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ELECTROMAGNETIC PROPERTIES OF CEMENTS FOR FIXATION OF ORTHOPEDIC CONSTRUCTIONS

[1)]Yanenko O. P.,[1)]Shevchenko K. L., [2)]Golovchanska O. D., [2)] Symonenko V. S.
[1)]National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
[2)]O. Bogomolets National Medical University of Ukraine, Kyiv, Ukraine
E-mail:op291@meta.ua; autom1@meta.ua

Introduction. *In practical dentistry, a significant number of various materials are used - for filling teeth, for implant restorative surgery, as well as materials for prosthetics. In this case, metals, dielectrics and their combinations are used. The article is devoted to the results of the study of electromagnetic properties of a group of dental materials - fixing cements, which belong to dielectric materials. Theoretical and experimental studies of EMC materials from the arsenal of maxillofacial reconstructive and restorative surgery were also conducted. Significant EMC deviations were detected in some materials. Scientific results of experimental studies and relevant recommendations are presented in a number of authors publications both in Ukraine and abroad*

Main purpose of this study*. Usually, the orthopedic constructions and the fixation cement are in physical contact with both the patient's hard and soft tissues. Since dielectric materials at a human body temperature of 310K form their own electromagnetic radiation (EMR), it is important to ensure their electromagnetic compatibility - the coincidence of EMR with biological tissues adjacent to the implant to exclude the appearance of complications during their long-term use. A highly sensitive (10^{-14} W) microwave radiometric system was used for the measurements. In process of research, the five most commonly used cement samples in orthopedics were studied. Therefore, the purpose of this study is to deter-mine the radiative capacity of cement as a material widely used in dental practice and to evaluate their level of electromagnetic compatibility with contacting biological tissues.*

Conclusions. *1. In the process of experimental and computational studies, the emissivity coefficients β_M of 5 cement samples were determined, which range from 0.13 to 0.63 units.1.*

2. The first three samples (№№ 3-5) have a high level of electromagnetic compatibility (60...98 %), samples (№№ 6, 7) show much less coincidence with the EMR of the human body.

3. The results of the conducted research can be used by orthopedic specialists to select materials with greater electromagnetic compatibility.

Keywords: *orthopedic construction; fixing cement; microwave radiation; electromagnetic fields and radiation; electromagnetic compatibility.*

Introduction. Formulation of the problem

In practical dentistry, a significant number of different materials are used: filling materials, materials for implant restorative surgery, as well as materials for prosthetics. In orthopedic dentistry, from the point of view of physics, metals and dielectrics are widely used in various combinations.

A number of general requirements have been defined for materials are in contact with biotissues of the human body, which they must meet during their long-term use [1, 2]. First of all, implant materials should:

– be biocompatible, bioinert or bioinactive;
– not to have carcinogenic, toxic and allergenic effects;
– be resistant to the influence of the body's internal environment and not cause corrosion;
– have thermal and electrical conductivity close to the surrounding biotissues;
– provide mechanical strength and spring-elastic properties.

It should be noted that a wide range of dielectric biomaterials are used in dentistry: various types of fillings, bone implants, orthopedic structures, etc. Unlike metals, dielectrics at a human temperature of 36...37°C (310 K) are able to form their own weak electromagnetic fields and radiation (EMR), which can interact with the cells of the human body adjacent to the dielectric material (implant). The level of this radiation depends on the ratio of the emissivity of the dielectric and biotissue. In the long term, such an interaction can affect the condition of the adjacent part of the body. The border of separation and contact between the implant and the tissue is important and various processes of both positive and negative nature can occur there [3, 4]. Weak electromagnetic fields and radiation, under constant action, can also affect this process and even the immunity of the human body [5]. Therefore, there is a need to measure EMR and conduct an assessment of electromagnetic compatibility (EMC) of dielectric materials with biotissues of the human body.

However, to carry out such measurements, at a human body temperature of 310 K, it is necessary the integral sensitivity of the measuring equipment should be at the level of 10^{-14}...10^{-15} W. Measurement of such weak fields and emissions is a significant problem that can be provided in single non-standardized radiometric systems [6].

The development of the elementary base of microwave (centimeter and millimeter) ranges, its cheapening and availability stimulated the appearance of new areas of use of microwave technology and radiometry and opened up the possibility of conducting such researches and measurements. Recently, similar equipment and technologies have become widespread and used not only for military purposes, science and technology, but also in industry, agriculture and national economy, biology and medicine [7, 8].

Radiometric equipment is quite actively used in medicine and biology to control weak temperature anomalies in the human body and diagnose cancer diseases, for metrological support of quantum medicine devices, for scientific research of electromagnetic radiation of physical and biological objects, for researching the properties of dielectric materials and substances [6-9].

The authors [10] had developed a similar non-standardized radiometric system (RS), which was certified by the State Standard of Ukraine [11]. The method of measurement and research and identification of dental materials was described by the authors [12]. With the use of the developed system, together with the specialists of the medical university, a number of studies of dental dielectric materials were conducted on the subject of their electromagnetic compatibility with the tissues of the human body. A study of dental fillings materials was conducted, and it was found that most materials have a coincidence or a slight deviation of radiation levels in comparison with the contacting tissues.

Theoretical and experimental studies of EMC materials from the arsenal of maxillofacial reconstructive and restorative surgery were also conducted. [13, 14]. Significant EMC deviations were detected in some materials. Scientific results of experimental studies and relevant recommendations are presented in a number of publications both in Ukraine and abroad [4, 10, 13, 14].

Main purpose of this study

A large number of dielectric biomaterials are used in practical orthopedic dentistry. Different designs for prosthetics are made from both metals and dielectric materials, so as metal-dielectric combinations.

Various designs of the orthopedic constructions are also used for prosthetics and restoration of defects in patients' dentitions. In most cases, prostheses of fixed construction are used. Preparation for such prosthetics is carried out in several stages. The stages include the preparation of the alveolar process of the jaw, preparation of the teeth, taking an impression and making a permanent structure, fitting and fixation on the tissues of the tooth with the help of fixing cement. Placement of an orthopedic construct in a permanent location usually involves subsequent physical contact with both the patient's hard and soft tissues.

Long-term use of a such construction is possible if the above requirements for materials which are in contact with living tissues, including electromagnetic compatibility, are met. At the same time, the assessment of this parameter can be carried out after a detailed study of the radiation capacity of similar dental materials and their comparison with the radiation of biotissues of the human body.

Therefore, the purpose of this study is to determine the radiative capacity of cement as a material widely used in dental practice and to evaluate their level of electromagnetic compatibility with contacting biotissues.

Preliminary information

Up to a dozen different types of powders are currently used for the manufacture of dental cements for fixing orthopedic structures. The leading producing countries are Germany, the Czech Republic, Japan, and the USA.

The main requirements for such materials determine their physico-mechanical, clinical-technological and physico-chemical properties. These requirements are basic in the development and manufacture of the powdery material that forms the basis of the fixing cement. At the same time, the cement itself has a number of parameters that characterize its quality and the duration of its operation:

– the thickness of the film that is formed at the place of fixation of the orthopedic structure;
– cement hardening time and working time;
– compressive and bending strength after fixing the orthopedic structure;
– water-absorbing and water-resistant properties.

The adhesive property of the cement material to the hard tissues of the tooth, which characterizes the strength and strength of adhesion to them, is also an important characteristic. Adhesion to metal, to ceramics, to dentin and enamel, which are in direct contact with cement during the operation of the orthopedic structure, can be distinguished here [15].

All powder substances for cement and cement itself are dielectric materials. At the same time, it is known from the course of physics that dielectric bodies when heated emit electromagnetic signals in a wide range of frequencies. This fully applies to orthopedic structures installed in the human body, the internal temperature of which is 36,6°C.

The integral power emitted by the dielectric material can be calculated using the Nyquist formula:

$$P = G(f,T)\Delta f = \beta kT\Delta f \ , \qquad (1)$$

where $G(f,T)$ – spectral density of the noise signal of the material at the analysis frequency f at the thermodynamic temperature of the material T; k – Boltzmann's constant, $k = 1,38 \cdot 10^{-23} J/K$; β – coefficient of emissivity of the object coefficient of emissivity of the object (for gray bodies β<1, for absolutely black body (ABB) β=1); Δf – measuring device analysis band (radiometer).

The human body, like dielectric implants, can be characterized by different radiative capacity β and electromagnetic incompatibility may occur between them. At the same time, both "+plus" (positive) and "-minus"(negative) flows of electromagnetic radiation can occur, which in different ways affect the tissues of the human body adjacent to the implant (orthopedic construction) [14]. Therefore, the authors consider it is useful to conduct a study of the electromagnetic properties of the most common samples of cements used to fix orthopedic structures.

Research objects. The following fixing cements were selected for the study. The samples were provided by the Department of Orthopedic Dentistry of O. Bogomolets National Medical University.

1. "Adhesor Fine" – zinc phosphate cement. Fine-grained powder, which provides the possibility of application in a thin layer (25 microns). Manufacturer of Adhesor Fine - AT Spofa Dental CZ.
2. "Adhesor Carbofine" – zinc phosphate cement. The characteristics are practically similar to the material of item 1.
3. Glass ionomer X-ray contrast cement GC "Fuji I" of increased strength. Provides tightness and long-term release of fluoride, which strengthens the hard tissue of the teeth. Produced by GC Corporation, Japan.
4. Ketac Cem radiopaque glass ionomer, radiopaque cement. Provides tightness and long-term release of fluoride, which strengthens the hard tissue of the teeth. Manufactured by 3M ESPE, Germany.
5. Glass ionomer radiopaque cement "Meron", VOCO, Germany. Provides tightness and long-term release of fluoride, which strengthens the hard tissue of the teeth.
6. "Celikon F" is a two-component, radiopaque glass ionomer cement. Provides tightness and long-term release of fluoride, which strengthens the hard tissue of the teeth, "Vladmyva" company.

The general precautions when using the specified materials, which are described in the instructions for users, should include the prevention of direct contact with the dental pulp.

Research methodology and technology

Research on the emissivity of cement samples was carried out in the laboratories of microwave radiometry and microwave measurement of National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute".

According to the instructions for use, samples of the studied cements with a diameter of 8 mm were made and placed in a metal container, according to the size of the aperture of the receiving antenna of the high-sensitivity radiometer. Containers with cement samples were placed in a standard thermostat TBC (TVS)-80, with a temperature equivalent to the temperature of the human body (36,6°C) and heated for 20 minutes.

The certified highly sensitive NU-2 radiometric system for the frequency range of 37...53 GHz was used as a measuring device. The research was conducted at a frequency of 51 GHz. The confirmed sensitivity of the radiometric system is provided at the level of 10^{-14} W, with an analysis band $\Delta f = 10^8$ Hz. RS is described in more detail in [10, 11].

After heating, the container with the cement sample was placed under the aperture of the receiving antenna on the additional RS heater and the radiation level was measured. For comparison, the radiation level of three experiment participants and a piece of animal bone were also measured.

The structural diagram of the measurement is presented in Fig. 1 and includes: an automated device for heating and maintaining a temperature of 310 K (1) with a power supply unit (2) and a temperature regulator (3), a metal plate (4) for heating the container with the material under study (S). The highly sensitive radiometric system includes a receiving antenna (A), an input attenuator (5), a RS radiometric channel (6) for converting millimeter range signals into a constant voltage output signal, and an electromagnetic radiation power indicator (7).

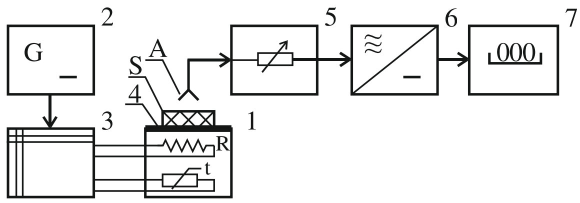

Fig. 1. Structural diagram of the system for determining the EMR of cements for fixing orthopedic structures

The samples of the studied materials were heated to the specified temperature in metal cups in a TC (TS) - 80M-2 thermostat with an error of temperature stabilization at the reference point of ±0.25°C. The size of the cups was determined according to the size of the aperture of the receiving antenna (Fig. 2). Heating in the thermostat was carried out for up to 20 minutes. Then the cup with material S was placed on the metal plate of the automated device 1 for heating and maintaining the temperature, and the EMR level was measured at a frequency of 52 GHz.

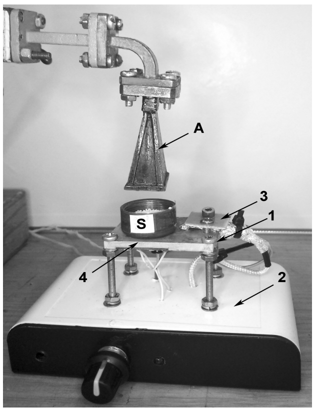

Fig. 2. External view of the receiving part of the radiometric system with an additional heating device

The measurement results are given in Table 1.

Radiation of the ABB at a human body temperature of 310 K, band 10^8 Hz, calculated according to formula (1), is P_{ABB} =4.2·10^{-13} W. Using Kirchhoff's formula, you can calculate the emissivity coefficient of the materials under study β_M (see table):

$$\beta_M = P_M / P_{ABB},$$

where, P_M – the radiation power of the cement sample, measured by RS; P_{ABB} – calculated ABB power.

Conclusions

1. In the process of experimental and computational studies, the emissivity coefficients β_M of 5 cement samples were determined, which range from 0.13 to 0.63 units.1.

2. The first three samples (№№ 3-5) have a high level of electromagnetic compatibility (60...98 %), samples (№№ 6, 7) show much less coincidence with the EMR of the human body.

3. The results of the conducted research can be used by orthopedic specialists to select materials with greater electromagnetic compatibility.

Table 1. The results of the measurement EMR of the studied materials.

№	The research object	Power level P_M (10^{-13} W)	Coefficient β_M	% coincidence with the EMR level of the human body
1	Human body	2,7	0.64	100
2	A sample of animal bone	3,15	0,75	117
3	Adhesor Fine	2,65	0.63	98
4	Adhesor Carbofine	2,4	0,57	89
5	Celicon Ф	1,6	0,38	59
6	GC Fuji I	0,9	0,21	32
7	Ketac Cem radiopaque	0,55	0,13	20

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[1)]О. П. Яненко, [1)]К. Л. Шевченко, [2)]О. Д. Головчанська, [2)]В. С. Симоненко

[1)]Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», Київ, Україна

[2)]Національний медичний університет імені О. О. Богомольця, Київ, Україна

ЕЛЕКТРОМАГНІТНІ ВЛАСТИВОСТІ ЦЕМЕНТІВ ДЛЯ ФІКСАЦІЇ ОРТОПЕДИЧНИХ КОНСТРУКЦІЙ

Статтю присвячено результатам дослідження електромагнітних властивостей групи стоматологічних матеріалів - фіксувальних цементів, які відносяться до діелектричних матеріалів. В практиці ортопедичної стоматології застосовуються різноманітні конструкції для протезування та відновлення дефектів зубних рядів пацієнтів. В більшості своїй це протези незнімної конструкції, які після декількох підготовчих етапів встановлюються на постійне місце з використанням того чи іншого цементу. Зазвичай ортопедична конструкція та фіксуючий цемент при подальшому використанні фізично контактують як з твердими, так і з м'якими тканинами пацієнта. Оскільки діелектричні матеріали за температури тіла людини 310 К формують власне електромагнітне випромінювання (ЕМВ), то важливим є забезпечення електромагнітної сумісності їхнього ЕМВ з прилеглими до імплантантабіотканинами для виключення появи ускладнень при їх довготерміновому використанні.

Також проводились теоретичні та експериментальні дослідження матеріалів ЕМК з арсеналу щелепно-лицевої реконструктивно-відновної хірургії. У деяких матеріалах були виявлені значні відхилення ЕМС. Наукові результати експериментальних досліджень та відповідні рекомендації викладені в ряді авторських публікацій як в Україні, так і за кордоном.

Метою даного дослідження є визначення радіаційної здатності цементів як матеріалу, що широко використовується в стоматологічній практиці, і оцінка рівня їх електромагнітної сумісності з контактуючими біологічними тканинами.

У статті наведено методику та матеріали проведених експериментальних досліджень. Електромагнітне випромінювання двох з п'яти фіксуючих цементів, що досліджували, ідеально збігаються з ЕМВ навколишніх тканин, одного – на 60 %, ще одного – на 32 % і останнього з досліджуваних матеріалів – на 20 %.У статті наведено структурну схему системи визначення ЕМВ цементів для фіксації ортопедичних конструкцій при їх використанні пацієнтом. Результати дослідження можуть бути використані лікарями для вибору більш сумісних фіксувальних матеріалів.

Ключові слова: ортопедична конструкція; фіксувальний цемент; мікрохвильове випромінювання;електромагнітні поля та випромінювання; електромагнітна сумісність.

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