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RESEARCH ARTICLE

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EVALUATION OF THE SURFACE ROUGHNESS OF MATERIALS RECOMMENDED FOR THE ART TECHNIQUE AFTER IMMERSION IN DIET SIMULATION SOLUTIONS

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ABSTRACT

Atraumatic restorative treatment (ART) is a form of treatment that uses glass ionomer cement as a restorative material and manual cutting instruments. The objective of this *in vitro* study was to verify the behavior of the glass ionomeras a function of the exposure to the following solutions: saliva, milk, cola-flavored soda, orange juice and cupuaçu *Theobromagrandiflorum* juice. A total of 75 samples were produced usingKetac™ Molar Easymix, Magic Glass and Chemflex™, which then were stored for 24 h in an oven at 37 °C. After reading the initial surface roughness, the materials were randomly divided into 5 groups of 5 specimens each. Subsequent readings were performed 1, 7, 15 and 30 days after the immersion of the materials in the solutions. The immersions were 5 minutes daily, with the control group immersed in artificial saliva. The results were submitted to analysis of variance (ANOVA) and the means compared usingthe Tukey test. The material that showed the best result was Chemflex, followed by Ketac Molar Easymix and Magic Glass.

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INTRODUCTION

Caries are a biopsychosocial disease caused by an imbalance in the native oral microbiota caused mainly by the frequent consumption of fermentable carbohydrates. These cavities are characterized as a chronic and multifactorial disease, which is caused by the imbalance between the loss and gain of minerals in the mineralized tissues of the tooth (Batista, 2020; Santana, 2018; Giongo, 2014). Despite the fact that in recent decades there has been a decline in the prevalence and decrease in the rate of progression of tooth decay, the diseaseis still considered an important public health problem in Brazil, as in many other countries around the world (Ministério da Saúde, 2012). Among a great diversity of therapies that can be used for carious lesions, the atraumatic restorative treatment (ART) stands out since it preserves tooth structure, avoids pulp irritation and minimizes patient discomfort (Massara, 2012; Frencken, 2012). Thismethod consists of a type of treatment in which the decayed tissue is removed exclusively by the use of manual cutting instruments (Frencken, 1999).

The principles of ART are minimal surgical intervention, preservation of healthy dental structure, reduction of the risk of endodontic treatment and future extraction, and no need for local anesthesia due to the absence of pain (Anusavice, 1999). Thus, the use of dental equipment that requires electrical energy, such as a high-speed drill, a low-speed handpiece, a vacuumtubeand light curing apparatus, is unnecessary (Frencken, 1999). For the filling of cavities, the precursors of ART used polycarboxylate cement, (Frencken, 2012) which was subsequentlyreplaced by glass ionomer cements (GIC) (Navarro, 2015). In this treatment modality, the use of GIC is recommended as a restorative material since it has characteristics of adhesion to the dental structure, fluorine release and a coefficient of thermal expansion that is similar to dental tissue, with the benefit of not requiring light curing (Liberman, 1994). Introduced to the market in the mid-70s, the firstGICs possessed the characteristics of adhesion to the dental structure and fluorine release. However, due to clinical requirements, its original formulation has been improved with the addition of tartaric acid, thus improving its viscosity and setting time (Silva, 2017; Tedesco, 2017). At present, there are conventional cements, which modified by resin and reinforced by metals.

Combinations in its chemical structure are carried out to enhance its benefits, and each modification aims to improve a physicochemical property of this cement. Currently on the market, in addition to being available as a powder and liquid in separate bottles, there are encapsulated glass ionomer cements (GIC-E), either in conventional or highly viscoseconsistencies and those modified by resin (Souza, 2020). Wear resistance and surface roughness in the oral environment are important criteria for determining and predicting the clinical deterioration of restorative materials (Prentice, 2005; Shaw, 1998). It is known that the phenomenon of erosion in the mouth is directly related to the presence of organic acids and inorganic electrolytes that originate from the diet (Pilot, 1999). The surface roughness of glass ionomer restorations is particularly important because it can provide rapid bacterial colonization and biofilm maturation, thus increasing the risk of caries.[17] In addition, the accumulation of microorganisms also generates the possibility of mechanical, biological and chemical irritation of adjacent soft tissues, which induces gum problems of greater and lesser intensity. The roughness of the surface can also affect the reflection of light and brightness, implying the loss of the natural aspect produced by the restoration (Deery, 1997). There are several clinical methods for assessing the roughness of restorative materials (Rahimtoola, 2000; Silva, 2006). The objective of this *in vitro* study was to verify the behavior of the GICs used in the ART technique, through the analysis of the initial and final surface roughness as a function of the exposure time in solutions of saliva, milk, cola-flavored soda, orange juice and cupuaçu juice.

MATERIALS AND METHODS

For the present study, seventy-five samples of the threebrands of glass ionomer cements recommended for the ART technique were prepared. The tested brandswere Ketac™ Molar Easymix (3M ESPE/AG D-82229,Germany); Magic Glass (VIGODENT S/A Indústria e Comércio, Brazil); andChemflex™ (Dentsply De Trey GmbH D-78467, Germany), as shown in Figure 1.

Figure 1. Glass ionomer cements used in the study

In all, 25 samples were obtained for each glass ionomer cement. The powder/liquid ratio and handling were carried out according to the manufacturer's instructions. Then, a knurled metal matrix, with dimensions of approximately 7 mm internal diameter by 2.5 mm thickness was filled with the aid of a Centrix syringe (Centrix Inc., USA) usingAccudose tips (Centrix Inc., USA) until fully filled, as shown in Figure 2. Soon after, they were covered with a polyester strip and a glass slide (Figure 3) for the removal of excess material and leveling of the surface of the cement with the upper face of the matrix.

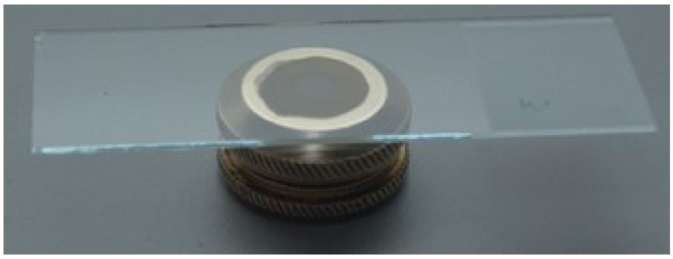

Figure 2. Filling of the matrix

These were left in position for 5 minutes, which corresponds to the initial setting of the material. Then, the samples were carefully labelled and stored in individual vials containing artificial saliva in anoven at 37 ^{o}C for a period of 24 h. After storage, each specimen was adapted to an existing cavity in a plastic plate (Tecnil, Brazil), and was individually measuredwith a roughness meter (TR200, Timer, USA).

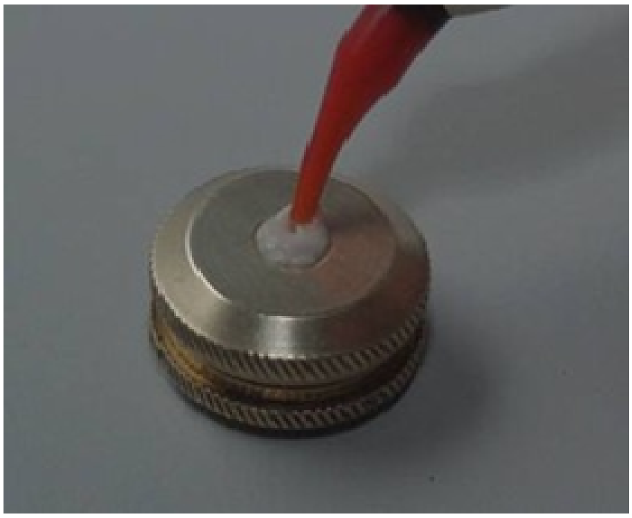

Figure 3. Leveling of the surface

In each reading operation, we considered the mean roughness (Ra), which represents the arithmetic mean between the peaks and valleys recorded, after the respective needle of the roughness meter runs over the surface under analysis. A 2.85 mm extension, with a cut-off of 0.25 mm was used to maximize the reading of the surface. Three readings were performed on each surface of the sample. Thus, the average of the three readings was considered the average roughness of each surface. The specimens were then re-stored, under the same conditions mentioned above, for 24 h before exposure to acidic solutions. All materials were randomly divided into five groups of five specimens each according to the simulator solution: G1 – artificial saliva; G2 – milk; G3 – cola-flavored soda; G4 – orange juice, G5 – cupuaçu (*Theobroma grandiflorum*) juice. The juices were obtained by diluting 70 grams of pure pulp in 30 ml of mineral water, the milk was whole, UHT milk. The reading of the average roughness of the materials was performed after 24 hours, and after 7, 15 and 30 days of immersion of the materials in each solution. Immersion was performed for a period of five minutes daily in each acid solution;with the control group G1 immersed only in artificial saliva (obtained from a compounding pharmacy and with pH=7). After the daily soaking in the respective acid solutions, each specimen was washed with deionized water and re-stored in artificial saliva. After the exposure of the specimens in 5 ml the solutions for the predetermined periods, the surface of the specimens was subjected to another surface roughness reading, similar to the initial roughness test. Representative samples of each group, at each time interval, were observed underscanning electron microscopy. The results of the readings were submitted to analysis of variance (subdivided portion) and the means were compared using the Tukey test, at a level of 5% probability, in order to verify whether the interactions were or were not significant.

RESULTS

The results obtained for the variables studied after performing the proposed analyses are depicted in Tables 1 and 2. It was observed that there was statistical difference between the intervals of 1 day (24 hours), 7 days, 15 days and 30 days of treatment for two of the glass ionomers, though not for Chemflex (CH), saliva: 1 day = 7 days = 15 days ≤30 days; Ketac Molar Easymix (KM), cupuaçu: 1 day = 7 days ≠ 15 days = 30 days; and Magic Glass (MG), saliva: 1 day = 7 days ≤ 15 days = 30 days. In the final evaluation of 30 days, the material that presented the best performance in the various solutions was Chemflex, followed by Ketac Molar Easymix and, finally, Magic Glass, which presented the highest roughness value.

DISCUSSION

Degradation of restorative materials in the oral cavity can occur in many ways, such as dissolution and disintegration, erosion, abrasion and bacterial activity. This need to evaluate the mechanical properties of glass ionomer cements under various conditions has existed since their creation, and remains to the present day due to the emergence of its modified versions and their wide use (Shaw, 1998). Thesemodifications entail significant differences in their properties, determining a particular clinical performance for each product found on the market (Gladys, 1997). In this study, the glass ionomer Ketac^{TM} Molar Easymix (3M ESPE/AG D-82229, Germany); Magic Glass (VigodentS/A Indústria eComércio, Brazil); Chemflex^{TM} (Dentsply DE Trey GmbH D-78467, Germany) were selected among the materials available on the market for the realization of the ART technique.

Table 1. Mean and standard deviations of surface roughness (µm) of glass ionomers after immersion in acidic solutions in the 1-day, 7-day, 15-day and 30-day treatment periods

		1 DAY	7 DAYS	15 DAYS	30 DAYS
Chemflex (CH)					
	Saliva	0.1247±0.02 a	0.1316±0.01 a	0.1477±0.01 ab	0.1711±0.02 b
	Milk	0.1349±0.01 a	0.1778±0.01 b	0.2850±0.02 c	0.3303±0.01 d
	Cola-flavored soda	0.1489±0.02 a	0.1825±0.01 b	0.2977±0.02 c	0.5690±0.02 d
	Orange juice	0.1479±0.01 a	0.1855±0.01 b	0.3815±0.02 c	0.5892±0.02 d
	Cupuaçujuice	0.1375±0.02 a	0.1703±0.01 b	0.2546±0.03 c	0.4459±0.02 d
Ketac Molar Easymix (KM)					
	Saliva	0.0941±0.00 a	0.1063±0.00 b	0.1178±0.01 c	0.1471±0.01 d
	Milk	0.0985±0.00 a	0.1028±0.01 b	0.1416±0.01 c	0.3717±0.02 d
	Cola-flavored soda	0.0977±0.00 a	0.1685±0.01 b	0.2695±0.01 c	0.5658±0.02 d
	Orange juice	0.0995±0.00 a	0.2629±0.01 b	0.4561±0.01 c	0.6714±0.02 d
	Cupuaçujuice	0.0999±0.00 a	0.1035±0.00 a	0.3807±0.01 c	0.4515±0.04 c
Magic Glass (MG)					
	Saliva	0.1983±0.01 a	0.2037±0.01 a	0.2554±0.03 b	0.2558±0.02 b
	Milk	0.1909±0.01 a	0.2229±0.01 b	0.3830±0.02 c	0.6499±0.01 d
	Cola-flavored soda	0.1842±0.01 a	0.3332±0.03 b	0.5503±0.03 c	0.8698±0.02 d
	Orange juice	0.1913±0.00 a	0.2247±0.01 b	0.4275±0.01 c	0.7759±0.02 d
	Cupuaçujuice	0.1951±0.00 a	0.2079±0.01 b	0.4269±0.01 c	0.5273±0.01 d

Table 2. Mean and standard deviations (µm) of surface roughness after 30 days of treatment

Solution	Chemflex	Ketac Molar Easymix	Magic Glass
Saliva	0.1711±0.02 Aa	0.1471±0.01 Aa	0.2558±0.02 Ab
Milk	0.3303±0.01 Ca	0.3717±0.02 Cb	0.6499±0.01 Cc
Cola-flavored soda	0.5690±0.02 Da	0.5658±0.02 Da	0.8698±0.02 Db
Orange juice	0.5892±0.02 Da	0.6714±0.02 Eb	0.7759±0.02 Ec
Cupuaçu juice	0.4459±0.02 Ba	0.4515±0.04 Ba	0.5273±0.01 Bb

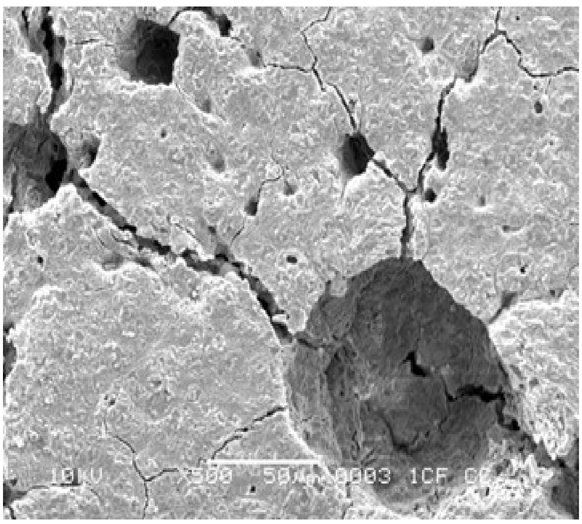

Figure 4. Chemflex after 30 days of immersion in cola-flavored soda for five minutes per day. Magnification: 500X

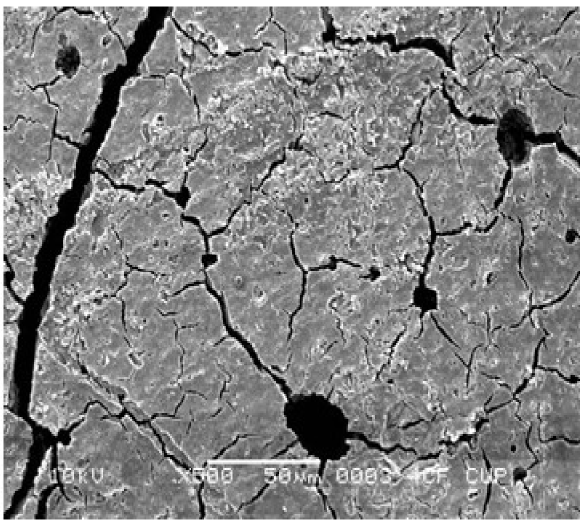

Figure 5. Chemflexafter 30 days of immersion incupuaçu juice for five minutes per day. Magnification: 500X

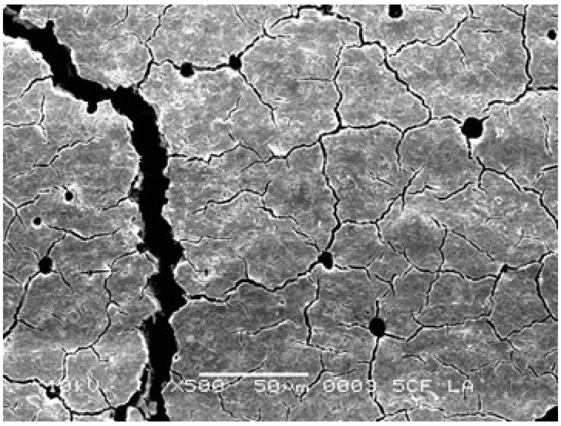

Figure 6. Chemflexafter 30 days of immersion in orange juice for five minutes per day. Magnification: 500X

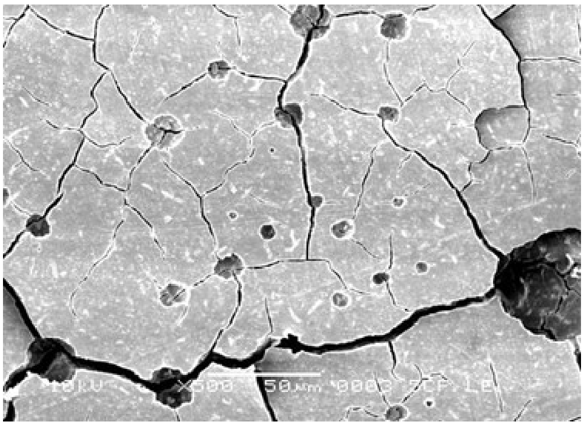

Figure 7. Chemflexafter 30 days of immersion in milk for five minutes per day. Magnification: 500X

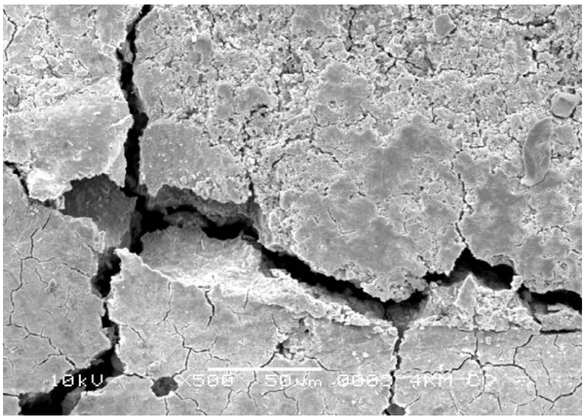

Figure 8. Ketac Molar after 30 days of immersion in cola-lavored soda for five minutes per day.Magnification: 500X

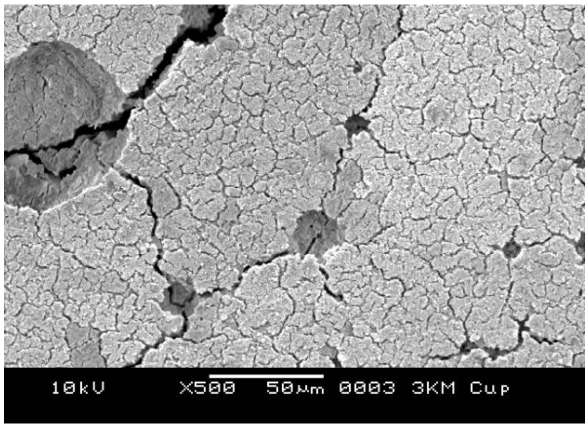

Figure 9. Ketac Molar after 30 days of immersion incupuaçu juice for five minutes per day. Magnification: 500X

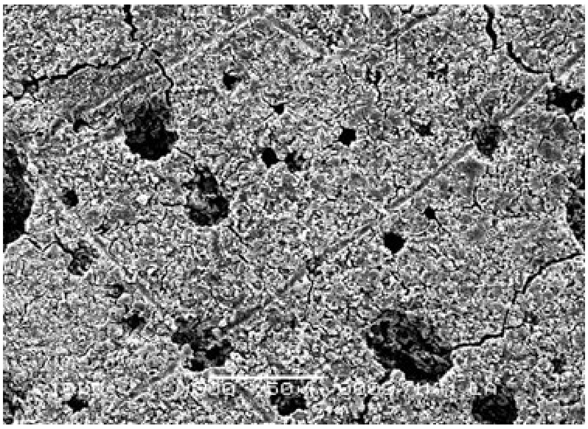

Figure 10. Ketac Molar after 30 days of immersion in orange juice for five minutes per day. Magnification: 500X

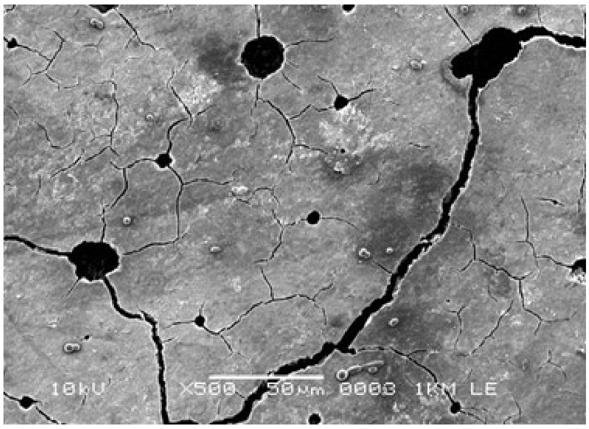

Figure 11. Ketac Molar after 30 days of immersion in milk for five minutes per day. Magnification: 500X

The pHs of the solutions were obtained with the aid of a pH meter (Mettler Toledo, Brazil), and pH was measuredfrom 2.8 to 6.4. The choice of thesolutions used in the tests aimed to reflect the various types of acidic drinks often consumedinBrazil, including an industrialized drink, such as cola-flavored soda, and two fresh juices, such as orange juice and cupuaçu juice, since these are both commonly consumed in the northern region of the country. Milk was also chosen, since it can affect the mechanical properties of the glass ionomer. Some works, among them, that of GLADYS *et al*. (1997), point out that hybrid materials, such as glass ionomer, cannot be polished like other restorative materials, since polishing causes the appearance of a rough surface that deteriorates more easily over time. Therefore, the porosity can be minimized by the use of Centrix tips and by the compression of the material against the walls of the cavity of the matrices or by a gloved and Vaseline-lubricated finger (Navarro, 2015).

In the present study, the reading of the roughness of the glass ionomers showed a significant difference between the materials. This difference is related to the incorporation of bubbles during the handling procedure and other characteristics such as the size, shape and distribution of the glass particles (Anusavice, 1999; Silva, 2017). This qualitative morphological analysis using scanning electron microscopy can be observed in Figures 4 to 15. In Table 1 and the following figures, it can be observed that after 30 days of immersion in acid solutions all materials presented greater roughness when compared to their initial roughness. By comparing the results, it can be observed that orange juice caused more dissolution in Chemflex and Ketac Molar Easymix (Fig.6, 10). According to MCKENZIE *et al*. (2003), the difference between the dissolution caused by natural juice and caused bycola-flavored sodais related to the presence of acids of different types in the solutions.

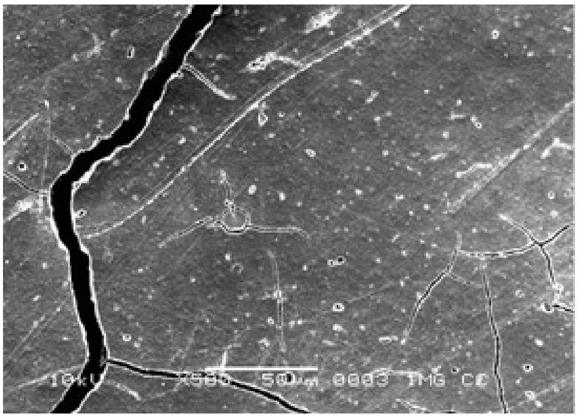

Figure 12 – Magic Glass after 30 days of immersion in cola-flavored soda for five minutes per day. Magnification: 500X

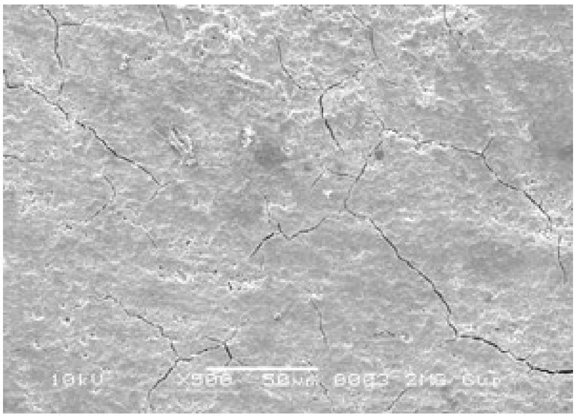

Figure 13 – Magic Glass after 30 days of immersion in cupuaçu juice for five minutes per day. Magnification: 500X

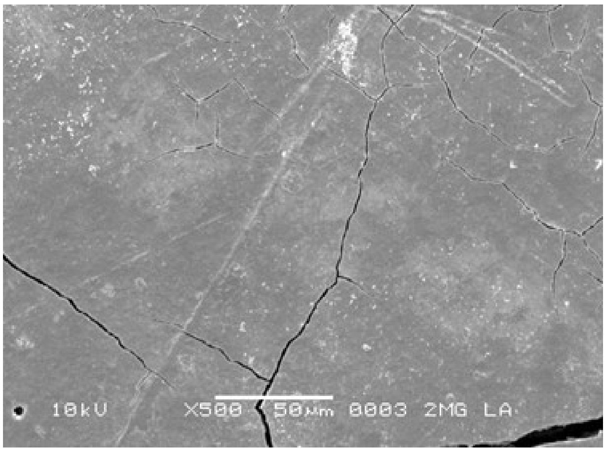

Figure 14. Magic Glass after 30 days of immersion in orange juice for five minutes per day. Magnification: 500X

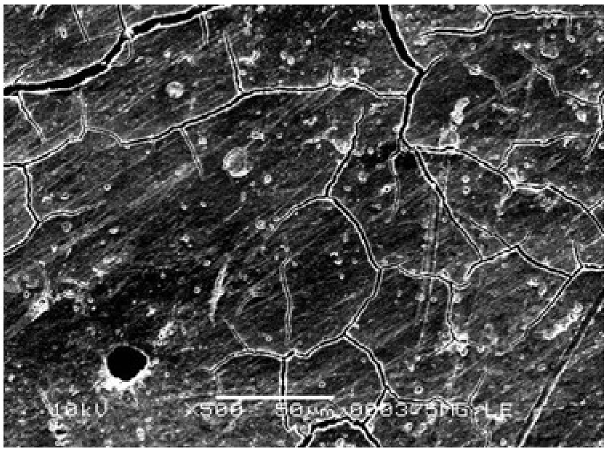

Figure 15. Magic Glass after 30 days of immersion in milk for five minutes per day. Magnification: 500X

In orange juice, there is the presence of citric acid, which is a type of carboxylic acid, while in cola-flavored soda there is phosphoric acid. Both acids are able to chelate the ions,such as calcium, that arepresent in the glass ionomer and form new compounds. However, the carboxylic acid present in fresh juice forms soluble compounds with calcium, while phosphoric acid from cola-flavored sodaforms insoluble compounds. Therefore, one of the reasons for the erosion of the material is the presence of carboxylic acid and not only because of the low pH of the solution. The material that obtained the best results after 30 days of immersion was Chemflex, followed by Ketac Molar Easymix and finally Magic Glass.

The lower values assigned to Chemflex may be related to the better integration between the glass particles and the matrix.[12]Our studies using acid solutions were carried out *in vitro*; however, *in situ* studies and clinical evaluations should be carried out, since the oral environment has complex characteristics that can interfere with the behavior of the materials. Glass ionomer cement is the most widely used in ART, and is recommended due to its satisfactory properties, its ability to adhere to tooth structure and since it allows for the preservation of the tooth; its release of fluoride and its ability to be recharged with fluoride, thus preventing, or stopping the development of dental caries. In addition, the coefficient of linear thermal expansion is similar to tooth structure, and the modulus of elasticity similar to that of dentin. GIC also has a tooth-like color and has biocompatibility with tooth pulp and gum. However, the glass ionomer is porous and the mechanical resistance of the ionomers are low when compared to the resistance of dental amalgams and composite resins.

The introduction of high viscosity glass ionomer cements in the early 1990s was an important contribution to ART. The improvement in the properties of these materials compared to those of conventional cements occurred as a result of the optimization of the concentration and molecular weight of the polyacid, combined with the decrease in the average size of glass particles. In this way, it allowed the increase of the powder/liquid ratio, thus improving its wear resistance, compression and flexural strength, as well as surface hardness and solubility (Gladys, 1997).

CONCLUSION

According to the results obtained and respecting the limitations of the study, it was observed that the exposure time of the samples was sufficient for the glass ionomer to undergo significant changes in surface roughness, with Chemflexshowing itself to be superior due to better integration between the glass particles and the matrixAlthough all the solutions have low Ph, orange juice presented a capacity for greater dissolution of the glass ionomer cement.

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