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Investigations of dielectric behaviour and relaxation time on Acrylic Resin based Denture biomaterials

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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. 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 analysis of the dielectric properties such as dielectric constant (ε'), dielectric loss (ε''), electrical conductivity (σ) and relaxation time (τ) in the frequency range, 100Hz–1MHz at room temperature for Acrylic based dental biomaterials namely Acralyn H, DPI RR Cold cure Acrylic Repair material and Quick Ashvin 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.*

Key Wards: *Dielectric constant (ε'), Dielectric loss (ε''), Electrical conductivity (σ), Relaxation time (τ) and Acrylic based dental biomaterials*

I. 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 and Relaxation time of different Acrylic based dental biomaterials from 100Hz to 1MHz frequency range along the tangential direction.

II. Material Methods

2.1 Preparation of dental samples

Acrylic polymer Resins based dental materials such as Acralyn H, DPI RR Cold cure Acrylic Repair material and H-Quick Ashvin were from Dental Products of India, Mumbai and Wazipur industries, Delhi. In the present investigation Dental materials in the form grain powders are converted into fine powder by using Ball Milling apparatus. 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. 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 dental material samples surface is painted with silver paste for electrode attachment.

2.2 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 LCR impedance analyzer [7].

III. Results and Discussion

Dielectric data for frequencies from 100Hz to 1M Hz at room temperature 308K are presented in Fig.1-3 by taking 5 samples each. 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).

The dielectric constant (ε') decreases for all of Acrylic based dental biomaterials by varying the frequencies decreases to 1MHz. Decrease of dielectric constant (ε') shows that the contribution of interfacial polarization becomes insignificant, and the predominant polarization is molecular; that is, energy is absorbed in the form of induced dipole moment of the molecule, and in the form of alignment of molecules having fixed dipole moment [8].

Fig. 3 represents the frequency response of electrical conductivity for Acrylic based dental materials 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), reveals that the significant variations which may be attributed to the extent of hydration, molecular architecture, nature and composition of molecules and dental bonding system.

Relaxation Time

Dielectric parameters of materials are function of many exponential controlled parameters, the main issue is the temperature dependency of characteristics of relaxation times, it represents rate of chemical reaction rates. The Cole – Cole plot is a simple, elegant and highly useful tool to determine dielectric relaxation of a material in a particular range of frequency. Dielectric relaxation exhibits in biomaterials due to the frequency and temperature dependence of dielectric parameters, different dielectric relaxations observed in different dental biomaterials with different characteristic frequencies (Table 1).The number of relaxations from Cole-Cole plots, which show proportionality to the concentration of dipoles contributing to the orientation polarization, increasing with increase accessibility of dipoles in biomaterials [9]. In the present investigation, the results of dielectric parameters of different type of dental materials, reveals that one dielectric relaxation. This concludes that in Acrylic resin based dental materials relaxation due to polarization of dipoles of acrylic based derivatives present in composition.

IV. 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 Acralyn H. 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.

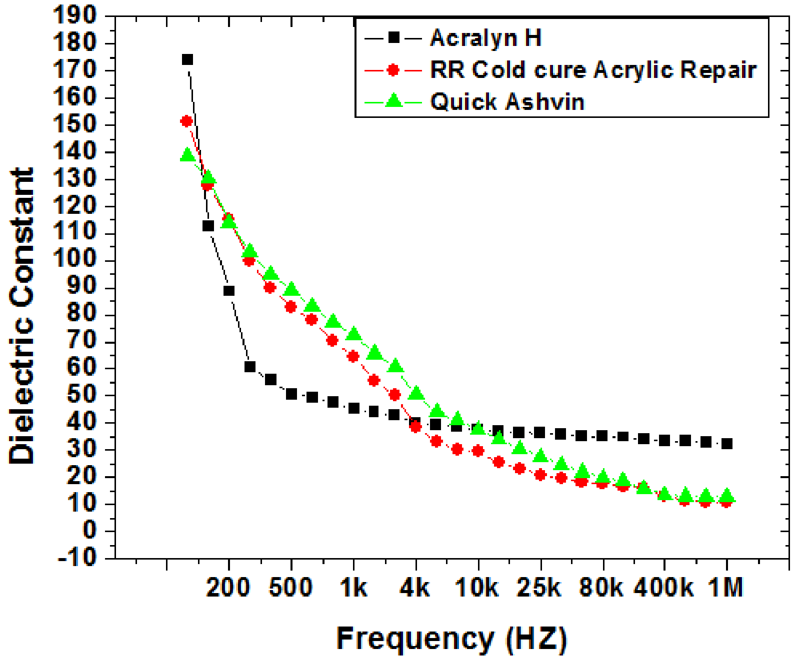

Fig. 1 Diectric constant(ε')as a function of frequency for Acrylic based dental materials

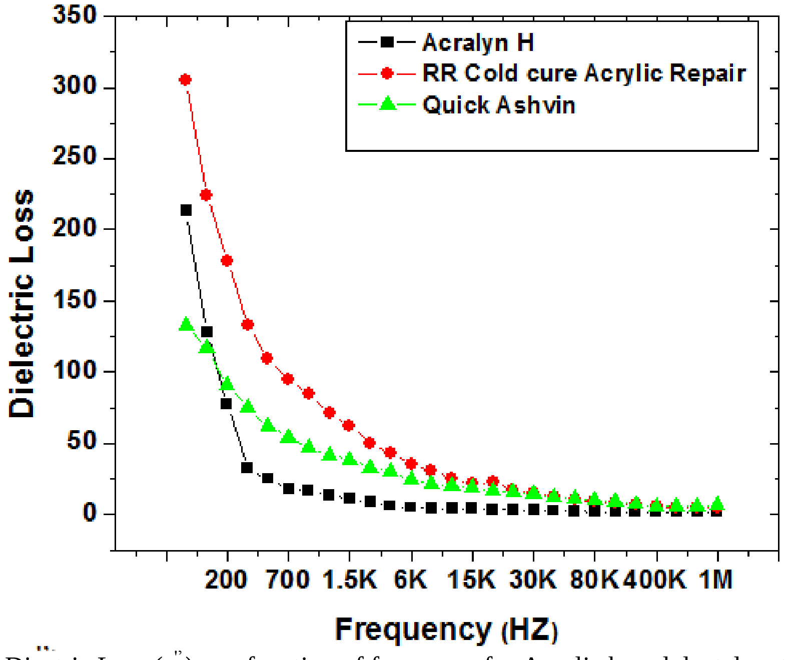

Fig. 2 Diectric Loss (ε'') as a function of frequency for Acrylic based dental materials

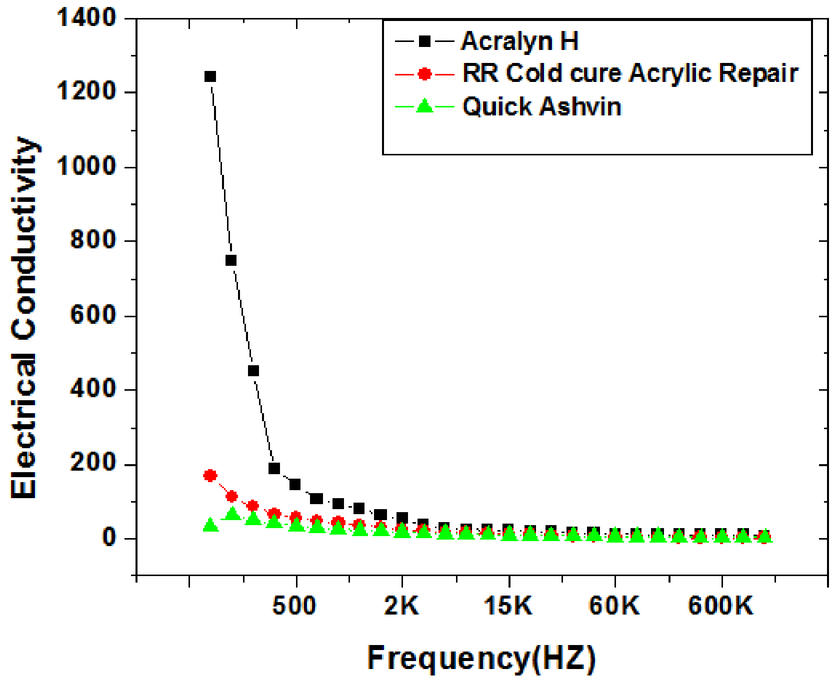

Fig. 3 Electrical Conductivity as a function of frequency for Acrylic based dental materials

Table.1. Data on Cole-Cole parameters

Name of the Dental material	Characteristic frequency(Hz)	U	V	□	Relaxation time(sec)
Acralyn H	2K	9.6	14.1	12	0.012µ
RR Cold cure Acrylic Repair material	1.5K	12.4	31	24.5	0.04 µ
Quick Ashvin	2K	17.1	24.5	39	0.02 µ

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