

Tribological Behaviour of Three Types of Glass Ionomers Dedicated to Applications in Dentistry

STELA CARMEN HANGANU^{1*}, ADINA OANA ARMENCIA¹, ALICE MIRELA MURARIU¹, LUCIAN CONSTANTIN HANGANU², STEFAN GRIGORAS², CIPRIAN STAMATE²

¹,GR. T. Popa” University of Medicine and Pharmacy, Iasi, Faculty of Dental Medicine, 16 Universității Str., 700115, Iași, Romania

²,Gheroghe Aschi” Technical University of Iasi, Faculty of Mechanical Engineering, 71 Mangeron Blv.,700050, Iasi, Romania

Romanian researchers, both dentists and engineers, are continuously involved to develop the knowledge concerning applications of different types of materials in restorative dentistry [1-4]. Only thus there is possible to be solved the main complex and interdisciplinary aspects targeting this large class of materials. Hence the present paper is focused on experimental studies of three glass ionomers taking into account their tribological behaviour in oral cavity under specific conditions.

Keywords: glass ionomers, tribology, corrosion, restorative materials, dentistry

Complex composition of materials used in restorative dentistry influences both their mechanical properties, and especially their behavior in the oral environment.

It is known that the oral environment effects on materials vary from dimensional changes that affect the binding force of tooth up to the invasion of microorganisms in the crevices resulting from loss of material by pitting. For this reason, the emphasis is on minimal removal of tooth tissue, and the use of adhesive restorative materials that may have therapeutic actions of demineralized dentin. Chemical structure and molecular organization of glass ionomer causes a certain behaviour after inserting fillings in the oral cavity.

The present study aimed both to determine the stability of three types of cement glass ionomers in artificial saliva and superficial and deep changes occurring in the mass of material.

Experimental part

There were studied three types of glassionomers: Fuji IITM (GC America), Fuji IITM LC (GC America) and Miracle Mix R (GV AMERICA), made in the form of plates with dimensions not exceeding 2 cm². Liquid medium used for this determination was proposed as a Duffo-Quezada artificial saliva with corrosive properties very close to those of natural saliva.

To study “forced corrosion” were used cyclic polarization curves (cyclic voltammograms), because it is known that when a material is positively or negatively polarized by applying a potential different than the corrosion potential (equilibrium potential), in the system can take place oxidation or reduction reactions more intense.

In this study, the electrode potential made with the studied material is positively increased with a constant speed to a pre-determined value after which it is scanned backwards (towards negative values) up to the initial value or to another value.

Throughout the sweeping potential it is measured the current flowing through the solution between the working electrode and an auxiliary platinum electrode.

Cyclic polarization curves were recorded in the potential range -500 mV and +2000 mV with a 10 mV/s sweep rate of potential.

It was started from a sufficient big negative potential in order to reduce any ionic or molecular species from the solution and possibly from the material surface, so that the electrochemical process takes place on a “clean” surface.

Rate of change of the working electrode potential was relatively high, resulting large enough intensities of current able to cover any accidental fluctuations from the system, but small enough to grasp all the processes taking place in the solution or on the electrode surface.

To characterize the surface morphology of the samples before and after electrochemical treatment it was used scanning electron microscopy. Microscope was a VEGA II LSH (Tescan Co., Czech Republic) type coupled with EDX detector QUANTAX QX2 (Bruker / Roentec Co., Germany).

Image acquisition is achieved with the software VEGA TC, while microanalysis is controlled by ESPRIT software.

To reduce the time needed to determine the interaction between materials and artificial saliva, we opted for “corrosion under tension”; the working electrode potential was kept constant at a value of 2V for a current density of 1000 times higher than the instantaneous current density (in the absence of applied electrode potential).

For all tests, the volume of artificial saliva from cell was by 50 mL, the voltage between the platinum electrode and alloy sample by $E = 2V$, for a period of 30 min. The sample of material was connected to the positive pole of the source.

Results and discussions

GC Fuji IITM and GC Fuji IITM LC materials behave quite similar in artificial saliva, both curves show a generalized corrosion. Thus, for GC Fuji IITM LC the anodic curve is linear (current density increases linearly with applied potential) within the potential range of 1000-2000 mV.

For GC Fuji IITM the phenomenon is generalized with tendencies towards pitting. The difference between the two samples is the breakdown potential values: 785 mV for sample I and 840 mV and sample II, however, being located within experimental errors (fig. 2).

Current densities values for an over-potential by 2V are quite large: $j_{cor}(2V) = 36.2 \text{ mA/cm}^2$ for sample I and $j_{cor}(2V) = 58.2 \text{ mA/cm}^2$ for sample II.

* email: carmenhanganu1957@yahoo.com

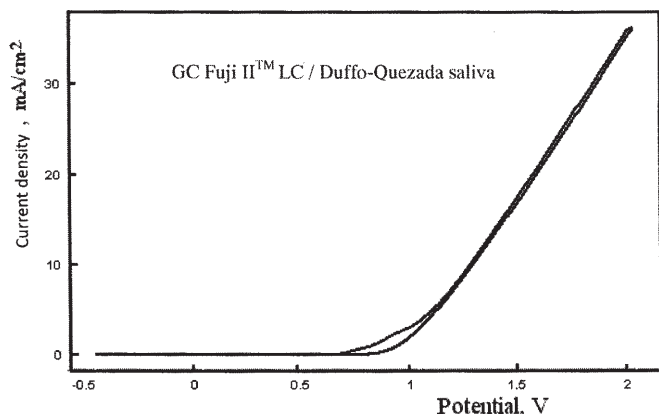


Fig. 1. Cyclic voltammograms for GC Fuji II™ LC in Duffo-Quezada saliva ($v = dE/dt = 10 \text{ mV/s}$)

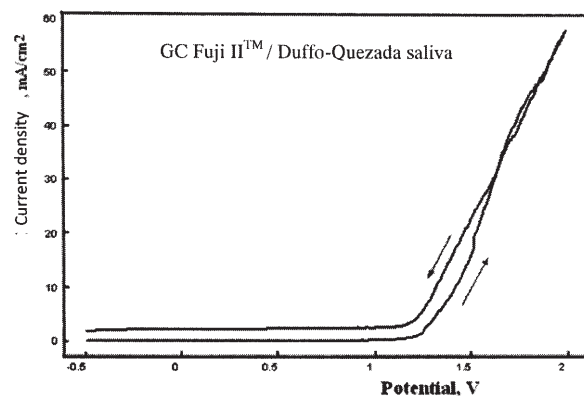


Fig. 2. Cyclic voltammograms for GC Fuji II™ in Duffo-Quezada saliva ($v = dE/dt = 10 \text{ mV/s}$)

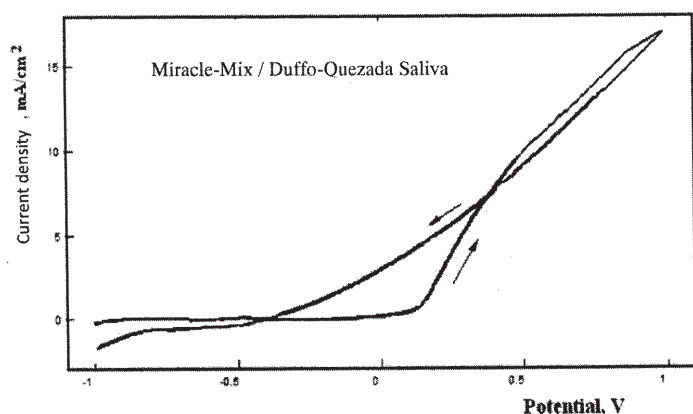


Fig. 3. Cyclic voltammograms for Miracle-Mix in Duffo-Quezada saliva ($v = dE/dt = 10 \text{ mV/s}$)

Cyclic voltammograms for Miracle-Mix in artificial saliva (fig. 3) were obtained in the potential range between -1000 ... +1000 mV. Polarization curve indicates that for the potential of more 800 mV a general damage occurs (on the entire area) while under this over-potential corrosion in points occurs.

Breakthrough potential is located in the small potential range (EBD = 112 mV) while re-passivation potential is located in negative values range (ERP = -415 mV). These values, at which are added the densities of very high current, show a low resistance to acid attack of this material

Stereo-microscopic analysis for Fuji II™ LC material shows microcracks due to polymerization, which could facilitate water absorption in oral environmental conditions, accompanied by corrosion appearance and a decrease in time of the material resistance.

The general image could be explained by different contacts between the two phases of the material during polymerization, with the inclusion of air bubbles in the empty gaps left after processing (fig. 4).

For Fuji II™ material it is observed the appearance of pitting facets to the restorative material level due to a low hardness of the glass ionomer (fig. 5). Applied in the oral

cavity may be associated with fractures and cracks that occur with decreasing material physiognomic adhesion to cavity walls.

Figure 6 shows the surface quality for Miracle-Mix material before (a) and after (b) initiation of corrosion phenomenon.

If initially (a) surface was smooth, with slight traces remained after the finishing process, after the corrosive attack (b) an occurrence of pitting areas, those "pinching" in the mass of material still remaining after the release in saliva of Ag and Al.

The two Fuji II™ materials have a very similar composition and a similar corrosion behaviour. From the material Au, Ti and Si are dissolved and passed into solution. A part of Al is oxidized on the glass ionomer surface forming Al_2O_3 , insoluble and adherent to the surface [5, 6].

For II™ materials, filler particles (F, C, Na) could affect the appearance of surface defects, along with other stakeholders (such as air bubbles incorporated during the polymerization), which is more evident when polymerization does not meet optimal conditions, but the release of material addition products, release that occurs in the first days of immersion in saliva [7-9].

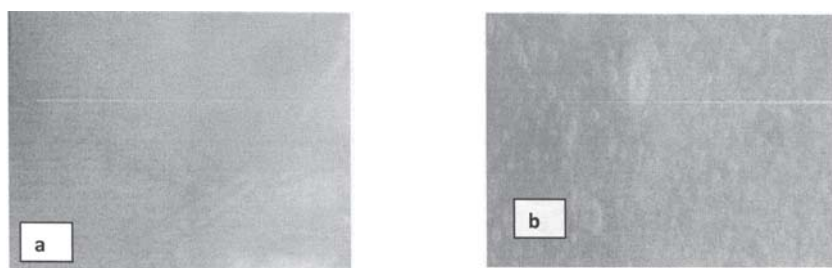


Fig. 4. Stereo-microscopic image of corrosion by pitting for Fuji II™ LC before (a) and after immersing in artificial saliva (b)

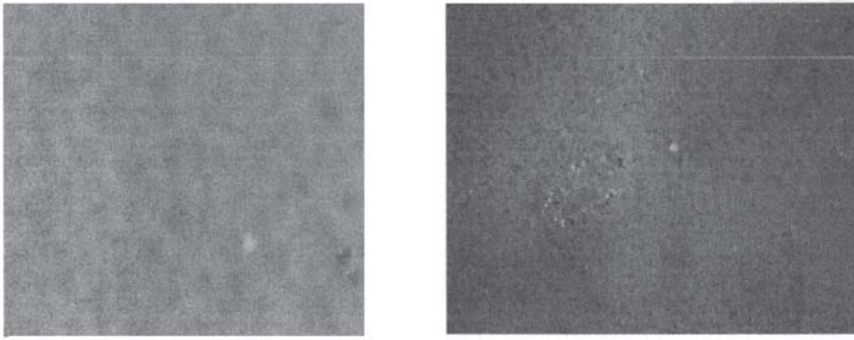


Fig. 5. Stereo-microscopic image of corrosion by pitting, cracks and fractures on Fuji II™ surface

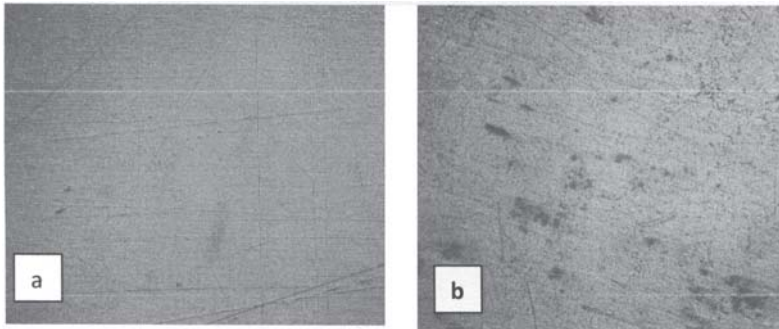


Fig. 6. Stereo-microscopic image of corrosion by pitting before (a) and after (b) occurrence of ion loss process for Miracle-Mix

For Miracle-Mix material, silver ions are released in saliva. However, given the large amount of oxygen in the surface composition of the material sample, it can be assumed that Ag remains on the surface as oxides. Regardless of the form of material degradation occurs, electrochemical corrosion effects are appreciable.

The presence of changes cracks in the mass of material is justified by resistance decreasing under loads consecutive to the loss of constituent elements as a consequence of corrosion process [8, 10, 11].

When is applying an external energy contribution, for example pressure developed during mastication loads (contribution that could lead to the formation of cracks), there are initiated some changes in the material structure (ie cracks with snatching of material) amplified by oral environmental conditions.

In artificial saliva it was initiated the process of electrochemo-corrosion phenomenon which, in turn, causes release of elements in the saliva, with adverse consequences for restoration itself. The surface quality is changed becomes rough, porous with cracked or material snatching.

By removing a main large concentration of ions decreases the material resistance in the oral environment, as is demonstrated by the results obtained in this study.

These changes were due to the disorganization of crystalline structure of the primary material during the polymerization and preparation process. During the link setting, crystal items with higher specific weight (for example Au, Al,) are positioned deeper in the material, while those with lower specific weight (Ag, Si) are situated more to the surface, producing so-called major segregation. In this way, the crystals situated to the surface will be more easily affected by aggressive salivary environment, favoring the release of ions in high concentration, accompanied by the damage of the surface of studied material [12, 13].

The diameter and shape of the particles are different. Fuji II™ LC material presents small particles, ranging in size between 1.26 μm -8.54 μm . The structure of these particles is homogeneous. Fuji II™ has a heterogeneous structure, particles having a size between 0.8 μm -2.4 μm . The same structure is present in the heterogeneous case

of Miracle-Mix material for which the particle sizes are ranging from 2.38 μm to 60 μm .

It is known that a heterogeneous distribution favors the initiation and propagation of cracks in the mass of material, accompanied by resistance reducing under acid attack (as seen in the case of Fuji II™ material).

If crystalline phases are uniformly distributed, the impairment is reduced accompanied by increasing of the material reliability (as it is with Fuji II™ LC material).

The presence of high amounts of aluminum decreases resistance, making it more brittle, more prone to corrosion (it is the case of Miracle-Mix material).

Polymerization increases viscosity very rapidly, forming finally a fairly rigid three-dimensional network. This explains the different behaviour of the three types of glass ionomers.

Conclusions

Cyclic voltammograms give information on the type of corrosion (general corrosion, localized corrosion, passivation, etc.), on the potential at which corrosion starts out with considerable speed (break-down potential) and on the potential of re-passivation. Variations in the structure and morphology of crystalline and amorphous phases of surface and deep layers influence the hardness, property which, in turn, is closely related to the corrosion behaviour of restorative material. Anisotropy (crystalline alignment dependence) influences the hardness of materials studied property which, in turn, influences their corrosion resistance in the oral environment.

References

- BORȚUN, C., GHIBAN, B., SANDU, L., FAUR, N., GHIBAN, N., CERNESCU, A., *Mat. Plast.*, **45**, no. 4, 2008, p. 362
- BORUN, C., M., CERNESCU, A., GHIBAN, N., FAUR, N., GHIBAN, B., GOMBOS, O., PODARIU, A., C., *Mat. Plast.*, **47**, no. 2, 2010, p. 240
- ARDELEAN, L., BORUN, C., PODARIU, A., C., RUSU L., C., *Mat. Plast.*, **49**, no. 1, 2012, p.30
- BORUN, C., M., CERNESCU, A., ARDELEAN, L., *Mat. Plast.*, **49**, no.1, 2012, p. 5
- YIP, H-K., SMALES, R., J., YU, C., GAO, X-J., DENG D-M., Comparison of atraumatic restorative treatment and conventional cavity preparations for glass-ionomer restorations in primary molars: One-year result, *Quintessence International*, 33, nr. 1, 2002, p. 17

6. YU, C., GAO, X-J., DENG D-M., YIP, H-K., SMALES, R., J., Survival of glass ionomer restorations placed in primary molars using atraumatic restorative treatment (ART) and conventional cavity preparations: Two-year results, *International Dental Journal*, 54, nr. 1, 2004, p. 42
7. IRIE, M, TJANDRAWINATA, R., SUZUKI, K., WATTS, D., C., Rootsurface gap-formation with RMGIC restorations minimized by reduced P/L ratio of the first increment and delayed polishing *Dental Materials*, 22, nr. 5, 2006, p. 486
8. IRIE, M., MARUO, Y., NISHGAWA, G., SUZUKI, K., WATTS, D., C., Class I Gap-formation in Highly-viscous Glass-ionomer Restorations: Delayed vs Immediate Polishing, *Operative Dentistry*, 33, nr. 2, 2008, p. 196
9. DAVIDOVIĆ, L., TOMIĆ, S., STANOJEVIĆ, M., ZIVKOVIĆ, S., Microleakage of Glass Ionomer Cement Restorations, *Stomatološki glasnik Srbije*, 56, nr. 2, 2009, p. 78
10. MOUSAVINASAB, S., M., MEYERS, I., Fluoride Release by Glass Ionomer Cements, Compomer and Giomer, *Dent Res J*, 6, NR. 2, 2009, P 75
11. PARDI, V., PEREIRA, A., C., MIALHE, F., L., MENEGHIM, M., C., AMBROSANO, G., M., A 5-year evaluation of two glass-ionomer cements used as fissure sealants, *Community Dent Oral Epidemiol*, 31, NR. 5, 2003, p. 386
12. NAGARAJA, U., P., KISHORE, G., Glass ionomer cement-The different generation, *Trends in Biomaterials and Artificial Organs*, 18, nr. 2, 2005, p. 158
13. ASMUSSEN, E., PEUTZFELDT, A., Long-term fluoride release from a glass ionomer cement, a compomer, and from experimental resin composites, *Acta Odontol Scand*, 60, nr. 2, 2002, p. 93

Manuscript received: 6.02.2013