

# **A Special Issue in Memory of Dr. Lucio Salgado**

Edited by  
Lucio Salgado (in Memory)

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Dr. Lucio Salgado**

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Selected, peer reviewed papers from the  
56 Brazilian Ceramic Conference (CBC),  
June 3-6, 2012, COLAOB, Latin American  
Cong. of Artificial Organs and Biomaterials, August 22-25, 2012  
TTT VI (VI Brazil Conf. on Heat Treatments), June 17-22, 2012  
IPMM - 7<sup>th</sup> International Conference on Intelligent Processing  
and Manufacturing of Materials September 2-3, 2012  
Brazilian Surface Treatments and Exhibition  
(EBRATS), April 11-13, 2012  
Ptech - Eighth International Latin American Conference on  
Powder Technology, November 6-9, 2011

*Edited by*

**Lucio Salgado (in Memory)**



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# **FOREWORD**

This special issue of Materials Science Forum is dedicated ‘in memorium’ to Dr. Lucio Salgado. It contains a collection of papers presented at the following important events organized by ‘Metallum Events’ under the leadership of Dr. Lucio Salgado.

## **PTECH 2011**

**Francisco Ambrozio Filho**

**Lucio Salgado**

The Eighth International Latin American Conference on Powder Technology was held in Florianópolis, Brazil, from 6-9 November 2011. This Conference was coordinated by an International Committee and it provided a forum for the presentation of the latest advances in all areas related to particulate materials. A large number of well-known scientists and engineers from many countries attended this Conference to present the latest developments in aspects related to the manufacture and characterization of metallic, inter-metallic, ceramic and composite materials. The presentations were made at Technical Sessions, either orally or in the form of posters. All abstracts were reviewed by a Technical Program Committee and the best papers are compiled in this issue.

## **56 CBC**

**Samuel M. Toffoli**

The Brazilian Ceramics Congress (Congresso Brasileiro de Cerâmica-CBC) was held in Curitiba-PR from 3-6 June 2012, along with the 1<sup>st</sup> Latin American Ceramics Congress and the IX Brazilian Symposium on Glass and Related Materials. This event enabled interaction among diverse sectors (Industries, Technical Schools, Universities, Research Institutes and Suppliers of Raw Materials and Equipment) contributing thus towards the enhancement of ‘Brazilian Ceramics’. This event, CBC, traditionally has a broad base where topics of interest in diverse ceramic segments (Red Ceramic, Ceramic Coatings, Refractories, Bioceramics, Technical Ceramic and Nanotechnology) are discussed and the themes in this congress included Energy, Environment, Mineral Resources, Technological Innovation, Quality, Human Resources and others.

## **VI TTT**

**Francisco Ambrozio Filho**

**Jorge Kolososki**

**Lucio Salgado**

The VI Brazilian Conference on Heat Treatment Themes (Temas de Tratamento Térmico-TTT) was held at Atibaia, SP, from 17-20 June 2012. This Conference provided a venue for the discussion of recent developments in this area and the global market, as well as the dissemination of new products, processes and technologies related to heat treatment. The main objective of this conference was to promote closer contact between professionals involved in heat treatment activities, quality control, product engineering and after sales. The participants were from manufacturers of equipment and supplies, research institutes, educational institutions, users of products and services for heat treatment in industries like automobile, mechanical, steel, electronics, appliances, petrochemical industries, etc.

## **VII COLAOB**

**Clodomiro Alves Junior**

The Latin American Congress on Artificial Organs and Biomaterials (COLAOB – Congresso Latino-Americano de Órgãos Artificiais e Biomateriais) is a consolidated event and a major one in this field in Latin America. Its success was due to the multi and trans disciplinary environment that helped guide discussions at the interface of healthcare and different engineering fields, making it a fertile environment for new researches and collaborations. The papers published in this edition of MSF were presented in Natal, RN, from 22-25 August 2012.

## **IPMM**

**Jacopo Seccatore**

**Giorgio Francesco Cesare de Tomi**

The 7th International Conference on Intelligent Processing and Manufacturing of Materials (IPMM) took place in Foz de Iguaçu, PR, Brazil, during September 2<sup>nd</sup> – 3<sup>th</sup>, 2012. The main theme of this conference was: *Sustainable Intelligent Approaches to Mining, Materials and Energy Resources*.

## **EBRATS**

**Wilma Ayako T. dos Santos**

**Douglas Fortunato de Souza**

The Brazilian Meeting and Exhibition on Surface Treatments (Encontro e Exposição Brasileira de Tratamentos de Superfície- EBRATS) took place from 11-13 April, 2012 at São Paulo –SP. It was the biggest Latin American Forum for the dissemination of processes, equipment, products and services related to Surface Treatments. EBRATS is held once every three years, and this meeting counted on the presence of national and foreign companies, renowned speakers and recognized authors of scientific, technological and innovative papers.

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## **CHAPTER 1:**

### **7th Latin American Congress of Artificial Organs and Biomaterials (COLAOB)**

## NITINOL ALLOYS - STUDY OF PHYSICAL AND CHEMICAL APPLICATION AS BIOMATERIALS

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**Keywords:** NiTi Alloys, Shape Memory Alloys, Biomaterials.

**Abstract.** The Nitinol is a term which represents the family of nickel and titanium alloys. With the discovery of the extraordinary biocompatibility of these alloys, their implementation has been emphasized in the medical devices and in general dentistry. The characteristics which make these alloys are of interest its superelasticity, shape memory effect and excellent biocompatibility, the latter two characteristics particularly interesting due to the fact that these materials confer the ability to self-expansion or contraction and not presenting rejection the organism. Thus, this study aims to evaluate three NiTi alloys compositions, being one rich in titanium, other poor and the last equiatomic, through tests of physical characterization and surface tension, after different heat treatments. After the results interpretation, it can be seen that the lower percentages by weight of nickel in their products from corrosion was the Nitinol rich in titanium subjected to heat treatment for 24 hours in the oven. Moreover, the same composition present the smallest angle in the test of surface tension.

### Introduction

Over the past century, a variety of materials have been employed in replacing natural teeth, including bone, animal teeth, human teeth, ivory, seashells, ceramics and metals. Therefore, merits highlight the field of biomaterials, which historically developed in order to obtain a satisfactory combination of physical properties close to those of the tissue replaced and biocompatibility, that is, given the requirement of functionality for which it was designed, stimulating or causing minimal inflammatory or allergic reactions [1, 2, 3, 4].

The NiTi (Nitinol) is a nickel (Ni) and titanium (Ti) alloy which has excellent properties such as biocompatibility, therefore its implementation has been emphasized in several devices in medicine and dentistry in general. Other interesting characteristics of this alloy is the superelasticity and shape memory effect (SMA - Shape Memory Alloy), that confers to the biomaterials the ability of self-expanding and non-rejection by organism [4, 5, 7, 8].

The use of metals or metal alloys for dental and medical applications requires structural and surface conditions that provide functionality and biocompatibility. The Nitinol alloys (NiTi) can meet these requirements by suitable heat treatments that result in mechanical properties favorable to applications and high corrosion resistance [5, 6, 9, 10].

### Materials and Methods

#### *Selection and classification of alloys*

Nitinol alloys were classified into three types, according to their composition: equiatomic (55% Ni - 45% Ti by weight); atomically rich in nickel (Ni 55.3% - 44.7% Ti by weight) atomically rich in titanium (54.7% Ni - 45.3% Ti by weight). Nitinol samples were manufactured at the Multidisciplinary Laboratory of Active Materials and Structures (LaMMEA), located at the Federal University of Campina Grande, with nominal compositions selected from commercial alloys in the

biomedical field. The elements used in alloy composition were commercial pure nickel and biomedical titanium ASTM F67-00.

### **Preparation of samples**

The pure elements were weighed on a precision balance and melted in a furnace to plasma brand of Discovery All EDG equipment, which uses the thermal plasma as a means of transmitting energy to melt metals such as titanium, nickel, chromium and cobalt. The technique used was the Skull melting.

### **Heat treatments**

The product obtained was subjected to homogenization at 850° C for 2 hours in a vacuum, according to the study of the phase diagram of the Nitinol alloy, in order to ensure uniform structure in all points of cylindrical bar. Then the bars were subjected to a bath in water around 25°C, intended to cause phase transformations responsible for the shape memory effect by relieving internal stresses of the alloy. After this stage, was performed a section of the bar with the cutter metallographic precision Buehler, model Isomet, yielding then discs 2mm thick and 5mm in diameter.

A second heat treatment was carried out. The purpose of heat treatment is to improve the properties of the alloy, resulting therefore in a higher biocompatibility. The samples were divided into two groups according heat treatments: Group 1 - the samples were subjected to 1000 ° C for 12 hours; Group 2 - the samples were subjected to the same temperature for 24 hours in an electric oven Sp Spencer. After the treatment period the samples were placed in an oven bacteriological New Ethics for twice the time at which it was heated to a temperature of 100 ° C.

### **Samples Analysis**

The samples were characterized and analyzed using three different assays: Scanning Electron Microscopy (SEM), X-ray Spectroscopy Energy Dispersive (EDX) and Surface Tension.

#### *Scanning Electron Microscopy (SEM), X-ray Spectroscopy Energy Dispersive (EDX)*

It was used in this research a device model TM-1000 Hitachi, up to 10000x, focal depth of 1mm, and resolution of 30nm fixed energy 15kV, low vacuum and pressure varied (1-270 Pa). By this technique can make micro and non-destructive analysis and determine a semi-quantitative amounts up to 2.1% of the elements present in the sample by issuing its X-ray spectrum.

#### *Surface Tension*

For this test we used the Angle Calculator 1.0 program and a equipment appropriated for this type of test, located in the Department of Materials Science and Engineering, at Federal University of Campina Grande. For an angle closest to the real, each experiment was measured for five times and the arithmetic calculation was done.

### **Results and Discussion**

After the heat treatment, it was observed that the samples had a crust formed mainly by titanium oxide which was easily removed. These crusts were also analyzed to see if, in the case of oxidation in the oral environment, the biomaterial releases more titanium or nickel, important information to determine the level of toxicity in the league.



### *Scanning Electron Microscopy (SEM)*

In equiatomic and in atomically rich in nickel alloys wasn't observed significant changes before and after the heat treatment, while the second has shown low surface porosity than the equiatomic alloy. In atomically rich in titanium alloy, the heat treatment one (12 hours of furnace), was observed a finer grain and compact structure in comparison with other compositions for a same thermal treatment. Also in this composition is evident in both cases of heat treatment a microporosity characteristic (figure 1).

About the morphological uniformity and porosity conditions studied, the rich in titanium alloy with thermal treatment of 24 hours in an oven suggests an adequate use for the medical and dental application.

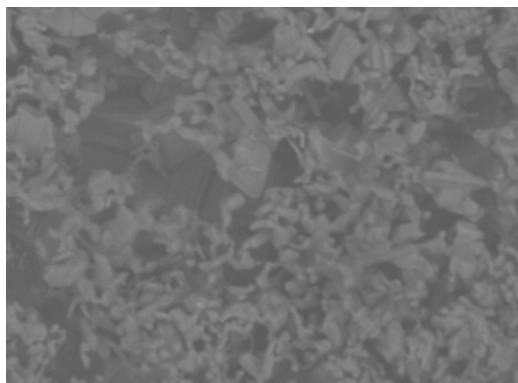


Figure 1 - Aspect of NiTi Alloy rich in titanium after 24 hours in the oven.

### *X-ray Spectroscopy Energy Dispersive (EDX)*

This analysis shown that wasn't observed characteristic variations between the three compositions heat treated for 12 hours in an oven, indicating the presence of specific concentrations of chemical elements. It may be noted that for the second heat treatment was observed growing on the substrate the presence of nickel in alloys of the following sequence: rich in titanium, equiatomic rich in nickel.

After detailed analysis of the compositions of SMA and the crust that forms on the samples, it is found that the alloy which has better biocompatibility is one that releases in the oral environment lower levels of nickel, since it is the metal that causes more hypersensitivity in humans.

Based on this, it was found that the crusts that covered the samples subjected to heat treatment for 24 hours in the oven showed lower levels of nickel in its composition at the end of the process. This crust is basically formed by titanium oxide ( $\text{TiO}_2$ ), being considered corrosion product.

In all EDX analyzes for alloys studied, either in the substrate or in the crust, revealed the predominant presence of titanium, confirming that this metal is more oxidizable than nickel.

### *Surface Tension*

The equiatomic alloy subjected to the heat treatment one is which has a higher contact angle ( $106.6^\circ$ ), meaning that it is less hydrophilic. The opposite can be observed in the rich in titanium alloy subjected to the heat treatment two. It was observed the smaller angle ( $90^\circ$ ) and the more hydrophilicity, therefore.

### **Conclusions**

Owing to the nickel material is a high potential for toxicity to the organism, the concept of porosity having a relevant aspect in clinical performance of the material and the surface tension indicate the degree of interaction (hydrophilicity) of the biomaterial with the biological environment, are concluded that according the three compositions and the heat treatments performed, the material

that have more suitable characteristics for application as biomaterial is the NiTi alloy rich in titanium subjected to the heat treatment 2.

Through these analyzes, it appears that the thermal treatment improve the qualities of the alloys, so they are more biocompatible and suitable for use as biomaterial.

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## DEVELOPMENT OF MTA / HAp BIOMATERIALS FOR USE IN ENDODONTICS

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**Keywords:** biomaterial, sealer, mineral trioxide aggregate, hydroxyapatite.

**Abstract.** This work aims to conduct a study of development and characterization of a new endodontic biociment, the MTA/HAp. To this was used MTA Angelus<sup>®</sup> and a HAp synthesized in the laboratory in the proportions by weight 99% MTA/1% HAp (BIOC 1) and 95% MTA/5% HAp (BIOC 5), where the hydroxyapatite was added in order to introduce MTA to the characteristic of osteoconduction. The tests for the characterization of new cement were: X-ray diffraction, scanning electron microscopy and radiographic appearance. The results showed that the new developed biociments were obtained efficiently, since they showed the same crystalline phases of its starting materials (mineral trioxide aggregate and hydroxyapatite), with a morphology consisting of agglomerates of homogeneous distribution of irregular size and shape particles pre-sintered spherical and radiopacity feasible to be used in endodontics.

## INTRODUCTION

The potential of synthetic biomaterials on regeneration of hard tissues is important, since they do not damage healthy tissues or pose risks of viral and bacterial contamination, and can be commercially available <sup>(1)</sup>. However, complex and costly methods are used for design and development of such materials. Major advances in the field of biomaterials have occurred mostly due to the increased number of patients in hospitals who want to improve their life quality, in order to replace the total loss or part of a human body member. Also the development of surgical techniques has expanded the demand for dentures, implants and medical equipment <sup>(1)</sup>.

The cements are defined as materials consisting of a powder and a liquid which, when mixed form a paste which hardens spontaneously at room or body temperature and bonds two surfaces. The dental cement is a product of chemical reaction between an acid and a base substance, most commonly oxide or hydroxide. In dentistry cement lends itself not only as a cementing agent, but also as thermal, electric and chemical insulator in pulp protection <sup>(2)</sup>.

Cements of calcium silicate such as MTA (mineral trioxide aggregate) and derivatives portland materials are hydraulic cements composed mainly of tricalcium silicate, tricalcium aluminate and gypsum. When hydrated, these hydrophilic components undergo a series of physical and chemical reactions resulting in nanoporous gel of hydrate calcium silicate with a portland soluble fraction or calcium hydroxide and calcium aluminate of hydrated phases <sup>(3)</sup>. An important property is that it can be used in damp and wet environments, such as water, blood and other fluids, thus being useful for orthopedic and dental surgeries <sup>(4)</sup>.

Filling materials such as cements based on calcium hydroxide, amalgam, IRM - intermediate restorative material and glass ionomer are extensively used as endodontic cements. However, the results divergence of studies on these materials showed that none of them meet the desirable characteristics of a suitable sealing material so far, which should offer excellent sealing, be easy to

handle, economical, provide biocompatibility and possess the ability to induce cementogenesis (cement formation) and osteogenesis (new bone formation) <sup>(5)</sup>.

Ceramic materials based on calcium phosphate in the form of porous implants or particulate materials have shown being suitable for replacements of bone tissues when they are subjected to only slight mechanical stresses. These materials when degrade form calcium and phosphate salts, being widely used for filling bone cavities, such as cements <sup>(6)</sup>. The representatives most used in the group of calcium phosphate bioactive synthetic materials (Ca/P) are the hydroxyapatite,  $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$ , and  $\beta$ -tricalcium phosphate,  $\text{Ca}_3(\text{PO}_4)_2$ , due to osteoconductivity, crystallographic structure and chemical composition similar to skeletal tissue <sup>(7)</sup>, with increasing application of these materials in the medical and dental areas <sup>(8)</sup>.

Besides its biological occurrence, the HAp can be synthesized in the laboratory by solid state reactions and through the wet method. The syntheses in solid state require high temperatures, but the material obtained is very crystalline and generally stoichiometric. Hydroxyapatite has been synthesized by several methods: precipitation in aqueous solution (direct pathway), solid state reaction (dry pathway), hydrothermal method (wet pathway) and sol-gel process. The method by direct pathway has been widely reported in the literature due to its good yield, low cost and use of relatively low temperature <sup>(9)</sup>.

Neto (2007) states that the osteoconductive cements based on calcium phosphate were introduced in the surgical practice as auxiliaries of internal fixation for specific fractures treatment. These cements, when hardening, do not produce heat, present resistance to compressive strength and, moreover, are slowly remodeled by the living organism. The main objective of the cement use is to fill spaces in metaphyseal bone, reducing the need for bone grafts <sup>(10)</sup>.

Given the above, this work aims at the development of a new biomaterial composed of mineral trioxide aggregate and hydroxyapatite, the MTA/HAp, with application in endodontics.

## MATERIALS AND METHODS

For this work accomplishment were used the following materials: Commercial mineral trioxide aggregate (MTA) ANGELUS® brand; Distilled water; Hydroxyapatite (HAp) synthesized by the wet pathway method.

The HAp AS synthesized was dried at 110 °C and passed through a sieve of 200 meshes (74 µm) and heat-treated at 1350 °C. Subsequently, 1% and 5% by weight of HAp was incorporated into the MTA. Therefore, initially the MTA cement was weighed in triplicate using an analytical scale and placed it in a porcelain crucible. Subsequently, the HAp obtained experimentally was added on the sealer at 1% to 5% by mass, mixing by hand with a spatula #24 and then being calcined at 500 °C/2 h. Subsequently, samples were handled with distilled water, placed in Petri dishes and dried in oven at 37 °C and 95% relative humidity for 24 hours. Cements obtained were identified according to the percentage of added hydroxyapatite and subsequently they were deagglomerated and passed through a sieve of 200 meshes (74 µm).

The designation received was: BIOC 1 (99% MTA added to 1% HAp); BIOC 5 (95% MTA added to 5% HAp). The precursor materials (MTA and HAp) and cements developed (BIOC 1 and BIOC 5) were characterized by: X-ray diffraction (XRD) on a Shimadzu (XRD-6000) diffractometer at 40 kV and 30 mA, radiation  $\text{CuK}\alpha = 0.154 \text{ nm}$  at the scan interval  $2\theta$ , between 5 and 70 degrees at 2°/min. • Scanning electron microscopy (SEM) at Philips electron microscope, model XL-30 - ESEM. Radiograph aspect (RX) in an X-ray apparatus Spectrum-70X Electronic model brand DABI ATLANT with a 0 ° angulation.

## RESULTS

Figure 1 illustrates the X-ray diffractograms of cements MTA, HPA, BIOC 1 and BIOC 5. According to Figure 1, the MTA cement aspect provides crystalline aspect and its majority phases are calcium silicate  $[\text{Ca}_3(\text{SiO}_4)\text{O}]$  (crystallographic data sheet 73-2077) and alpha phase of bismuth

oxide [ $\alpha$ - $\text{Bi}_2\text{O}_3$ ] (crystallographic data sheet 76-1730). As secondary phase component were identified traces of aluminum oxide (crystallographic data sheet 1-1180). The remaining crystalline phases present in the chemical composition provided by the manufacturer, at lower percentage, could not be identified due to the X-rays' detection limit (5%).

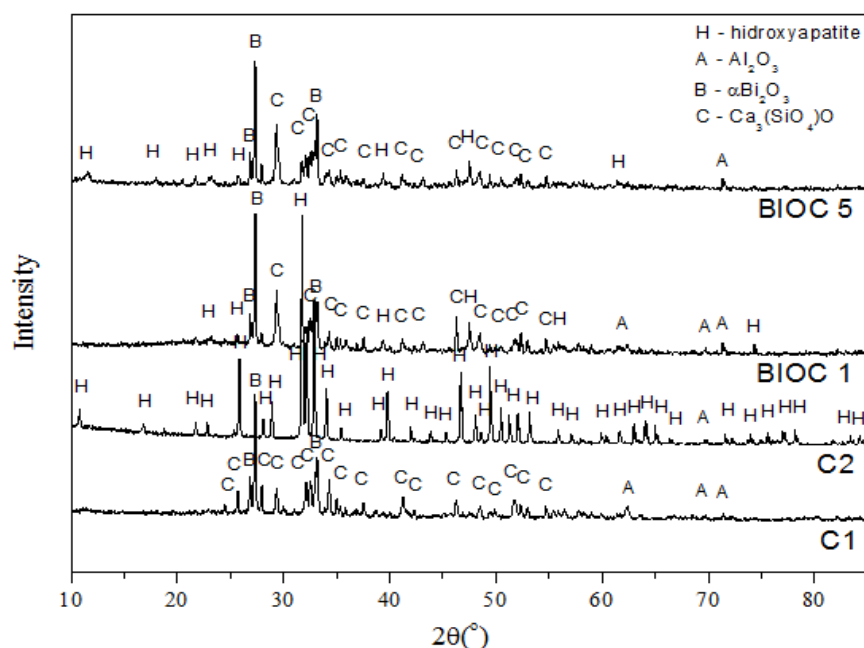


Figure 1 – X-rays diffractogram of cements.

Comparing the X-ray diffractogram of synthesized HAp with the standard sample (72-1243 crystallographic data sheet of the JCPDS database) there is only formation of the single phase of hydroxyapatite. It is also noteworthy that an XRD spectrum similar to that observed in this study for synthetic hydroxyapatite was also observed by Kusriani and Sontang (2012)<sup>(11)</sup> when studied the effect of sintering temperature on a bovine hydroxyapatite and another synthetic through the characterization by X-ray diffraction.

Analyzing the XRD spectrum of cements BIOC 1 and BIOC 5, the presence of the phases present in the precursor materials - MTA and HAp was observed, once it was possible to observe the same peaks observed in the diffractograms of pure MTA and HAp, thus confirming obtaining two new endodontic compounds by mineral trioxide aggregate and hydroxyapatite phases.

Figure 2 shows the micrographs of MTA cements, HAp, BIOC 1 and BIOC 5. By analyzing the micrographs shown in Figure 2, it is found that the morphology of pure commercial MTA consists of agglomerates with round shape, narrow size distribution and size smaller than 10  $\mu\text{m}$ . The agglomerates are apparently formed by small particles with low interparticle porosity. This morphology was also observed by Oliveira et al (2007)<sup>(12)</sup> for commercial MTA Angelus when performed a comparative study between the Pro-Root and Angelus MTA and Portland cement.

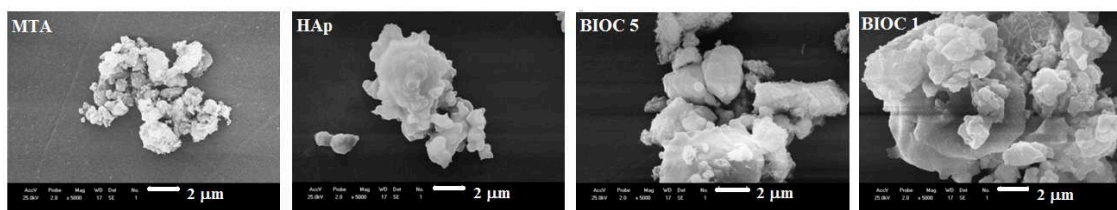


Figure 2 – Micrographs of cements.

By analyzing the HAp morphology, it is observed that it is constituted by agglomerates of size smaller than 5  $\mu\text{m}$ , with broad size distribution and irregular shape with approximately spherical particles, being pre-sintered (with neck formation between particles) and tightly bound. This characteristic is typical of materials subjected to thermal treatment at elevated temperatures. Morphology similar to that observed in this study, hydroxyapatite in form of agglomerates, was also observed by Rigo et al (2007)<sup>(13)</sup> for HAp, when studying the synthesis and characterization of HA obtained by the precipitation method and Leeke et al (2012)<sup>(14)</sup> when studying the effect of processing conditions to obtain nanoparticles of hydroxyapatite.

For the morphology of the new endodontic cement BIOC 1, it is constituted by agglomerates around 19  $\mu\text{m}$  with heterogeneous distribution in size and irregular shape. Particles are approximately spherical and also pre-sintered as HAp probably due to the heat treatment after the incorporation of 1 wt% HAp to the MTA. It was also observed that these particles are strongly bond. Regarding the cement BIOC 5, the morphology is constituted of agglomerates of approximately 10  $\mu\text{m}$ , with homogeneous distribution in size, irregular shape and particles strongly bound as observed in HAp and BIOC 1. By analyzing the micrographs shown in Figure 2, it is observed that the agglomerates size tended to decrease with increasing percentage of hydroxyapatite added to the MTA.

Figure 3 shows the periapical radiograph of four teeth elements whose dental cavities were filled with the four cements studied, MTA, HAp, BIOC 1 and BIOC 5. By analyzing the MTA radiograph is possible to observe that even when outside the tooth element, it has a high rate of radiopacity because their outlines are clearly visible and easily identifies the boundaries between it and the tooth; this high MTA radiopacity is provided by the presence of bismuth oxide in its composition. Observing the HAp radiography, it does not have good radiopacity compared with the MTA, since it is not perceptible the boundary between tooth and its contours. Radiographic appearance similar to that presented by HAp was observed for new cements BIOC 1 and BIOC 5, where one can observe slight increase in BIOC 1 radiopacity compared to BIOC 5, because cement BIOC 1 contains higher amount of MTA in its composition, thus helping in better identification of its contours. But the two cements developed satisfactory radiopacity for use in endodontics (preview identified).

## CONCLUSIONS

The MTA presents as main constituents:  $\text{CaO}$ ,  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$ , consisting of agglomerates of approximately 10  $\mu\text{m}$  and showing high radiopacity due to the presence of bismuth in the composition. The HAp was efficiently obtained by direct synthesis, once it was obtained the monophase consisting of hard agglomerates, pre-sintered nanometric particles (5  $\mu\text{m}$ ) and low radiopacity. New endodontic cements developed from the HAp addition to MTA at concentrations of 1% and 5% by weight BIOC 1 and BIOC 5, respectively, were efficiently obtained since all had the same crystalline phases of their precursors material with morphology consisting of agglomerates of 19  $\mu\text{m}$  (BIOC 1) and 10  $\mu\text{m}$  (BIOC 5), all with homogeneous size distribution and irregular shape with pre-sintered spherical particles. Regarding the radiopacity of new cements, they were intermediate, greater than that of HAp and lesser than MTA, showing that the two new cements are viable for use in endodontics.

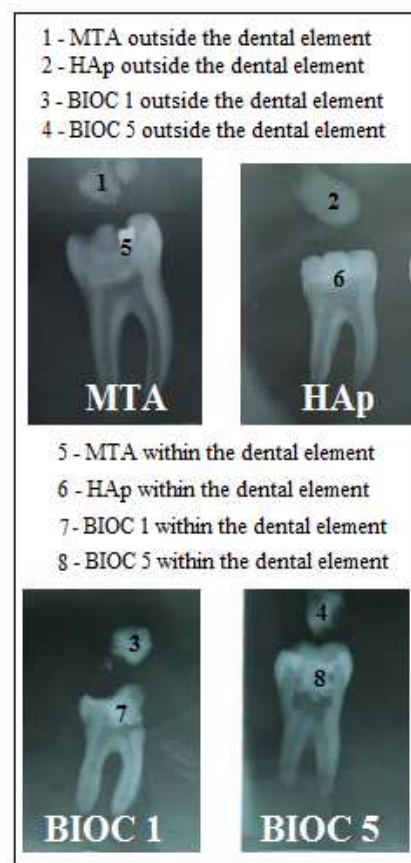


Figure 3 – Radiograph aspects of cements

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## GLASS IONOMER CEMENT – DEVELOPMENT AND CHARACTERIZATION MICROSTRUCTURAL

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**Keywords:** Cement, Ionomer, Microstructure, Oxides, Fluorine

**Abstract:** The Glass Ionomers Cements (GICs) are materials widely used in dentistry, have advantages such as fluoride release and chemical adhesion to the dental substrate. They are recommended as a restorative material, luting agent in prosthetic dentistry and also in medicine. However, there is need for developing new bone cements as an alternative or replacement to the current polymethylmethacrylate cements, therefore, the objective of this research was to develop an experimental GIC and characterization regarding morphology, chemical composition and crystallinity. This composite was characterized by X-ray diffraction (XRD), Infrared Spectroscopy Fourier Transform (FTIR) and optical microscopy (OM). For comparative study, was used the GIC Vidrion R (SS White) in the control group. These cements are presented in semi-crystalline diffraction patterns, the FTIR spectra observed characteristic bands of these materials and microstructural study of the cements showed homogeneous distribution of filler in the polymer matrix, corroborating with the literature.

## INTRODUCTION

The glass ionomer cements (GICs) are materials commonly used in dental practice since they were introduced commercially in 1972, due to its favorable properties such as adhesion to tooth structure and metal, anti-cariogenic, mild irritation pulp and bioactivity. Its disadvantages include: weakness or low toughness, low tensile strength, susceptibility to loss or gain of moisture in the early stages of the curing reaction of the material (DARVELL, 2012; MOUNT, 1998; WILSON, 1972).

The GICs are formed from an acid-base reaction between alumino-silicate glasses and an aqueous acid polialcenóicos. Are presented commercially in the form of powder and liquid, and the composition of the powders according to most authors, consisted of SiO<sub>2</sub> (29%), Al<sub>2</sub>O<sub>3</sub> (16.6%) and CaF<sub>2</sub> (34.3%). The aqueous acid solution is composed of water (45%), polyacrylic acid (30%), tartaric acid (10%) and itaconic acid (15%) (DARVELL, 2012; ANUSAVICE, 2007; BUSATO, 2005). These materials exhibit unique properties that include: ability to ion exchange with the tooth surface; fluoride release for a lifetime membership to the restoration and maintenance of tooth structure with marginal sealing for long periods. Limitations in clinical use are related to their mechanical properties, as mechanical strength of this material is inferior when compared with amalgam and composite resin, also presenting negative characteristic as a slow polymerization reaction (REIS, 2011; COSTA; NOORT, 2010; BARBOSA; NGO; 2008).

Currently, the development of GICs is related to the fact that this material is used in biomedical applications, especially for bone replacements. In orthopedics have advantages over cements polymethyl methacrylate (PMMA) because it has minimally exothermic polymerization reaction,



absence of release of residual monomers and potential release of incorporated therapeutic agents in the formulation (ORÉFICE, 2006; BROOK, 1998).

For best performance of these materials as their biomechanical properties, over time changes have been proposed in the compositions of cement, varying the compositions of glasses and polymeric components. The inclusion of such bioactive bioceramic particles, bioactive glasses, glass ceramics and ceramics of calcium phosphate composites are usually added to by giving the biocompatibility of these materials both as bioactivity, thus improving cell adhesion, as well as dental remineralization (DOROZHKIN; GUASTALDI; KIM, 2010; ORÉFICE; CORRÊA, 2006).

This study aimed to develop a glass ionomer cement for experimental use in dentistry, analyzing microstructural characteristics such as morphology, chemical composition and crystal structure of these materials and benchmark their characteristics with the characteristics of a glass ionomer cement business (control group).

## MATERIALS AND METHODS

The glass ionomer cement selected for this study as the control group was Vidrion R (SS WHITE) because it is a cement of conventional glass ionomer dental restorative material as indicated. The composition of the powder is described by the manufacturer consists of particles of sodium calcium aluminum fluorosilicate, barium sulfate, polyacrylic acid and pigments and liquid, tartaric acid and distilled water. All materials and reagents used in this study are listed in Table 1.

**Table 1** - Materials and reagents used in the study.

Materials / Reagents	Provider
Vidrion R	SS WHITE
Silicon Oxide ( $\text{SiO}_2$ )	VETEC
Aluminum Oxide ( $\text{Al}_2\text{O}_3$ )	VETEC
Calcium Fluoride ( $\text{CaF}_2$ )	VETEC
Aluminum Fluoride ( $\text{AlF}_3$ )	SIGMA ALDRICH
Aluminum Phosphate ( $\text{AlPO}_4$ )	SIGMA ALDRICH
Acrylic Acid ( $\text{C}_3\text{H}_4\text{O}_2$ )	SIGMA ALDRICH
Tartaric Acid ( $\text{C}_4\text{H}_6\text{O}_6$ )	VETEC
Itaconic Acid ( $\text{H}_2\text{CCH}_2\text{C}(\text{=CH}_2)\text{CO}_2\text{H}$ )	SIGMA ALDRICH

To cement the trial proposition, we used the compositions of the powders and of liquids GICs mentioned in the literature for these materials are presented commercially in the form of powder and liquid, where the particles are contained in vitreous powder and the acidic components in net. By mixing the powder with the liquid obtains a paste (cement), which is cured after a few minutes. For the preparation of glasses (powder) initially reagents ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{CaF}_2$ ,  $\text{AlF}_3$ ,  $\text{AlPO}_4$ ) were weighed separately in predetermined proportions, with a precision scale and soon after mixed and homogenized in an agate mortar. This mixture of oxides was placed in an alumina crucible for sintering in the kiln. The test was started when the furnace temperature reached  $1.200^\circ\text{C}$  when the crucible is inserted in the oven and maintained at this temperature for 2 hours. Immediately after this period, the furnace was turned off and held removing the crucible. At this moment was carried out rapid cooling (thermal shock) the melt in a metallic tank with water and the material was again crushed and homogenized in mortar and then sieved (350 mesh sieve) to obtain the glass powder.

To prepare the acidic solution, the acidic components ( $C_3H_4O_2$ ;  $C_4H_6O_6$ ;  $H_2CCH_2C(=CH_2)CO_2H$ ) were completely dissolved in deionized water at 1M solution.

For the preparation of the cement experimental was carried out the mixture of glass powder with the aqueous solution of polyacrylic acid ratio powder / liquid ratio 1:1. For the measurement the powder was used a "scoop" provided by the manufacturer of the cement used in this study. Powder and liquid were mixed manually every time by one operator using a plastic spatula on a glass plate at room temperature ( $22 \pm 1^\circ C$ ) until obtaining a fluid paste consistency and glossy. The paste formed was poured into molds for making spherical shapes of the samples. The cement was protected with a polyester strip and left at room temperature for 24 hours to complete curing of the material, and thereafter the samples were demoulded and characterizations performed; samples in this group were termed '**CIV EXP**'. To compose the control group, specimens of cement were prepared with the same processing conditions described for the experimental cement; samples of this group were called - '**CIV commercial**'.

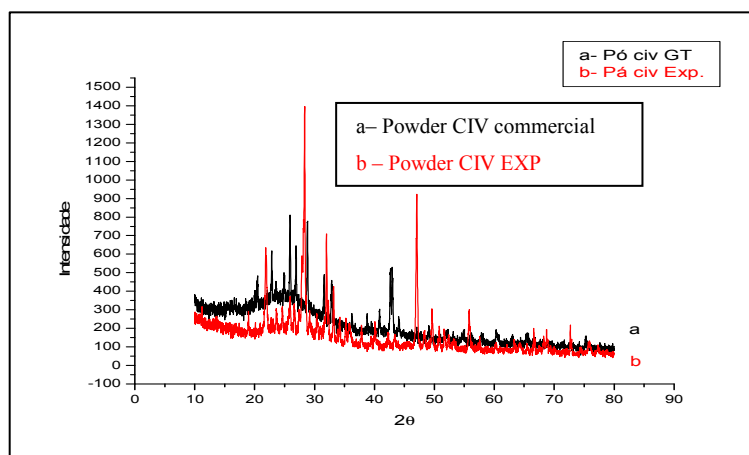
All samples were characterized by the techniques of X-ray diffraction (XRD), Infrared Spectroscopy Fourier Transform (FTIR) and optical microscopy (OM), the Laboratory for Biomaterials Development and Certification Northeast (CERTBIO) of the Academic Unit Materials Engineering (UAEMA), Federal University of Campina Grande - UFCG.

## RESULTS AND DISCUSSION

### Chemical and Structural Characterization

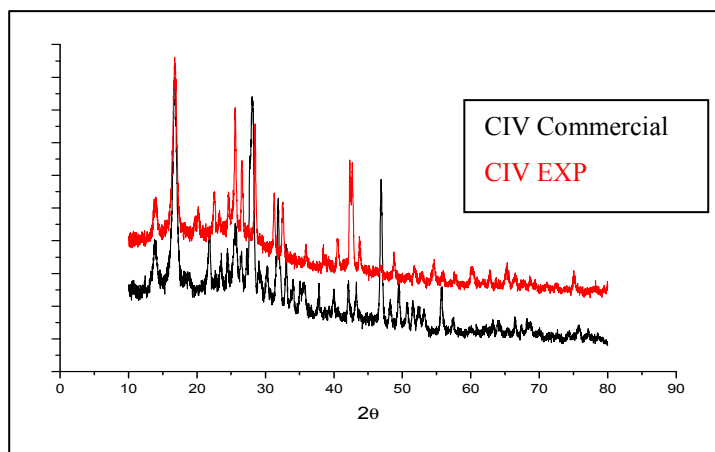
#### *X-Ray Diffraction (XRD)*

For characterization by diffraction of X-rays, the samples (in powder form) were prepared and characterized using radiation  $K\alpha$  of Cu in a diffractometer SHIMADZU (model XRD 6000) with scan angle  $5^\circ < 2\theta < 80^\circ$ , in assembly Bragg-Brentano system  $\theta$ - $2\theta$ , with the scanning step of 0,02 ( $2\theta$ ), with an interval of 0,5 seconds for each sample. The identification of the phases present was made by comparing the data obtained with the chips patterns of the database maintained by JCPDS - International Center for Diffraction Data. In Figure 1 are observed X-ray diffractograms of the powders of the cement and cement experimental after heat treatment.



**Fig. 1** - XRD patterns of the cement powder: Commercial (a) and experimental (b).

The powder diffractogram of the cement, in Figure 1, shows predominantly amorphous phase, however, the cement powder in the presence of experimental there crystalline phases formed during the cooling process of the material after calcination. In Figure 2 are the observed X-ray diffraction patterns of commercial and experimental cements after cure.



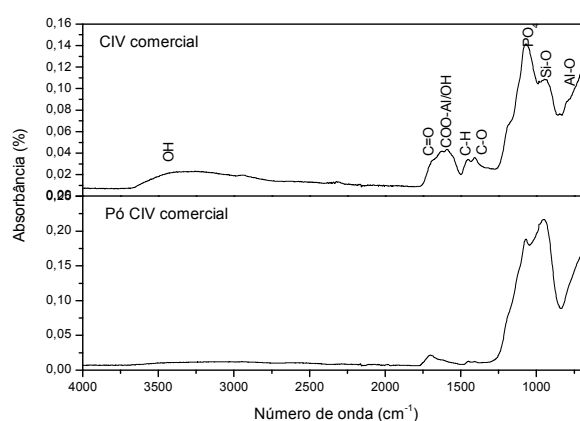
**Fig. 2** - XRD patterns of cements: Commercial (a) and experimental (b).

The XRD patterns of Figure 2 reveal the presence of crystalline phases, is considered a semi-crystalline material or glass-ceramic. According to the literature, these compounds exhibit character amorphous when calcined at temperatures below  $800^{\circ}\text{C}$ , however above this temperature begins to crystallize the material (BARBOSA, 2008; BERTOLINI, 2005).

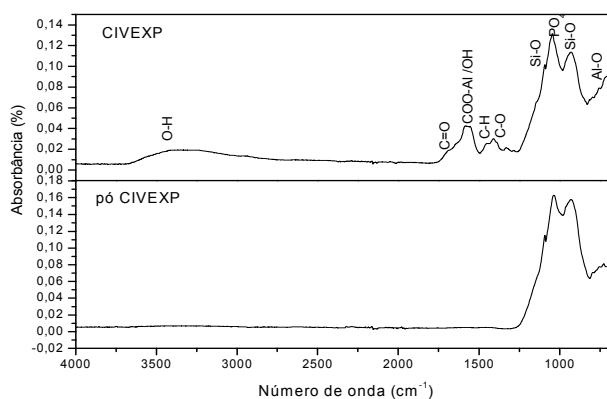
By comparison of the diffractogram pattern available in database JCPDS - International Centre for Diffraction Data, observed in the experimental diffractograms of cement presence of crystalline phases corresponding to calcium fluoride ( $\text{CaF}_2$  – JCPDS 77-225) and silicon oxide ( $\text{SiO}_2$  – JCPDS 76-936). It was observed that aluminum oxide present in the composition of these cements showed no crystalline phase.

#### *Spectroscopy in the Region of Fourier Transform Infrared (FTIR)*

FTIR analysis was performed to identify the bands characteristics of powders and of cements used in this experiment, and the results are shown in Figures 3 to 5. Figure 3 shows the spectra of the powder and the cement, whereas in Figure 4 one can observe the spectra of experimental powder and cement, and in Figure 5 the spectra of commercial and experimental cement after cured.



**Fig. 3** - Spectra cement and cement powder commercial.



**Fig. 4** - Spectra of the cement and the cement powder experimental.

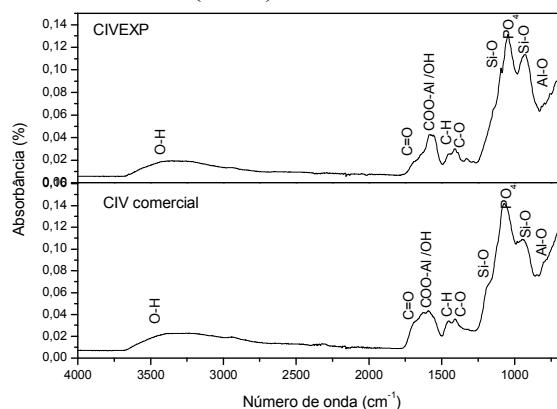
The spectra of the powders of commercial and experimental cements in Figures 3 and 4, showed characteristic bands of Si-O e  $\text{PO}_4\text{S}$  and without the presence of bands characteristic of bonds C-O, C=O and O-H.

In the spectrum of the cement powder, in Figure 4, there is a band in the range  $1700\text{ cm}^{-1}$  related to C=O bond that is linked to the acid component and incorporated into the lyophilized powder. Generally polyacrylic acid necessary for chemical reaction is present in the liquid material thus when it is lyophilized to powder called Glass Ionomer Cement anhydrous (SIDHU, 2010; REIS, 2009; CONCEIÇÃO, 2007; ANUSAVICE, 2005). In experimental cement powder was not added any of the acidic components, thus, were not found their characteristic bands.

In Figure 5 the spectra are observed cements commercial and experimental showing that the absorption bands in the region of  $1466$  and  $1646\text{ cm}^{-1}$  may be attributed to the symmetric and asymmetric stretching of the link COO-Al, suggesting that the Si-O-Al network vitreous were hydrolyzed by polyacrylic acid (BERTOLINI, 2005; YOUNG, 2004; MAEYER, 2002).

The bands related to the stretching of bonds, C-O, C-H and C=O, which according to the literature are related to polyacrylic acid, lie at  $1400\text{ cm}^{-1}$  (C-O bonds),  $1452\text{ cm}^{-1}$  (C-H bonds) and  $1710\text{ cm}^{-1}$  (C = O bonds). However, no bands were observed characteristics of residual double bonds in the carbon cements, indicating an effective cure reaction. This fact was also observed in the work of Bertolini (2005) and Young (2004).

In the region  $960$  a  $1200\text{ cm}^{-1}$  band is found for the intense phosphate cements we analyzed, while bands located in the regions  $3500$  e  $1600\text{ cm}^{-1}$  are attributed to the stretching of the O-H bond and the angular deformation of the link H-O-H, referring to vibrational modes of water, similar results observed by Barbosa (2008) and Bertolini (2005).



**Fig. 5** - Spectra of experimental and commercial cements.

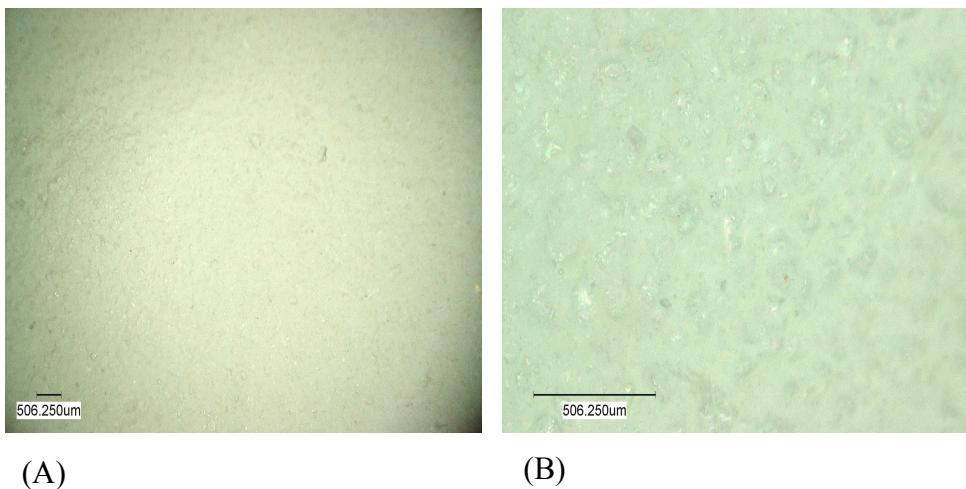
In the range of  $1100$ - $1000\text{ cm}^{-1}$  band is intense concerning the other asymmetric stretch of Si-O network vitreous and bands located in the region  $720$  a  $700\text{ cm}^{-1}$  are attributed to the symmetric stretching of the Si-O-Si in  $\text{SiO}_4$  tetrahedron. Peaks corresponding to Al-O can be identified in the region  $800$  a  $670\text{ cm}^{-1}$  (BERTOLINI, 2005; YOUNG, 2004).

## Morphologic characterization

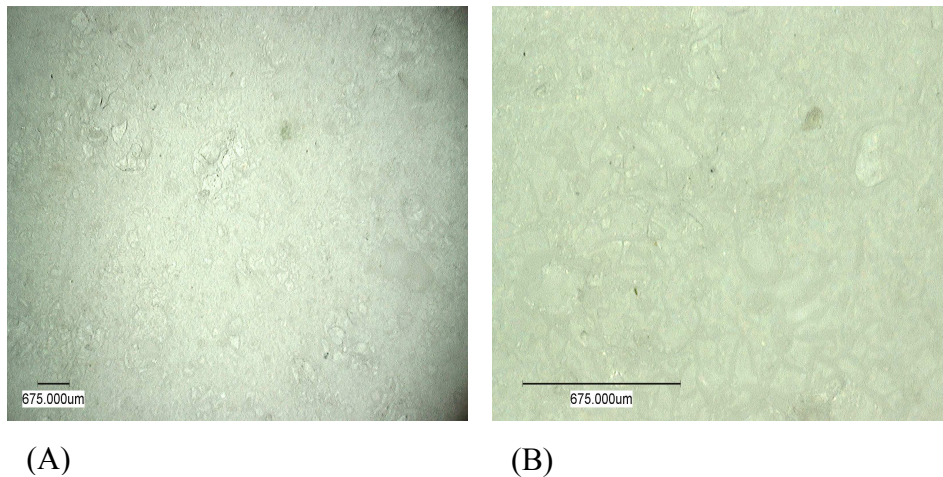
### Optical Microscopy (OM)

Can be seen in Figures 6 and 7 the MO micrographs of the microstructure of the surfaces of samples of commercial and experimental cements, after cure, where we can observe the distinction between the phases constituting the cements: organic matrix and inorganic particles. According Anusavice (2005), the content of inorganic particles has significant value in understanding the composites, and associated factors such as shape, size, chemical composition and distribution of particles facilitates the study of the physical and mechanical properties of restorative materials and cements such as wear resistance and hardness.

The study of microstructural surface of the samples of both cements showed that there was a similarity in shape, size and arrangement of inorganic particles, and can observe irregular shape and sizes of these particles, however, there is a slightly rough surface but without the presence of pores visible, similar results were observed by Denisova *et al.* (2004) and Oliveira (2005).



**Fig. 6** - Micrograph (MO) of the cement: (A) 350x, (B) 1750x



**Fig. 7** - Micrograph (OM) cement experimental: (A) 350x, (B) 1750x

The micrographs obtained from experimental samples of the cement showed less surface homogeneity compared to commercial cement with formation of agglomerated particles. This fact may be due to the manual process of mixing the material, by inadequate incorporation of the powder to the liquid during agglutination. This fact may alter the mechanical properties of the cement, which will be evaluated in mechanical tests in later stages of this research.

## CONCLUSION

From the results obtained, one can conclude that the obtained material presents a characteristic semicrystalline material, and they confirm to literature; FTIR analysis it was observed the presence of bands specific characteristics of these materials, cements and the study of the microstructure showed there was adequate distribution of inorganic particles in the polymer matrix, however, for this experimental cement distribution was not uniform.

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## BIOCOMPATIBILITY OF DENTAL RESTORATIVE MATERIALS

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**Abstract.** Biocompatibility is the ability of a material appropriate trigger a biological response, when applied to the body, without causing a chronic inflammatory reaction, foreign body reaction or toxicity, is related to the interaction of the cell / biomaterial. A few materials, if any, are completely inert from the physiological point of view since, most of the components with a variety of potential toxic or irritating. In addition, chemical reactions during cure of the material may also produce undesirable effects. In order to increase knowledge about the characteristics and properties of materials and their interaction with the biological environment, this study aimed, through literature review, guide and inform didactically professionals and academics on the importance of biocompatibility of restorative materials more direct use in dental practice: silver amalgam, composite resins and glass ionomer cements. It was concluded that, among the restorative materials studied, the glass ionomer cement showed the best characteristics and properties that confirm its biocompatibility in dental practice.

## INTRODUCTION

Significant advances the use of biomaterials in dentistry, in order to repair bone tissue and teeth lost by some kind of disease or accident, has enabled professionals using innovative therapeutic rehabilitation, reestablishing the physical, psychological and social patients.

Although a wide range of dental restorative biomaterial on the market, very few materials meet all the necessary requirements for the use of a biomaterial, being the most relevant one biocompatibility (PASCHOAL, 2011).

The biocompatibility, or bioaceitação, is the ability of a material has to develop an appropriate biological response on contact with living tissues or fluids. The interaction that occurs at the interface material / fabric is dynamic and depends on a number of factors such as: the place to be implanted biomaterial, material properties and biological response of the host (REIS, 2009; ANUSAVICE, 2005).

No material dental is completely safe, so the decision about the use of these materials must be balanced in the potential risks and benefits determined by the professional, overlapping the benefits against the possible risks. A material considered to be biologically compatible should not:

Damage to the pulp and soft tissues;

*Contain toxic substances that cause problems systemic in nature;*

*Have agents that induce allergic responses;*

*Submit carcinogenic potential.*

In addition to these criteria, when choosing a restorative material for use in dental practice, one should consider the factors that influence the response of the complex dentinopulpar as the depth of



the cavity, the age and condition of the patient pulp (LIMA, MONDELLI, 2006; ANUSAVICE, 2005; WATAHA, 2001).

The measurement of the biocompatibility of dental materials is performed through three basic types of tests: in vitro and in vivo animal testing or application usage conducted in animals or humans. It is necessary that any material designed for use by dental pass three tests before being marketed, because no single test can accurately assess the biological response of the material (REIS, 2009; ANUSAVICE, 2005).

## LITERATURE REVIEW

### *Adverse effects of dental materials: toxicity, inflammation, allergy and Mutagenicity*

There are several biological responses that can occur when a material is placed in contact with living tissue, this response may be inflammatory in nature, allergic, toxic and mutagenic, and this classification based on pathological and histological analyzes (REIS, 2009; ANUSAVICE, 2005).

The toxicity is dose related material which can cause cell death or tissue. The use of a non biocompatible material of the dental element can cause an increase in the inflammatory response, leading to cell death and tissue necrosis. The second type of biological response is a material inflammation. The inflammatory response involves the activation of the host immune system to defend it from threats, and this inflammatory response can also result in toxicity or allergy. It is important research on the biocompatibility of dental materials, pulp and periodontal diseases because they are, in most cases, chronic inflammatory responses to infection in the long term (REIS, 2009; ANUSAVICE, 2005).

The inflammatory response is very difficult to distinguish the allergic response. The allergic reaction occurs when a body specifically recognizes as foreign material and reacts disproportionately to the quantity of material present, involving the immune system as a whole, including monocytes or macrophages and lymphocytes T and B. She is an antigen-specific antibody response in some individuals, resulting histologically in an inflammatory response that can be difficult to differentiate a nonallergic inflammation or low grade toxicity (REIS, 2009; ANUSAVICE, 2005).

Mutagenic reactions occur when components of a material alters the sequence of base pairs of DNA in the cell, being called mutations. Can be caused by direct interactions between a substance and the DNA, or indirectly by changes in cellular processes that maintain the integrity of DNA. Vários metal ions dental materials, such as nickel, copper and beryllium, and some resin materials exhibit mutagenic potential, however, responses caused by dental materials for direct use are, in most cases, the local order, without systemic involvement (REIS, 2009; ANUSAVICE, 2005).

### *Dental biomaterials*

The dental restorative materials are biomaterials used to repair or replace the tooth structure and should combine a set of special features: be easy preparation and application; exhibit high resistance to corrosion and degradation in the oral environment, be biocompatible; quickly acquire the necessary mechanical properties as high pressure resistance, thermal be expanded compatible with the natural tooth; hermetically sealing the neighboring tooth tissue; in color and transparency compatible with the natural tooth and also have low cost (CONCEIÇÃO, 2007; ANUSAVICE, 2005).

The materials for dental applications can be structurally divided into the following categories: metallic, ceramic, polymeric and composite materials. The classification of these materials is associated with the types of interatomic bonds predominantly present and how atoms bind. Metallic materials are materials in which there is predominance of metallic bonding, ceramic materials are generally organic compounds in which the atoms are linked by covalent or ionic bonds, whereas the polymers constitute a group of materials that are formed from a process called polymerization '.



Composite materials are those formed by combining two or more chemically distinct materials, having a recognizable interface between them, whose constituents retain their identities, resulting in a new material with superior properties to that material which originated (CONCEIÇÃO, 2007; REIS, 2009; ORÉFICE, 2006; KOVARIK, 2005). Figure 1 shows the classification of materials with examples thereof within the dental clinic.

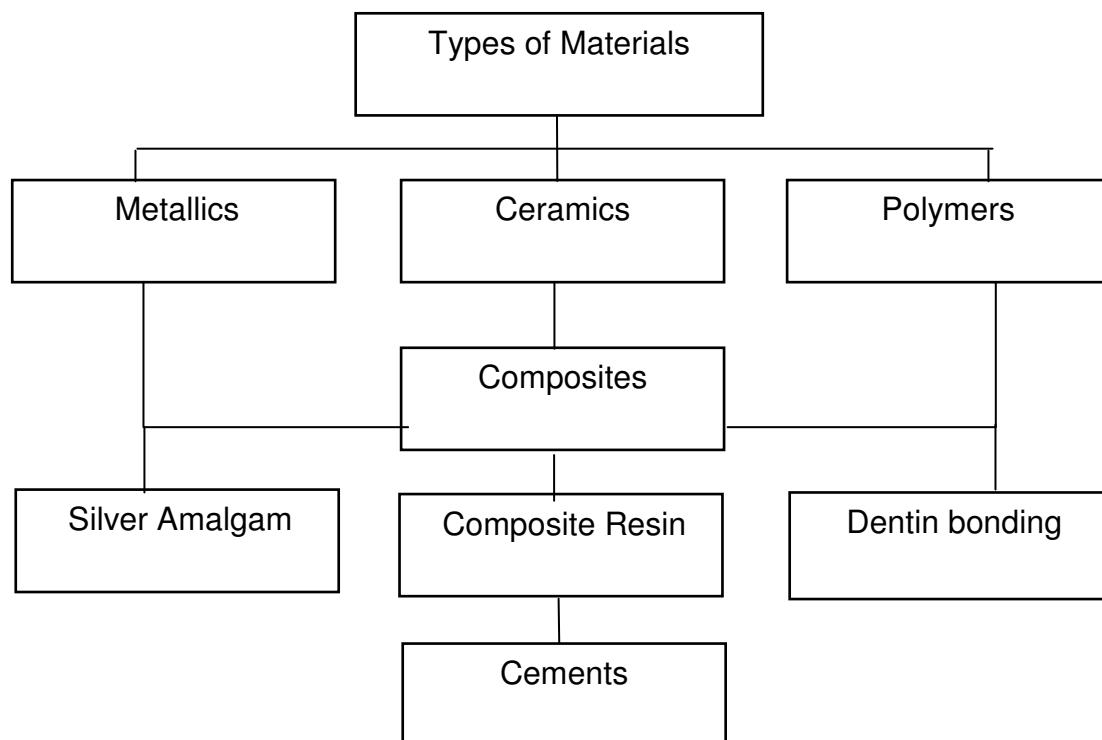


Figure 1 - Classification of materials(ORÉFICE, 2006).

### ***Composite Resins***

Due to growing demand for a direct restorative material which mimetizasse characteristics of teeth, researchers have developed composites, consisting of a polymer matrix, particles of inorganic fillers and coupling agents (BUSATO, 2005).

Polymeric matrix: In dentistry, the biggest advance in terms of composite materials occurred from the work of Bowen, 1963, where he developed a new type of composite resin based on bisphenol A-glycidyl methacrylate (Bis-GMA). Bis-GMA resin can be described as an ester of an aromatic dimethacrylate, sintered from an epoxy resin (ethylene glycol bis-phenol A), and methyl methacrylate. Most compounds dental uses a mixture of monomers dimethacrylates aromatic and / or aliphatic, the main Bis-GMA, triethylene glycol dimethacrylate (TEGDMA) and urethane dimethacrylate (UDMA) (DARVELL, 2012; ORÉFICE, 2006; ANUSAVICE, 2005). Figure 2 shows the structure of the molecules of Bis-GMA, TEGDMA and UDMA.



bloodstream via alveoli, where it is distributed in the body, especially into tissues adipose and nervous (ANUSAVICE, 2005).

Studies have shown that the vapor release amalgams sufficient to cause absorption 1-3  $\mu\text{g}$  of mercury per day, depending upon the amount of alloy present. Mercury is also ingested during the wear of amalgam restorations, about 45  $\mu\text{g}$  per day can reach the gut in the form of amalgam particulate or be dissolved and released as  $\text{Hg}^{2+}$  ions. Symptoms of the toxicity of mercury are related to the form of the mercury being the lowest level to any known toxic effect is 3  $\mu\text{g}$  / kg. Acute symptoms are neurological or renal going paresthesia (at levels  $\geq 500$   $\mu\text{g}$  / kg) to ataxia ( $\geq 1000$   $\mu\text{g}$  / kg), joint pain ( $\geq 2,000$   $\mu\text{g}$  / kg) and death ( $\geq 4000$   $\mu\text{g}$  / kg). Symptoms of chronic exposure include weakness, fatigue, anorexia, weight loss, insomnia, irritability, shyness (distrust), dizziness and tremors in the extremities or eyelids (ANUSAVICE, 2005).

However, studies conducted in populations exposed to mercury professionally, no evidence that dental amalgam mercury released is harmful (DARVELL, 2012; REIS, 2009; ANUSAVICE, 2005).

### **Glass ionomer cement**

The conventional glass ionomer cements (GICs) are presented commercially in the form of powder and liquid. The powder is composed of silica ( $\text{SiO}_2$ ), alumina ( $\text{Al}_2\text{O}_3$ ), calcium fluoride ( $\text{CaF}_2$ ), aluminum fluoride ( $\text{AlF}_3$ ), aluminum phosphate ( $\text{Al PO}_4$ ) and sodium aluminum fluoride ( $\text{Na}_3\text{AlF}_6$ ) the liquid comprises by an alkenoic acid, and polyacrylic acid as used (30%), itaconic acid (15%), tartaric acid (10%) and water (45%). These materials exhibit unique properties that include: ability to ion exchange with the tooth surface, release fluoride for a lifetime membership to the restoration and maintenance of tooth structure with marginal sealing for long periods. Limitations in clinical use are related to their mechanical properties, ie mechanical strength of this material is inferior when compared with amalgam and composite resin, also presenting negative characteristic as a slow polymerization reaction (REIS, 2009; COSTA, NOORT, 2010; NGO, 2010; BARBOSA, 2008).

The first category of glass ionomer cements introduced into dentistry was named cements conventional glass ionomer (CIVC), however, in order to improve the physical and mechanical properties, these materials have undergone some changes in its composition. One was the inclusion of hydrophilic monomers such as 2-hidroxiethyl-methacrylate (HEMA) and polymerization initiators, thus resulting in the glass ionomer cements, resin-modified (RMGICs) (SILVA, 2010; CONCEIÇÃO, 2007; BUSATO, 2005).

The biocompatibility of ionomer cements is attributed to some reasons such as the ability to adhere to tooth structure, high molecular weight polyacrylic acid present in the composition, minimally exothermic curing reaction and rapid pH neutralization. These materials are initially very acidic ( $1.6 \leq \text{pH} \leq 3.7$ ), however, after full polymerization occurs an increase of pH ( $5.4 \leq \text{pH} \leq 7.3$ ) (SILVEIRA, 2010; SCHMALZ, 2009; NICHOLSON, 2003).

The diffusion of existing polyacid in its formulation by dentinal tubules is restricted due to the fact that they are macromolecules of high molecular weight and high propensity to unite with calcium tooth; these reasons allow the use of cement as a liner material in areas near the pulp. Just as the dental pulp, the soft tissues of the oral cavity show high levels of tolerance to glass ionomer cement because when used in subgingival restorations do not act as irritants to these tissues (SCHMALZ, 2009; DAGUANO, 2007; COSTA, 2000).

The cytotoxicity of these materials is a property that is a point of discussion in the literature because there is no unanimity of opinion. Some authors cite some factors that can contribute to the cytotoxicity of these materials, such as changes in pH, temperature increase during the curing process of the cement and release of ionic components as aluminum ions, sodium, fluoride, calcium, zinc and strontium. However, some *in vitro* studies have shown that the cytotoxic effects of RMGICs are more evident when compared with those of conventional GICs, and this is attributable largely to incorporation of the HEMA monomer. Due to the low molecular weight of HEMA and its hydrophilic characteristic, it has been described that when the ideal degree of polymerization is not

reached, a residual amount of the monomer can easily diffuse through the dentinal tubules and reach the pulp cells (LESSA, 2008; JORGE, 2004; MJOR, 2002; COSTA, 2000).

The canals or dentinal tubules are responsible for the diffusion of fluids through the dentin and are directly related to this protective function. These tubules are shown grouped and cross the dentin throughout its thickness (Figure 3), containing the cytoplasmic cell - the odontoblasts present in dental pulp (LUFTI, 2010; ORÉFICE, 2006; ARANHA, 2006).

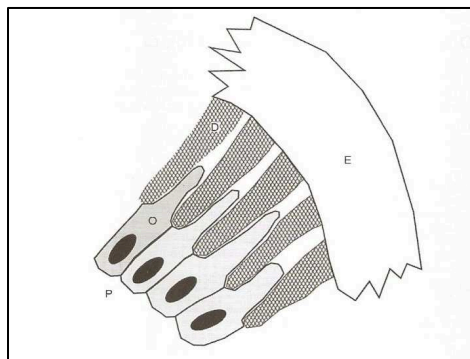


Figure 3 - Diagram of the complex enamel-dentin-pulp where the enamel (E) is the outer covering of the tooth, the dentin (D) is a compound of collagen and mineralized tissue containing the cytoplasmic processes of odontoblasts (O) based on pulp (P) (Source: ANUSAVICE, 2005).

Residues of methacrylate monomers can be incorporated into the lipid bilayer of the cell membrane leads to solubilization of odontoblasts this structure and consequent irreversible cell damage. Thus, the RMGICs should not be placed in direct contact with the pulp tissue, however, studies show the compatibility of these biological cements when used in contact with gums and oral mucosa (LUFTI, 2010; MANEENUT, 2010; SCHWAP, 2009; LESSA, 2008; ARANHA, 2006).

Outside of dentistry, the GICs have found indications as surgical cement in orthopedic implants in cranio-facial reconstructions for cochlear implant fixation and sealing of defects in the skull. These materials are not inert, but bioactive, after his deployment a response mediated by ion exchange is generated, and this reaction is dependent on the composition, location and type of fabric. These cements can be designated as biocompatible substitutes for bone cements and osteoconductive activity generating favorable clinical and biological responses (ORÉFICE, 2006; GU, 2005).

Cement polymethylmethacrylate (PMMA) have been indicated for cementation of hip prostheses for many years, but subsequent failures with the use of these materials have been reported due to several factors: there are biocompatible, does not adhere to the bone and have high shrinkage when polymerized, being its exothermic curing reaction. The GICs have numerous advantages over PMMA cements, such as good adhesion to bone, stability in aqueous environment and minimum exothermic reaction of polymerization (MANEENUT, 2010; HATTON, ORÉFICE; 2006; GU, 2005; ROGERO, 2003).

## CONCLUSIONS

According to the literature no material is completely biocompatible, however, among the most direct restorative materials used in clinical dentistry, the glass ionomer cements are conventional materials that have better biological properties.

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