EVOLUTION OF GLASS IONOMER CEMENTS, BIOCOMPATIBILITY VS CYTOTOXICITY

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ABSTRACT

The exhaustive revision of the universal literature shows us that the nowadays use of Glass Ionomer Cements (GICs) is controversial, because many researchers state that GICs are biocompatible with dental tissues, while others demonstrate its cytotoxicity, especially when they are modified with resin (RMGIC). The aim of this study is to emphasize the cytotoxicity of these materials and its limitations in the clinical use to the dentistry community. Each year many patients with dental necrosis caused by this material, are treated in our Endodontics Clinic. Clinicians must have the appropriate knowledge to use them properly. Based on this literature review, and in our previous histopathological findings it can be concluded that RMGICs and metal reinforced GICs (CERMET) have higher cytotoxic effects on pulp tissue, that conventional GICs.

Keywords: Glass Ionomer, Cytotoxicity, Biocompatibility.

Evolución de los Cementos de Ionómero de Vidrio, biocompatibilidad vs citotoxicidad

RESUMEN

La revisión exhaustiva de la literatura universal nos muestra que a la fecha, el uso de los Cementos de Ionómero de vidrio (CIVs) es controversial, porque muchos investigadores afirman que son biocompatibles a los tejidos dentales, mientras que otros demuestran su citotoxicidad, especialmente cuando son modificados con resina. (CIVMR). El objetivo de este estudio es enfatizar la citotoxicidad de estos materiales y sus limitaciones de uso clínico, a la comunidad odontológica. Cada año muchos pacientes con necrosis dental son atendidos en nuestras clínicas de Endodoncia. Los clínicos deben tener el conocimiento apropiado para usarlos adecuadamente. Basándonos en la literatura previamente revisada, y en nuestros previos hallazgos histopatológicos, se puede concluir que RMGICs y GICs reforzados con metal (CERMET), tienen un efecto citotóxico mayor en el tejido pulpar, en contraste con GICs convencionales.

Palabras claves: Ionómero de vidrio, citotoxicidad, biocompatibilidad

INTRODUCTION

Glass Ionomer Cements (GICs) were developed in England in 1971 by Alan D. Wilson and Briand E. Kent [1]. Its precursors were aluminum containing fluorosilicate glasses cements, from here the liberation of fluoride ions [2,3].

The original composition of the silicate glass powders used in GICS was based on the formula SiO_2-AI_2O_3-CaF_2-$AIPO_4$-Na_3AIF_6. The liquid was an aqueous solution of polyacrylic acid with tartaric acid [4-7]. At first, they were called ASPA for their basic ingredients: Aluminum Silicate and Polyacrylic Acid [3].

The Glass ionomer was introduced to the dentistry community in 1976 at a congress in Adelaide, Australia by Dr. McLean, who improved the GIC and published a series of articles mentioning for the first time their qualities and progress in dentistry [1].

The original formula was optimized. For example, the addition of itaconic acid that increases the reactivity of polyacrylic acid and makes it less viscous and tartaric acid extended the working time of the cement and sharpened the set [8].

The GICs have shown being a very versatile group with many applications in modern clinical odontology. They are defined as a water-based cement where the glass powder and the polyalkenoic acid make an acid-based reaction. The acid attacks the surface of the particles of powder, liberating ions of calcium and aluminum obtaining adhesion between the powder and the liquid [4].

A similar adhesion occurs on the surface of the tooth because phosphate ions are displaced by the polyalkenoic acid and penetrates the enamel and the dentine. Each phosphate ion takes with it a calcium ion to maintain an electrolytic balance that produces a stronger layer of ions. The fluoride ions are also released into the acid-base reaction and once freed they can move in and out of the cement. The result is that restoration of GIC can act as a reservoir of fluoride and slowly liberate ions into the tooth and thus act as a defense mechanism against caries while the restoration exists in the mouth [2].

USES OF GIC

There are several uses for the cement, and Mount [2] classifies them thus:

- Type 1. To cement crowns, fix prosthesis and brackets
- Type 2. For restoration
  - 2.1 For aesthetic restorations
  - 2.2 To reinforce restorative cements
- Type 3. For the base or lining of cavities.

The components of GIC are the same in all types, but their powder-liquid proportion varies in terms of the needs of the dentist.

One use of the GIC that is not widely known is the Atraumatic Restorative Treatment (ART) also known as Alternative Restorative Treatment [9]. This treatment for cavities was developed in 1980 in Tanzania and consists of the removal of demineralized tissue, using only manual instruments. After this, the tooth is restored with GIC.

All of this occurs outside of the dental clinic and is focused on the infantile population of underdeveloped countries, specifically in the marginalized zones where people do not have the resources to get to a dental clinic.

The objective is to preserve the tooth in the mouth for the longest possible time. This treatment is recommended by the World Health Organization [10].

MAIN ADVANTAGES OF GICS:

- Liberation of fluoride makes a cariostatic activity. This is the reason why it is often used on patients with a history of recurring cavities. When used as a luting cement the cavity process stops [2].
- Adhesion. They adhere strongly to the enamel and the dentine because they do it physically and chemically. (Fig 1)
- They do not adhere chemically to porcelain nor to gold-based alloy.
- They have a film so thin that they reach widths of less than 25 microns.
- Expansion-Contraction very similar to dental structure.
- Fluidity. This is a valuable characteristic when cementing fixed prosthesis that have parallel preparations with grooves, permitting precise marginal adaptations.
- Solubility and compatibility. They have more solubility than other cements. It is a material with a water base and so is compatible with low adverse environments such as the mouth [7].

DISADVANTAGES

Among the main weaknesses of the GICs is their fragility since they lack the resistance to fracture mostly on edges and on the incisive angles.

It is a material that is not easily polished, so the surface remains rough and has little translucence. They also have little resistance to erosion. In 1984 McLean [11] reported that they wear down 3 times more quickly than resins. They have a long working and setting time and because of their high fluidity characteristic, this can irritate the pulpal tissue when a cavity is prepared, because during these processes the dentinal tubules are exposed. (Fig 2)

But the main inconvenience is their great acidity due to their very low pH after being mixed and put in place. At the clinic, the sensitivity of the patients is very common, and it can cause pulp necrosis [8,12-14].

CERMET CEMENTS

Due to the inconveniences of the GICs and with the purpose of making them more resistant they are mixed with materials like gold and silver, this is how industry develops ceramic-metal cements (CERMET).

With this combination cement qualities have been enhanced. The main clinical use of the Cermet is as a substitute for dentin. When it is placed the dentin must not be too dry, otherwise the cermet should not be dried with the air syringe since this significantly reduces the adhesion.

Another use is to reconstruct and/or make dental stumps with endodontic treatment. As with the basic glass-ionomers, they contain fluoride and have cariostatic action [11].

One more change made to GICs was the addition of resin. Resin Modified Glass Ionomer Cements (RMGICs) were developed in 1988 by adding polymerizable hydrophilic resin to conventional glass-ionomers [15].

At first it was introduced as a material for lining cavities and as a restoring material. These materials were created to overcome the problems of low mechanical resistance but maintaining the clinical advantages of the GICs.

The chemical composition of the RMGICs is fluoride of aluminum silicate, polyalkenoic acid photocurable lateral chain, that is inside of the basic composition of the polymer used, photocurable monomer as HEMA (2-hydroxietil methacrylate) and water. The first commercial RMGIC was patented in 1989 [15].

The RMGICs resulted much more resistant than the conventional GICs but when chemically forged a great

quantity for HEMA is liberated and this can cause Cytotoxicity [16,17].

BIOCOMPATIBILITY

Biocompatibility is a very important characteristic in any material to be used in the human body.

According to Nicholson [18] the biocompatibility of the GICs was reviewed many years ago and in conclusion the postulates are valid at present. Specifically, for clinical application the GICs are biocompatible due to the following properties:

1. Well accepted by the mouth tissues
2. Slow extra thermal adjustment
3. Quick neutralization
4. Releases generally benign ions [18].

PRESENT STATE OF THE GICS

It has been more than 20 years since the GICs arrived at our clinics and since then they have been used in almost all their varieties. The use of any materials entails the possibility of an adverse reaction, which is why they must be used with care and following the instructions of the manufacturers[19].

Unfortunately, at the Endodontic Clinics in Mexico, we see the increment in usage of these materials year after year causing pulp necrosis and because of this, patients tend to need endodontic treatment.

The symptomatology after the use of GICs is variable, some people report increasing pain. Others report that after the pain increases there is a swelling of the gum that causes a fistula. Other patients do not report pain, only a big swelling of the gum of the affected tooth and/or a fistula, making endodontic treatment necessary.

A study made in our school showed that after the use of GICs the treated teeth presented various degrees of pulp lesions, that goes from the disruption of the odontoblastic layer to necrosis [13]. When cervical lesions are restored with GICs they produce hypersensitivity. This is due to the excessive setting time that permits the very acid pH to reach the pulp tissue, producing pulpitis that many times is irreversible. Therefore, when there are very deep cavities and there is a suspicion that the pulp is near, it is widely recommended to use calcium hydroxide [8].

Yiu proved using electronic microscopy that an absorption layer forms between the dentin and the RMGICs. This coat forms after the setting of the cement. This phenomenon happens in deep restorations and is absent in places near incisal. This is mainly due to the great quantity of water in the dentine near the pulp and the ions that interchange when RMGIC is applied [15].

The aim of this study is to emphasize the cytotoxicity of these materials and its limitations in the clinical use to the dentistry community.

MATERIALS AND METHODS

We analyzed 30 caries-free human premolars extracted for orthodontic treatment, coming from the Orthodontics Clinic of the Postgraduate Studies Division in the Facultad de Odontología of the Universidad Nacional Autónoma de México. México City.

After extraction Class V cavities were prepared with a high speed, water-cooled handpiece using No. 33 inverted cone burs. Then premolars were divided into two groups of 15 teeth each. One of them (group 1) was filled with Ketac Silver® (3M/ESPE Dental Products, St. Paul, MN, USA), according to the manufacturer's instructions. It is a metal reinforced (CERMET) Glass Ionomer. The other (group 2) remained only with preparation. Later all of them were mounted on aluminum stubs with colloidal silver, coated with a 20 nm thick gold layer, and examined with a JEOL 2000 SEM (JEOL, Tokyo-Japan).

RESULTS

In group 1 filled with Ketac Silver® , shows a very good union between teeth and cermet cement. (Fig 1). These findings reinforced that GICs adheres strongly to the enamel and the dentine.

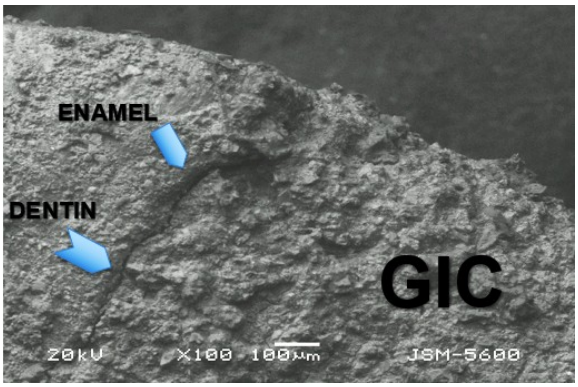

Fig. 1. SEM micrograph demonstrated the union between the GIC with dentin and enamel

In group 2, teeth with Class V cavities, open tubules whose size and form varies, together with small quantity of smear layer were observed. This layer is insufficient to obliterate exposed dentinal tubules, so any substance located in this cut dentin is capable to irritate the dental pulp via odontoblastic process. (Fig 2)

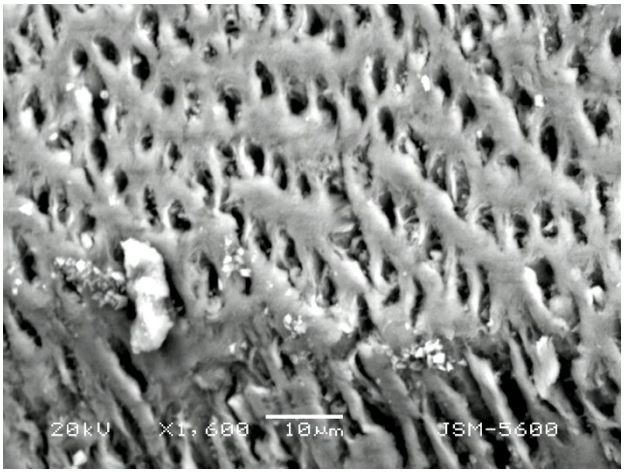

Fig.2. SEM micrograph demonstrated exposed dentin tubules after cavity preparation. Notice that the smear layer quantity is few.

DISCUSSION

Ideally, a dental material should be harmless to the pulp and soft tissues, they should not contain any toxic diffusible substances that can be absorbed into the circulatory system causing a systemic toxic response, they should be free of potentially sensitizing agents that could lead towards an allergic response, and have no carcinogenic potential [13] .

When GICs were first introduced with just one acid (polyacrylic), pulpal responses were classified as bland. Now with addition of copolymers from polyacrylic acid and other acids, the pulpal reactivity to them has been increased[13].

Svare and Mayer demonstrated that a pH of 2.8-2.9 provokes a vascular thrombosis in the pulp, if the pH does not rise in the following 5 minutes the damage can reach necrosis[20].

Many investigators reported sensitivity after the use of GICs, especially when they are used as a luting agent [21- 23]. Fig 1 is a clear example of how GICs have strong adhesion to dentin and enamel. Dental sensitivity can be explained because, after cavity preparation there are many exposed dentinal tubules (Fig 2), which allow diffusible substances causes pulpal damage.

Various studies related to cytotoxicity have shown that Glass-ionomers cause damage to pulp tissue [8,13,19,24]. This coincides with all the cases that we have attended at the Endodontic Clinic of the University of Mexico (12%).

Aranha [19] has demonstrated that Vitrebond (3M ESPE Dental Products, St. Paul, MN,USA) presented the highest cytotoxicity effect compared with other GICs

since the liquid of the RMGICs contains monomers with resin like HEMA in different concentrations which is responsible for the cellular death.

Siqueira [24] shows the cytotoxicity of GICs containing silver nanoparticles, mentioning that residual components released from these materials may diffuse through the dentinal tubules and damage pulpal tissue. According with Kim [25] this is caused by the continuous acid-base reaction rather than chemical polymerization.

Kanjevac [26] demonstrated that the main disadvange of metal-reinforced GICs and RMGICs is their higher cytotoxicity in comparison with conventional GICs.

These results agree with our previous histopathological findings [13].

On the other hand, some authors affirm the biocompatibility of GICs. [2, 27]. Nicholson [18] mentions that biocompatibility of the GICs was reviewed many years ago and the postulates are valid at present. Ersahan [28] evaluated the cytotoxicity of 5 contemporary GICs and found that except for Ionolux GIC, none of the other GICs showed any toxicity.

The GICs have been used widely because one of the principal characteristics was the cariostatic effect but other authors demonstrated detection of caries around the restorations with glass ionomer simple or resin modified [29-30].

The nowadays use of (GICs) is controversial, because many researchers state that GICs are biocompatible with dental tissues, while others demonstrate its cytotoxicity, especially when they are modified with resin (RMGIC) or metal reinforced (CERMET). The use of CERMET should be confined to the manufacturing of stumps in the post endodontic reconstruction or in tooth endodontically treated.

Also, we must remember that one of the pulp tissue reactions to external attacks is forming zones of acute inflammatory infiltrate, later becomes in chronic inflammatory infiltrate, but if the irritant is not removed, then necrosis occurs.

The specification number 41 of the ANSI/ADA says that all medication that causes cytotoxicity must be modified or removed from the market. [31]

It is necessary to do new investigations for manufacturing GICs with no cytotoxic effects.

CONCLUSION

Based on this literature review, and in our previous histopathological findings it can be concluded that RMGICs and metal reinforced GICs (CERMET) have higher cytotoxic effects on pulp tissue, that conventional GICs.

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