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ELECTRICAL PROPERTIES OF FEW DENTAL MATERIALS

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ABSTRACT

Bioelectrics is a new interdisciplinary field, unifying an interdisciplinary team of scientists who integrate knowledge of electrical principles and theory, physics, material sciences, molecular cell biology, animal sciences and medicine. It investigates interactions of electric fields with cells and tissues for a number of possible basic science and therapeutic applications. There are also possible environmental applications. In the present investigation, the application of an electric field has been shown to positively influence on few dental materials currently used in dentin bonding systems. This study presents an experimental characterization of the electrical properties of dental materials namely Acrylic resin, Alginate, Dental plaster, Dental stone, Glass ionomer and Silver amalgam with the aim of both correlating them to their chemical structures and seeking an insight into the mechanisms of migration under an applied electric field.

1. INTRODUCTION

Biomaterials are those materials that are compatible with living tissues. The physical properties of these materials, their potential to corrode in the tissue arrangement, their surface configuration, tissue induction and their potential for eliciting inflammation or rejection response of all important factors of under this area. The biomaterial discipline has evolved significantly over the past decades[1].

The electrical properties of biological cells and tissues are very remarkable. They typically display extremely high dielectric constants at low frequencies, falling off in more or less distinct steps as the excitation frequency is increased. Their frequency dependence permits identification and investigation of a number of completely different underlying mechanisms, and hence, dielectric studies of biomaterials have long been important in electrophysiology and biophysics[2].

Electrical properties of the biomaterials in which, electrostatic field can persist for a longer time and offer a very high resistance to the passage of electric current under the action of the applied direct current voltage and hence sharply differ in their basic electrical behavior from conductive materials. Much may be known about the structure of matter from measurement upon polar liquids and solids, at extremes of frequency and often involving absorption of electrical energy as shown by the measured dielectric loss (Imaginary Permittivity) and frequency dependence of the dielectric constant (Permittivity) [3].

Permittivity is a physical quantity that describes how an electric field affects a dielectric medium [4]. It is determined by the ability of a material to polarize in response to electric fields, and thus reduce the total electric field inside the material. In general, the response of a solid medium to external fields depends on the frequency of the field. This frequency dependence reflects the fact that material polarization does not respond instantaneously to an applied field due to material inertia[5]. This leads to power losses generated by the polarization process (dielectric losses) and to a phase delay between polarization and electric field. When the applied electric field exhibits a sinusoidal behavior, this delay can be mathematically expressed by considering a complex quantity for the electrical permittivity[6]

$$\bar{\varepsilon} = \varepsilon' - j\varepsilon'' \qquad -------- (1)$$

The real part (ε') i.e., dielectric constant and the imaginary part (ε'') of the permittivity i.e., dielectric loss are associated with the extent of polarization and (1) by the vacuum permittivity constant $\varepsilon_0 = 8.85\times10^{-12}$ F/m. This paper deals with variation of dielectric properties, such as dielectric constant, dielectric loss factor and electrical conductivity of different dental materials from 100Hz to 1MHz frequency range along the tangential direction.

2. MATERIAL METHODS

2.1 Tested dental implants

Acrylic Resins[Polymethyl methacrylate-as beads or grindings], **Alginate[** Ester salts of alginic acid, sodium, Calcium sulphate, zinc oxide, potassium titanium fluoride, diatomaceous earth, sodium phosphate, coloring and flavouring agent],**Dental plaster[**sodium tetraborate decahydrate, potassium sulphate and potassium sodium tartrate],**Dental Stone[**Sodium citrate, sodium tetraborate decahydrate, potassium sulphate, potassium sodium tartrate], **Glass ionomer [**Powder form contains silica, alumina, sodium fluoride, cryolite, calcium fluoride, calcium phosphate] and **Silver Amalgam [**Silver, tin, copper and zinc].

2.2 Preparation of dental samples

In the present investigation artificial dental powders materials collected in dental hospital, Bangalore for study of dielectric properties. Dental materials i.e. powders are converted into specimens in the form Pellets or discs by using Ball Milling apparatus for dielectric measurements. The dental material samples surface is painted with silver paste for electrode attachment. The reagent powders were mixed and ball milled using Restch PM 200 planetary ball mill in agate bowls with agate balls. It was then ground well in an agate mortar once till a fine powder was obtained. Intimate mixing of the materials was carried out using agate mortar for 4 h and then ball milled using Restch PM 200 planetary ball mill in acetone medium for 20 h with agate balls of different sizes in diameter in agate bowls. The slurry was dried and the dried powder was pressed into disc shape of size 2.5 cm diameter and 1 cm height using suitable. A small amount of saturated solution of 3% polyvinyl alcohol was added as a binder. The powder was then pressed in to pellets of 1.2 cm diameter and 2 mm thickness and toroids of dimensions 1.2cmx0.8cmx0.4cm (Do x Di x h) using a hydraulic press at a pressure[4]. Pellets of 1.2 cm diameter and 2 mm thickness and toroids of dimensions 1.2cmx0.8cmx0.4cm (Do x Di x h) using a hydraulic press at a pressure of 150MPa.The samples obtained after sintering from both the techniques were polished on fine carborundum powder to remove a thin layer from the surface regions.

2.3 Measurements of Dielectric parameters:

For the study of dielectric Properties of dental materials are taken in the pellet form. After that dental samples in the form of pellets are painted with silver paste for electrical conductivity. Dielectric constant and dielectric loss factor were measured at low frequencies from 100Hz to 1MHz by the computer using the low frequency impedance analyzer Hioki 3532-50 LCR-Hi tester Koizum, Japan.

3. RESULTS AND DISCUSSION

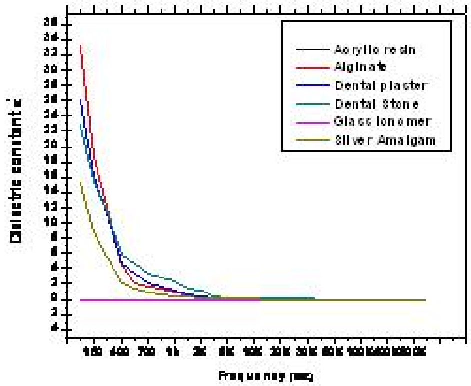

Fig. 1 Diectric constant(ε') as a function of frequency for different dental materials

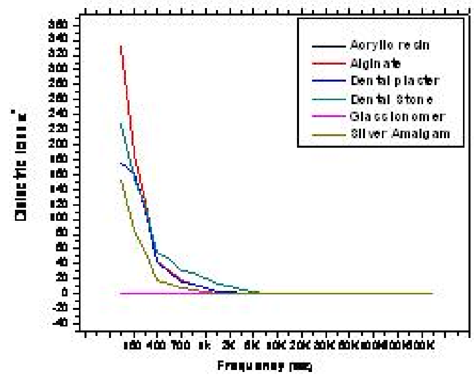

Fig. 2 Diectric loss (ε'') as a function of frequency for different dental materials

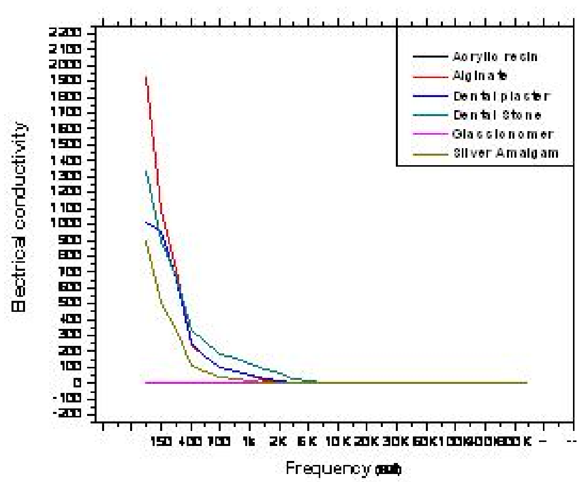

Fig. 3 Electrical Conductivity as a function of frequency for different dental materials

The measured electric properties of the tested dental materials shown in Figs. 1,2 and 3. The dielectric constant (Fig1) and dielectric loss (Fig2) as a function of frequency for the different dental materials tested at room temperature are reported in Fig. 1&2. Both real and imaginary permittivity is largely affected by frequency. In particular, dielectric constant at high frequencies, i.e. from 1 MHz down to a frequency characteristic for each material, is ranging from 1 kHz (max) to 100Hz (min) for the two dental materials Alginate and dental plaster respectively.

Fig. 3 reports the frequency response of electrical conductivity for the same as in Fig.1&2 at room temperature. The electrical conductivity shown exhibits a similar behavior compared to permittivity, being constant in the low-frequency range and variable at high frequencies (Fig. 3). The frequency of transition between these two regimes depends on the material, ranging from 100 Hz to 1 kHz for Alginate and dental plaster respectively.

Comparison of real part of permittivity (dielectric constant) and conductivity for the tested dental materials obtained from plots of Figs. 1 and 3, at frequencies for which the permittivity and conductivity are frequency-independent, i.e. at high (1 MHz) and low (100 Hz) frequencies, respectively. Permittivity and conductivity showed a similar behavior, i.e. materials having the lowest permittivity also showed small values of conductivity and vice versa. It should be noted that among the different materials, conductivity varied in a wider range with respect to permittivity. It showed the largest values of electrical permittivity and conductivity by Alginate, Glass ionomer had both the lowest conductivity and permittivity, while other exhibits intermediate values of conductivity and real permittivity.

4. CONCLUSIONS

The results of the present study revealed that electrical properties can be correlated with the chemical structure, in particular, the higher the polar contribution for the higher the permittivity and conductivity. Molecular size can play a smaller role in the case of molecules with similar polar properties. In this case, smaller molecules present higher conductivity with respect to larger molecules. Hence, it can be concluded that structural constituents and moisture content of dental materials have integrated activity in influencing the dielectric properties of dental materials. However, within the same dental sample, the dental parameters (density, moisture content etc) are more or less the same. The increase in the hydration increases the dielectric loss and dissipation factor. The dielectric constant is more in Alginate. This may be conclude that based on chemical composition and structure these dielectric materials can used as various ways in dental bonding systems and their biological activity.

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