalgam; in 1997 this number was 50% and in 2002 this number was 70%! Restoring in tooth colored materials is nowadays the first option in the teaching programs at the dental schools in the Netherlands.
The multi-phase silver amalgam excellently served dentistry for almost 200 years! Reasons for wanting alternative direct restorative materials were the limited flexural and edge strength and corrosion. The latter was main cause of undesired release of metal ions in the human body and poor aesthetics. Whether the use of amalgam in dentistry should be limited or avoided for biological reasons is still open for discussion. In the Netherlands, the official standpoint is that there is no scientific evidence that amalgam is a serious hazard for the patient, whilst the dental team can be at risk of mercury poisoning, if no adequate hygienic measures are taken (Dutch Health Council, 1998).
The corrosion also leads to increased porosity, which on its turn contributes to higher brittleness. Because of its intrinsic brittleness, the restoration should be as bulky as possible, and by absence of adhesion, cavity preparation is based on macro-mechanical retention. Both measures imply that placement of amalgam is usually associated with excessive sacrifice of sound tooth structure ("extension for prevention").
Today, the opinion holds that, if prevention has failed, the dentist should only minimally sacrifice sound tooth structure when restoring the tooth. Within this concept, adhesion is essential. There are at the present two classes of materials

which allow direct restorations with adhesive techniques. These are resin-based composites and glass-ionomer cements.

Resin-based composites

It goes beyond the scope of this paper to cover structure and properties of resin-based composites, but some essentials have to be addressed. In mechanical sense, the heavily filled resin-based composites with smaller filler particles can compete more or less with dental amalgam in mechanical perspective (Manhart et al., 2004). (see table 1).

	enamel	dentin	amalgam	microfill	hybrid
hardness (KHN)	360	60	100	30	90
compressive strength (MPa)	250	280	360	260	300
tensile strength (MPa)	35	260	60	40	50
elastic modulus (GPa)	50	12	30	6	14

Table 1. Some mechanical properties of a lathe-cut amalgam compared with tooth structure resin-based composites (McCabe JF, 1996 and other sources)

With the latest generations of adhesives and restorative materials, the life time of a composite restoration almost equals that of an amalgam (Manhart et al., 2004). Greatest features of resin-based composites are their aesthetics and presumed ease of application. Indeed, the placement procedure seems easy and straight forward: minimal cavity preparation without special attention for macro-mechanical retention, recommended bonding procedure and placement is mandatory, where set-on-command is apparently guaranteed by sophisticated light-curing. Successful bonding to dentin is only possible if a certain substrate condition is guaranteed. Proper bonding requires deep knowledge and great skill; more than before, the quality of the restoration is determined by the dentist factor. The latest bonding generations became more operator friendly, but their clinical durability is reduced (De Munck et al. 2003). On top of this premature in situ degradation of bonding and composite limit the lifetime of these kinds of restorations (Söderholm, 2003). Therefore, it has to be emphasized that use of rubber-dam is obligatory. Notwithstanding this high-technology approach of resin- based composite application, it has to be understood that it takes approximately 2-4 times more time to make a composite than an amalgam restoration. Therefore, resin-based composite restorations cost much more chair time and for that reason are relatively expensive.

As a matter of fact, it takes a good dentist to make a good composite and a bad one to make a bad amalgam. If a plenty skilled dentists are available, resin-based composites may contribute to very satisfying dentistry, but problems arise if there exists a shortage. Table 2 shows the dentist density in a series of European countries.

Country	active dentists	inhabitants	inhabitants/dentist
Austria	3 789	8 100 000	2138
Belgium	7 600	10 020 000	1342
Denmark	5 039	5 300000	1052
Finland	4 968	5 100 000	1027
France	40 229	58 700 000	1459
Germany	61 900	82 000 000	1325
Greece	11 728	10 500 000	895
Iceland	322	275 000	854
Ireland	1 531	3 600 000	2351
Italy	48 100	57 000 000	1185
Luxemburg	269	418 000	1554
Netherlands	7 162	15 700 000	2192
Norway	4 153	4 400 000	1059
Portugal	4 200	10 000 000	2381
Serbia and Montenegro	4 381	7 479 437	1707
Spain	15 723	39 500 000	2512
Sweden	8 650	8 850 000	1023
Switzerland	4 650	7 000 000	1505
Turkey	20 000	65 000 000	3250
UK	25 170	58 000 000	2304
Total	**2 279 564**	**457 123 000**	**2005**

Table 2. Dentist density in various West-European countries
(EU Manual of Dental Practice 2000)

The variety in number of dentists per 1000 inhabitants is striking and might have repercussion on either the number of patients receiving dental care or on the quality of the dentistry in that particular area. This problem might be solved if the dental treatment was not becoming more and more demanding.

The conclusion so far might be that consciously placing, the technique sensitive resin-based composite restorations offer highly aesthetic alternatives for amalgam. They can be used with minimal invasive treatment. Bonding to enamel is reliable, but that particularly the quality of the dentin bonding is questionable and that the bonding procedure is demanding and thus costly for wide-scale dentistry. Restorative systems which demands highly skilled dentists for the creation of reliable and durable restorations are less desirable in

the perspective of reducing the continuing increase of costs of health services. There is a general demand for delegation of simple treatments to health team members with a lower degree of education.
In dentistry the delegation of the restoration of small cavities to dental hygienists or dental nurses is widely explored. For such an approach more simple restorative systems are required.
A possible solution in this area might be found in application of the direct bonding glass ionomer cements as a less demanding alternative to resin-based composites

Glass ionomer cements

The early conventional glass-ionomer materials were technique-sensitive, slow setting, opaque when set and sensitive to both desiccation and hydration during setting. This led to premature surface deterioration. Most of these problems have (more or less) been solved in newer generations of glass-ionomer cement. Setting has been accelerated and hydration problems have been reduced. However, unlike composites, their use in stressed situations is still questionable. The most common indication of the newer, heavily filled, reduced particle size glass-ionomer cements is in non-stress bearing build-ups, root caries, tunnel restorations and long term provisional restorations in primary and adult dentitions.
The cement is formed as a result of poly-acidic attack of the outer shell of fluoride containing soluble aluminum-glasses. Dissimilar to resin- based composites that have no chemical reactivity after setting, glass ionomer cements remain reactive for a prolonged time. Also quite the opposite to resin-based composites, bond formation of glass ionomer cements to mineralized tissue is no problem. Although the bond strength reaches only 25% of that can be obtained with resin-based bonding systems, the bond is reliable and far more degeneration resistant than the resin systems, where the hybrid layer can break up with time (Pashley et al., 2004; Yoshida et al., 2004,). Glass-ionomer cements do not require extra provisions for consistent retention or adhesion, as they adhere directly to, even humid, dental hard tissues (Mount, 1994; McLean, 1996) (See also Fig. 1). As filling material, glass-ionomer cement mimics tooth color not as good as composites do and show faster surface loss by wear, but since it is less technique demanding it may serve in many ways more

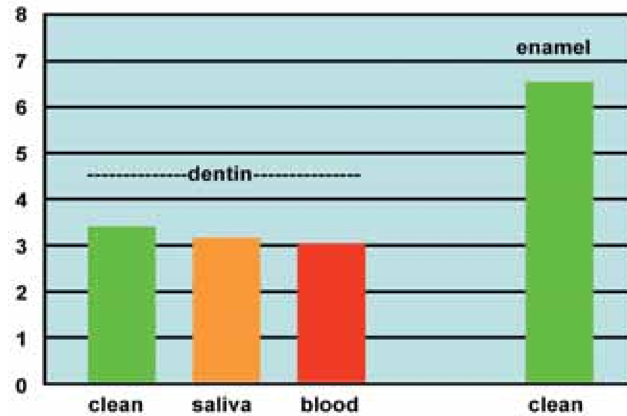

Fig. 1.GIC bond strength [MPa] to clean and contaminated substrates.

successfully than resin-based composites. Dependant on tradition, in some countries (e.g. Australia, UK) full glass-ionomer Class III restorations are generally accepted, while the material is merely used as only dentine replacement in sandwich restorations. For the time being resin-based composites possesses superior surface characteristics.

The resin-modification of glass-ionomer cements, introduced to obtain command set glass- ionomer cements, did not contribute to higher wear resistance (De Gee et.al, 1996). Resin modified glass-ionomer cements are materials in which a hydrophilic polymerizing resin is added to the glass-ionomer matrix. The admixed resin improves initial aesthetics and tensile strength and fracture toughness. Also desiccation and hydration problems are reduced. Resin-modified glass-ionomer cements set partly through an acid-base reaction and a polymerization of the resin component of the matrix. The resin component can be light-cured. Another portion of the setting process involves the typical acid-base process between the filler and the poly-acid matrix. The latter reaction does not progress as complete as is the case with traditional glass-ionomers. The hydrophilic character of the resin component also contributes to osmotic swelling.

Another step in merging the characteristics of resin-based composites with those of traditional glass-ionomer cements was the introduction of the poly-acrylic acid modified composite resins, also called compomers. Compomers were intended as to optimally combine the properties of glass-ionomers and resin-based composites. If regarded as a more or less temporary restorative, compomers can replace resin-based composite in anterior proximal restorations and have become in many countries the material of first choice in pediatric

dentistry. In almost all other applications, traditional composites and glass-ionomer cements are preferred because of greater strength and wear resistance and better dimensional stability. As a matter of fact, a disadvantage of compomers is that ease of handling was obtained at the cost the established specific properties of hybrid resin-based composites and a proper glass-ionomer reaction.

Within the framework of mixing resins with inorganic materials, it has to be realized that conventional glass-ionomer is a pure inorganic material and thus is predisposed to acid erosion. Fig. 2 shows how decreasing pH affects wear significantly.

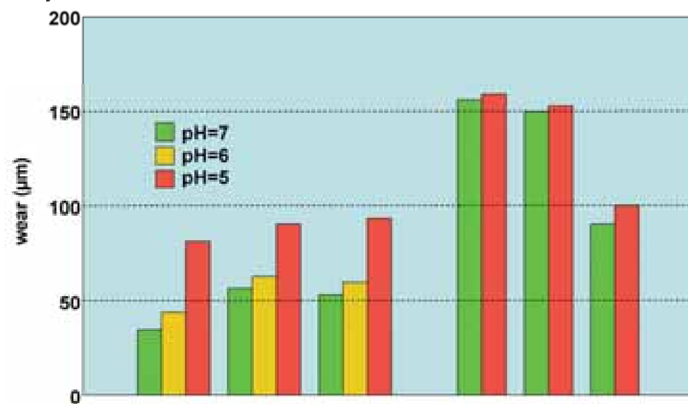

Fig. 2. pH-dependent erosive wear of conventional and light-curing glass-ionomers.

This acid susceptibility is less present for the resin-modified glass-ionomers. Note that wear as such for the resin-modified types is considerably faster than for conventional ones. Fig 3 shows how conventional glass-ionomers seriously can erode when used interdentally in risk patients. Also excessive consumption of soft drinks might put conventional glass-ionomer restorations at risk (See Table 3).

water	7.0	mineral water	4.1
coffee	3.8	orange juice	3.2
beer	4.3	seven-up	3.2
yoghurt	3.8	apple juice	2.8
wine	3.4	coca cola	2.7

Table 3. pH values of some soft drinks

For direct restorative dentistry, the slow setting of conventional glass-ionomer cements is felt as an inconvenience. Apart from the nuisance of waiting for finishing the restoration, a drawback of the slow setting is that the water

Sealants

Thanks to their applicability under humid conditions and direct bonding to tooth enamel (Aboush and Jenkins, 1986), the inorganic glass-ionomer cements are also practicable alternatives for resin fissure sealings. Notwithstanding the affirmed low wear resistance of glass-ionomers, which causes the sealant to erode already after some months, its preventive effect was reported still effective after 5 years (Mejare and Mjör, 1990; Smales and Gao, 1997). Arends et al., (1989), Campos Serra and Cury (1992) and Glasspoole (2001) explained this result by effective fluoride released from the glass-ionomer, which forms in relatively short time a reservoir in the adjacent enamel in a fluoridated hydroxyl apatite structure. Even the temporary presence of this material would already be responsible for the prolonged prevention efficacy. SEM images, obtained by replica techniques from the fissures showed clinically imperceptible, retained material (see Fig. 5).

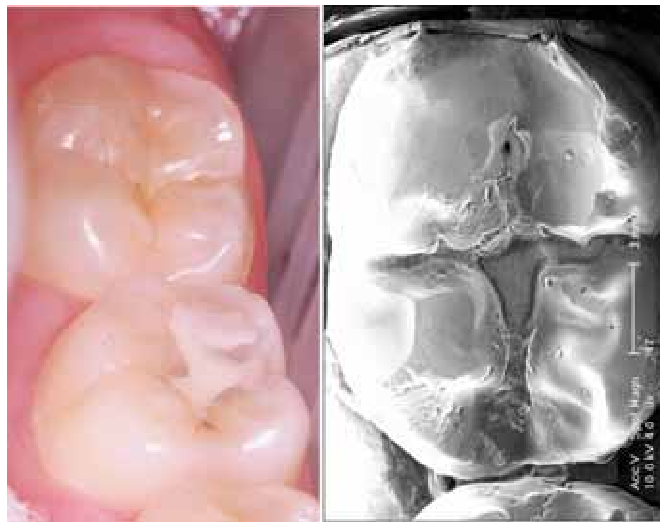

Fig. 5. Clinical and SEM aspect of a two-year old glass-ionomer fissure sealing in a 47. The transformation is visible at the borderline of the fissure.

The presence of this material may be responsible for the prolonged prevention efficacy (Arends et al, 1989; Campos Serra and Cury, 1992). Literature is not conclusive on the reason why this retained material is more resistant to erosion (Davidson, 1998; Okada et al, 2001). Shimokobe (1993) suggested that under oral conditions, glass-ionomer sealants might gradually change into a new,

more durable structure with high retention. He expected that with help of the mineralizing potential of saliva, glass-ionomers might transform into an enamel-like structure called "pseudo enamel". In addition to the satisfaction with glass-ionomer as an effective way of preventing fissure caries, Van Duinen et al (2004) observed clinically visible changes in the glass-ionomer as shown in Fig. 5 and 6. These changes referred to translucency, smoothness and hardness. In analogy to the (re-) mineralizing power on tooth structures (Segura et al, 1997), the potential of saliva as a reinforcing agent for restorative materials was suggested.

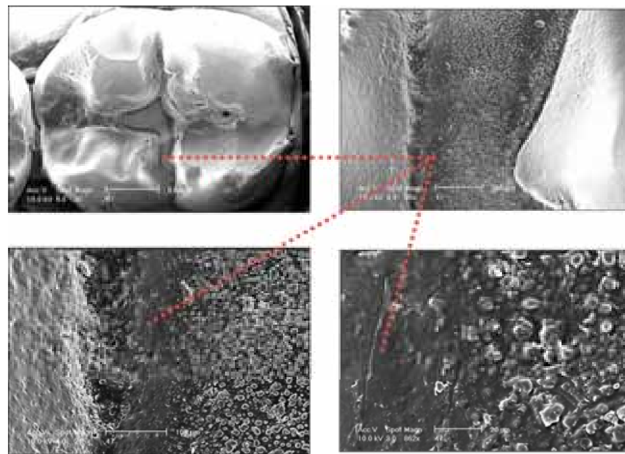

Fig. 6. Various SEM magnification aspects of the altered glass-ionomer sealing of Fig. 5.

The ideal pit and fissure sealant should be a full proof obstruction for the damaging effects of dental plaque at sites of the tooth that hardly can be cleaned with domestic measures. A tight-adhering, erosion-resistant, impermeable layer covering the tooth fulfills that goal. If the retention and its erosion resistance are guaranteed for a substantial number of years, there is nothing against the use of the, basically inactive, resin-based materials for this purpose. However, application of resins requires extensive tooth surface conditioning, whilst the hydrophobic material is essentially unwelcome in the humid oral environment. In contrast to this, the hydrophilic glass-ionomer requires only minor substrate conditioning and shows a tight adhesion to enamel but unfortunately will erode easily.

The findings of Mejare and Mjor (1990) that teeth sealed with resins more frequently develop caries than teeth sealed with glass-ionomer, in spite of the fact that the bulk glass-ionomer sealant had visually vanished within a few

months, were explained. by SEM-imaging, which revealed still retained "glass-ionomer" in the depth of the fissure at sites, where clinically no remnants of the cement were detectable. These remnants may be the same as the "intermediate" layer as postulated by Wilson et al. (1983), being the product of an exchange reaction between the poly-acid and the hydroxyl-apatite. That deeply hidden, difficultly accessible inorganic layer should possess a high acid- resistance as it constantly will be covered by dental plaque. It is reasonable to attribute this quality for a great deal to fluoride from the glass-ionomer. Van Duinen et al. (2004) demonstrated that glass-ionomer adjacent to tooth structure and in contact with the oral fluids, frequently altered into a material with unexpected cutting resistance and displaying raised Calcium- and Phosphate content. It was remarkable that such an altered layer was only detectable after a couple of years' performance, whilst its thickness increased with time. This indicates that, with time, the exchange process continues and consequently the glass-ionomer restoration gains in quality, starting from the outer surface and the junction with tooth structure. It appears that, glass-ionomer performs clinically better than from laboratory research may be expected (Okada et al, 2001; Ferrari and García-Godoy, 2002). As saliva and its minerals play a crucial role in mineralization processes (Boksman et al, 1987), it can be understood that only under in vivo circumstances the glass-ionomer surface changed into the new structure. Okada et al (2001) showed that glass-ionomer stored in saliva has an improved surface hardness compared to samples stored into water. Also in deeper areas exchange processes has been reported. Geiger and Weiner (1993) demonstrated between dentin and glass-ionomer an intermediate exchange layer containing fluoridated carbonate-apatite.

Yet literature is not conclusive on the clinical efficacy of glass-ionomer cements fluoride as measure to prevent demineralization or promote remineralization of adjacent tooth structure (Mjör, 1996; Wilson et al., 1997; Seppä, 1992). It has to be stressed that in these review articles on clinical trials on secondary caries prevention by glass-ionomer vs. amalgam or composite restorations, the reason why glass-ionomer was used was not given. It might very well be so that glass-ionomer was merely selected in caries prone patients.

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apatite in the tooth would be permanently transformed into fluoro-hydroxy-apatite (Forss and Seppä, 1990). The lower is the pH, the greater gets the fluoride release, a feature that justifies glass ionomer cements to be called intelligent materials (Davidson, 1998).

Conclusions

In contrast to resin bonding, the adhesion of glass-ionomer to tooth structure is not technique sensitive and its quality increases with time. Therefore glass-ionomer might turn out to the more reliable restorative material in minimal invasive dentistry based on adhesive techniques.
Glass-ionomer is not only bioactive, but has even features of an intelligent material.
1. For socio-economical reasons, direct restorative techniques are preferred over indirectones.
2.Interest in amalgam is fading.
3. Resin based composites are unforgiving, and still are far from perfect.
4. Shortcomings of composites invariably have to be tackled by sophistication of placement techniques.
5. Glass-ionomers and their application technique is still open for improvements.
6. Glass-ionomers are forgiving, bio-active and intelligent materials.
7. Glass-ionomers holds a great potential to become the first choice direct restorative material.

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