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New Strategies and Attempts to Improve Glass Ionomer Dental Cements

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Abstract

Glass ionomer dental cements are widely used in dentistry due to the high adhesion to the teeth, low contraction during the setting reaction, continuous release of fluoride ions and biocompatibility. The cements are made of an inorganic polymeric oxide mixed with a mixture of organic acids, i.e., polyacrylic and tartaric acid. There are new researches to improve the characteristics of the glass ionomer dental cements, especially the fracture toughness, flexural strength, compressive strength and shear bond strength. There are metal or fiber reinforced cements, resin-modified ionomer and use of nanoparticles and hydroxyapatite. The Sol-Gel method can be used to produce the inorganic polymeric oxide, with uniform particles, homogeneous composition and nanometric size. These characteristics are not obtained by the industrial method and can improve the quality of the cements. In this work, new attempts to make glass ionomer were reviewed and in conclusion, it is necessary new strategies to improve the glass ionomer dental cements.

Keywords: Glass ionomer dental cements; Dentistry; Sol-Gel method; Restorative material

Introduction

Glass ionomer dental cements are widely used in dentistry due to the high adhesion to the teeth, low contraction during the setting reaction, continuous release of fluoride ions and biocompatibility [1]. The cement was developed in 1969 and since the creation new formulations and materials are being evaluated and tested to improve the physical and chemical characteristic of this restorative material, especially the fracture toughness, flexural strength, shear bond strength and compressive strength [2]. Glass ionomer can be classified in three groups: as a restorative material, luting cement and basis for dental resin. To be used as a restorative, the compressive strength must be higher than 100MPa and as luting cement, higher than 70MPa. The use as a basis is recommended if the restoration is very deep, near to the dental nerves and the biocompatibility of the glass ionomer will not irritate the teeth [1,2].

The cements are made of an inorganic polymeric oxide mixed with a mixture of organic acids, i.e., polyacrylic and tartaric acid. The setting reaction occurs by an acid attack to the inorganic oxide, release of aluminum and calcium ions, formation of salt bridges between the polymers and hardening of the cement [3].

In this work, the researches in the field of the glass ionomer cements and the new strategies and attempts to improve these materials were reviewed. The subjects were the inorganic polymeric oxide, resin-modified ionomer, metal or fiber reinforced cements, the use of nanoparticles and hydroxyapatite and the Sol-Gel method.

Inorganic Polymeric Oxide

The inorganic oxide is a white powder, mainly composed by silicon, aluminum, fluorine, calcium, sodium, phosphorous and oxygen atoms. There are various formulations and the composition determines the characteristics of the material.

The oxide has an amorphous structure that is commonly named glass material. A commercial composition and new formulations are show in Table 1 [1,4-6].

It was observed that the formulations were mainly composed by SiO_2, Al_2O_3 and $AlPO_4$. Aluminum and calcium are necessary to the setting reaction and fluorine is a bactericidal and remineralizing agent. Moztarzadeh et al. added TiO_2 and La_2O_3 to improve the mechanical resistance of the glass ionomer.

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Table 1: Inorganic oxides used in glass ionomer dental cements.

Glass material	% SiO_2	% Al_2O_3	% AlF_3	% CaF_2	% NaF	% $AlPO_4$
Commercial	24.9	14.2	4.6	12.8	19.2	24.2
Wilson	41.6	28.5	1.5	15.5	9.2	3.7
Moztarzadeh*	40.0	25.0	0.0	13.0	11.0	5.0
Hill	24.9	14.2	11.0	12.8	12.8	24.2
Cestari**	24.9	14.2	11.0	12.8	12.8	24.2

*Made with 4% TiO_2 and 2 % La_2O_3. **Made by the Sol-Gel method.

Table 2: Compressive strength of three brands of glass ionomer cement.

Sample	Compressive strength (MPa) after 1h	Compressive strength (MPa) after 24h	Compressive strength (MPa) after 7 days
Brand A	42.0	83.4	95.7
Brand B	70.3	125.7	148.0
Brand C	99.5	147.9	155.5

Besides the formulation, the manufacturer and different brands can affect the compressive strength of the glass ionomer dental cements. Bresciani et al. evaluated three chemically-cured glass-ionomer cements and the results were represented in Table 2 [7].

Resin-Modified Ionomer

Resin-modified ionomer was developed to merge glass ionomer cement characteristics with resin materials. Resins are usually harder and with higher mechanical resistance than glass ionomers, but show lower adhesiveness and shrinkage during the setting reaction that can possibly form unsealed borders between the teeth and the restoration.

Lereche et al. evaluated commercial glass ionomer and commercial resin. The samples were subjected to stress tests by superficial penetration in bi-rooted teeth restored at 2 and 4 mm depth. It was concluded that the resin showed higher hardness when compared to glass ionomer [8].

Osorio et al. tested commercial resin-modified glass ionomer with a bioactive agent to improve the restorative material. Micro tensile bond strength test (MTBS) and compressive strength test were performed. They concluded that the compressive strength lowered and the MTBS lowered to the glass ionomer cement of the Brand A and decreased to the Brand B (Table 3) [9].

Li et al. compared the differences in flexural strength and compressive strength between resin-modified luting glass ionomer cements that are commonly used in clinics. The results were represented in Table 4 [10].

It was observed that the resin-modified ionomer presented higher values to the samples of the brands A and B. In the brand C, the resin did not elevate the flexural and compressive strengths significantly.

Shebl et al. performed shear bond strength tests to evaluate the efficacy of bonding restorative materials to dentin. The results were represented in Table 5 [11].

It was observed that the nano-filled resin-modified ionomer showed the highest value in the tests. Nanoparticles increased the reactive surface of the oxide and leaded to a higher setting and the resinous material contributed to the higher bond strengths.

Glass Carbomer is a new generation of the glass ionomer cement and it is composed by nano-filled carbonized glass, but, according to the results, the Carbomer showed the lowest bond strengths.

Metal or Fiber Reinforced Cements

Some authors tried to improve the mechanical resistance of the glass ionomer cements with metal or fiber reinforcement. The use of metal particles should be restricted to regions that the colour of the restoration is not important, because the cement become darker than the teeth. Kerby et al. incorporated metal particles of silver and stainless steel in conventional glass ionomer and obtained higher mechanical strength [12].

Hammouda et al. reinforced conventional glass ionomer restorative material with short glass fibers, with 1mm length and 10µm thickness. Kobayashi et al. also tried to increase the strength of glass ionomer cement by compounding short fibres. They concluded that fibers acted as a reinforcing agent and increased diametral tensile strength, flexural strength, flexural modulus and fracture toughness [13,14].

Use of Nanoparticles and Hydroxyapatite

Kumar et al. incorporated nanochitosan in the glass ionomer dental cement to enhance the mechanical properties. The sizes of the nanoparticles were between 110 and 235nm and the compressive strength rose from 110MPa without nanochitosan to 190 MPa. The flexural strength also rose, from 12.7MPa to 21.3MPa [15].

Moshaverinia et al. added nanohydroxyapatite to the glass ionomer cement and resulted in higher values of mechanical properties. The cements exhibited higher compressive strength (178MPa), higher diametral tensile strength (19.5MPa) and higher flexural strength (27MPa) as compared with the control group (160MPa, 14MPa and 18MPa, respectively) [16].

The Sol-Gel Method

The Sol-Gel method is a new route to produce glasses at lower temperature (110°C) than the industrial process (1500°C) and enables the production of the polymeric oxide from the central atom to the macromolecular size of the material. This fact allows the production of a material with higher homogeneity than the industrial process and enables repeated chemical bonds of silicon, oxygen and aluminum atoms (Si-O-Al). This conformation improves the setting reaction of the glass ionomer cement [17,18].

Commercial glass ionomer show this conformation, but also present silicon, oxygen and silicon linkages (Si-O-Si) and aluminum, oxygen and aluminum bonds (Al-O-Al). These bonds are not reactive with polyacrylic and tartaric acids, resulting in an incomplete setting and that lower the mechanical resistance [18].

In the Sol-Gel method it is possible to control the particle size of the materials by changing the pH, precursors, solvents, concentration, reaction time, temperature and catalyst. The size distribution and use of nanoparticles or microparticles to produce glass ionomer change the fracture toughness, flexural strength and compressive strength.

Cestari et al. produced glass nanoparticles by the Sol-Gel

Table 3: Resin-modified glass ionomer with bioactive agent.

Samples	Compressive strength (MPa)	MTBS (MPa)
Brand A	183	9.0
Brand A + bioactive agent	151	8.1
Brand B	142	7.8
Branb B + bioactive agent	122	10.8

Table 4: Flexural and compressive strength of glass ionomer and resin-modified ionomer cements.

Samples	Flexural strength (MPa)	Compressive strength (MPa)
Glass ionomer	14.2	85.2
Resin-modified: Brand A	36.5	128.5
Resin-modified: Brand B	23.6	131.7
Resin-modified: Brand C	14.7	89.8

Table 5: Shear bond strength tests.

Sample	Bond strength (MPa) after 24h	Bond strength (MPa) after 3 months	Bond strength (MPa) after 6 months
Glass ionomer	5.3	7.8	5.9
Nano-filled resin-modified	9.3	12.1	6.7
Glass Carbomer	2.2	6.7	5.7

method with uniform distribution and sizes between 30 and 100 nm, with homogeneity of forms and shapes compared to commercial glasses (particles between 6 and 8 micrometers). A material with nanoparticles, therefore, presents itself as an interesting material for the glass ionomer cement [18].

Glass ionomer cements are usually biocompatible and Cestari et al. evaluated the synthesis and biocompatibility of an experimental glass ionomer cement prepared by a non-hydrolytic Sol-Gel method. It was concluded that the new material showed mild or absent tissue reaction after 42 days, being biocompatible when tested in the connective tissue of rats [17].

Conclusion

New formulations to the glass ionomer dental cements are being developed to improve the mechanical resistance of the materials. Some authors systematically altered the concentration of the oxides. Others authors, incorporated new elements, i.e., titanium, lanthanum and strontium. Metal particles were also added to glass ionomer cements, but the colour of the restoration was darker than the teeth.

Resin-modified ionomers have overcome the conventional glass ionomer in several tests, including compressive, flexural and shear bond strengths. But the brand of the glass ionomer is a factor that should be considered, i.e., comparing the conventional glass ionomer (Table 2, brand C) with the resin-modified (Table 4, Brand B) it was observed that the glass ionomer showed higher compressive strength.

The incorporation of nanochitosan and nanohydroxyapatite elevated the mechanical properties of the glass ionomer dental cements and the glass fibers acted as a reinforcing agent and increased diametral tensile strength, flexural strength, flexural modulus and fracture toughness.

The Sol-Gel method can be used to produce the inorganic polymeric oxide, with uniform particles, homogeneous composition and nanometric size. These characteristics are not obtained by the industrial method and can improve the quality of the cements.

In this work, new attempts to make glass ionomer were reviewed and in conclusion, it is necessary new strategies and researches to improve the glass ionomer dental cements.

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