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A THERMAL RESISTANCE STUDY OF DENTAL PROSTHESES MARKED WITH INTELLIGENT MATERIALS (NFC, AEROGEL) – IMPORTANCE IN MEDICO-LEGAL ODONTOLOGICAL IDENTIFICATION

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Abstract: As a result of the frequent occurence in the medico-legal practice of highly compromised cadavers, we feel compelled to turn our attention to the medico-legal odontological identification as one of the few efficient methods when dealing with such a high degree of biologic destruction (ie: combustion, air and land traffic accidents, submersion, etc). We carried out this study by means of marking complete dental prostheses using an NFC (near field comunication) tag, which contains individual identification data, and Aerogel – a fireproof material. During this study the physico-chemical resistance of these intelligent materials was tested by exposure to various temperatures.

The Aerogel was applied for the first time in the field of medicine in our study. The physico-chemical properties of this material allowed us to encase it in the prosthesis. Also, inserting the identification data in the NFC tag as a social security number was also in itself a novel approach.

Keywords: Aerogel, NFC, medico-legal odontological identification, marking of dental prostheses.

INTRODUCTION

The goal of this study was to develop an innovative method of marking dental prostheses by inserting certain new/smart materials in order to preserve individual data, amounting to a potentially medico-legal odontological identification technique which can be used despite of the cadaver's degree of degradation.

Experimenting with these devices hinges on the need of inserting essential data – taking into account the esthetic aspect, and the use of a particularly light and fireproof material, important features which were included in remarkably small objects.

METHODS AND MATERIALS

Description of the utilized smart materials

NFC - near-field communication represents a set of communication protocols over very short distances (Fig. 1).

The abbreviation means Near Field Communications, and it uses wireless technology to transfer data between two devices over distances of no more than 10 cm. The NFC module and antenna are very tiny. The module, being the size of a penny, can be included in various form factors, and the antenna can easily be placed on a smartphone's case or battery [1].

Two reasons justify why this technology cannot operate on distances over 5-10 cm. Firstly, the passive and active devices involved communicate on low rated currents. Secondly, the NFC was initially thought out as a contactless payment system, which entails high-security measures. The first Android running NFC-equipped smartphone was the Nexus S model, launched in 2010 [2]. This technology is implemented worldwide by hundreds of companies and it is currently used in a plethora of devices: smartphones, tablets, laptops, personal computers, speakers and even vehicles [3].

Smartphone – any smartphone running the NFC Reader application which was used to insert and read data on the NFC (pacient individual information) (Fig. 2).

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Aerogel - "frozen smoke" or "wonder material of the future"

The chemical and physical properties of aerogel

One of the most infamous and valuable physical properties of aerogel is its incredible density, ranging between 0.0011 and 0.5 g/cm³, with an average of 0.020 g/cm³. These numbers translate into it being only 15 times heavier than air and just 3 times denser. Aerogel was first created by American chemist Steven S. Kistler in 1931. He prepared a silicon dioxide (SiO2) hydrogel (a water-based gel) using a reaction between sodium silicate and hydrochloric acid [4].

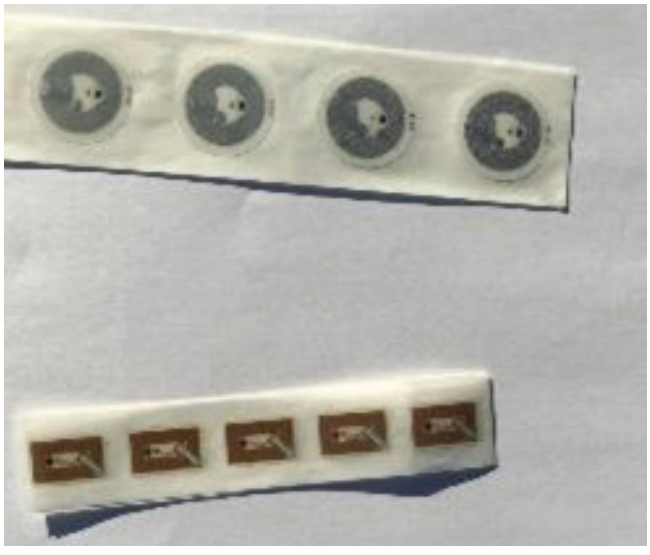

Figure 1. Types of NFC tags, own research.

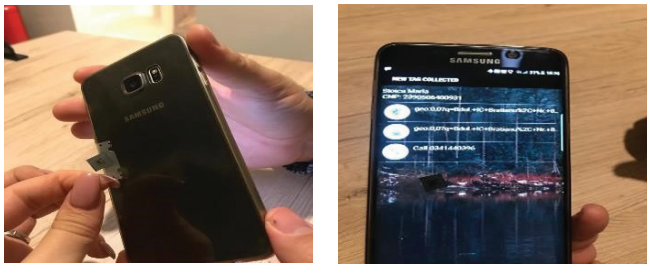

Figure 2. Inserting/Reading data using a smartphone, own research.

This reaction is presented below:

$$NaSiO_3 + 2HCl = [SiO_2 \times xH_2O] + 2NaCl$$

For nearly three decades, the research involving aerogel was neglected due to the lack of authentic knowledge regarding the exceptional properties of this kind of material and the challenges accompanied by its preparation. Aerogels once again caught the eye of the scientific community once the shortcomings of the Kistler method were ironed out in the 1960s when a new method of developing silicon dioxide gel was discovered. The first application of aerogels was in the field of physics, more precisely in high energy detectors (Cerenkov detector)[5].

Materials used in the technical stage of developing acrilic dental prostheses

Required materials for the experimental prostheses exposure to combustion: control prostheses (standard academic models), intelligent materials (NFC, AEROGEL), smartphone, thermo-insulating bricks, gas tank, burner, platinum resistance thermometer

I. Methodology of exposing mobile (definite) acrylic prostheses to combustion

This experiment consisted of creating a combustion setting by applying a gradual increase in

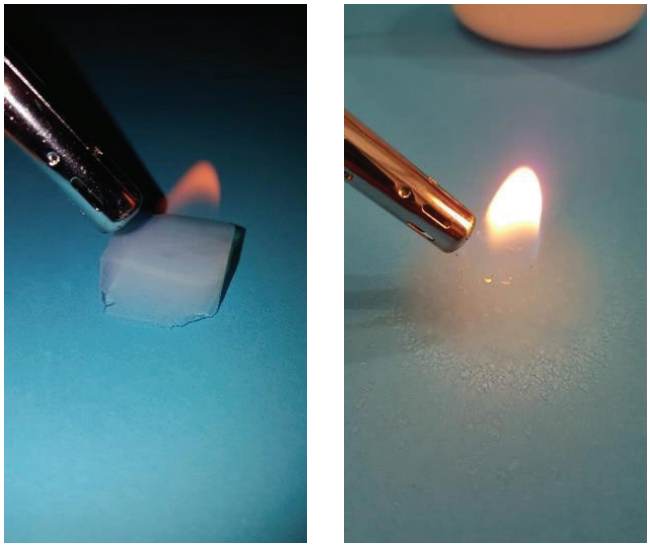

Figure 3. Aerogel's resistance to an open flame, own research.

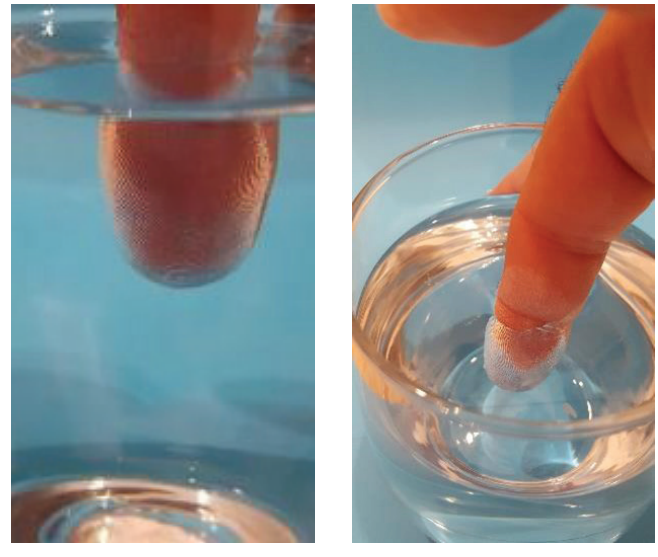

Figure 4. Hydrophobic property of Aerogel, own research.

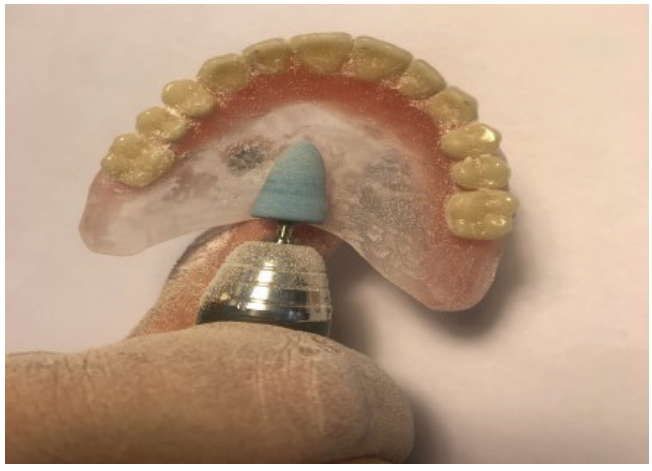

Figure 5. Complete mobile acrylic prosthesis – finishing stage, marked with an NFC tag encased in Aerogel – "sandwich" technique, own research.

Figure 6. Furnace made out of thermo-insulating bricks, own research.

Figure 7. Furnace view of the direct flame over a pig head containing a marked acrylic prosthesis, own research.

temperature, defining the ultimate resistance test for the NFC and Aerogel.

During this experiment, we encased smart materials in definite dental prostheses through a binding technological process (Fig. 5).

Taking into account the technological aspects mentioned above and to better research the potential high temperature reached in a fire, we developed a furnace made out of thermo-insulating bricks, together with a burner connected to a gas tank. Marked prostheses were then placed in the furnace (Fig. 6).

To better mimic a household fire's effects, especially charring, we used pig heads – which act similarly to a human head, in which we placed the marked prostheses. The burner's flame was directed at the pig head for a more accurate reading of the temperature it was exposed to (Fig. 7).

The temperature reached in the thermo-insulating brick furnace was monitored using a platinum resistance thermometre (Fig. 8).

For this experiment, we opted for the smallest (5 x 5 x 0.2 mm) NFC tags (currently available on the market) and with a maximal thermal resistance of 200°C, according to the manufacturer, to get a better understanding of up to what temperature can the marked mobile acrylic prostheses withstand. Both prosthetic models were tested – marked with only a bare NFC and NFC encased in Aerogel("sandwich" technique – aerogel binding process).

We placed in each of the 12 pig head's oral cavity either a bare NFC marked acrylic prosthesis or one including an NFC tag bound in Aerogel, after which they were subjected to temperatures between 100-900°C. The temperature was raised gradually in 100°C increments. After each phase, the NFC tags were removed from the oral cavity and repeatedly scanned to check if the data was still readable. Every pig head was exposed for exactly 5 minutes per 100°C incremental increase.

Figure 8. Platinum resistance thermometer placed in the furnace for temperature monitoring, own research.

Figure 9. View of carbonized pig head at temperature of 900°C and remainder of prosthesis extracted from the oral cavity, own research.

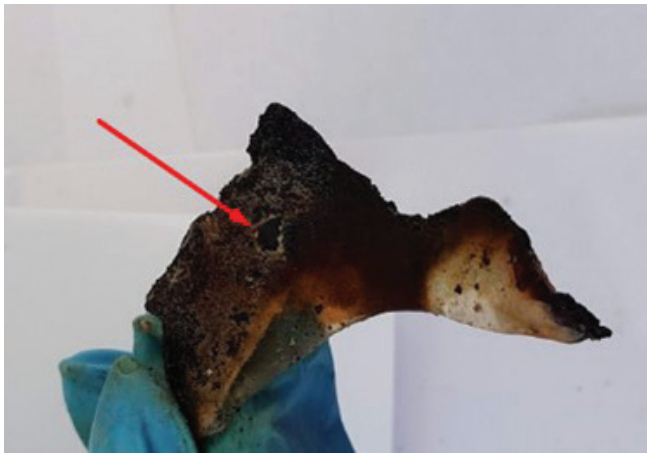

Figure 10. Remainder of complete acrylic prosthesis marked Aerogel-encased NFC. Notice the molten acrylic and the Aerogel acting as a protective film around the NFC tag (own research).

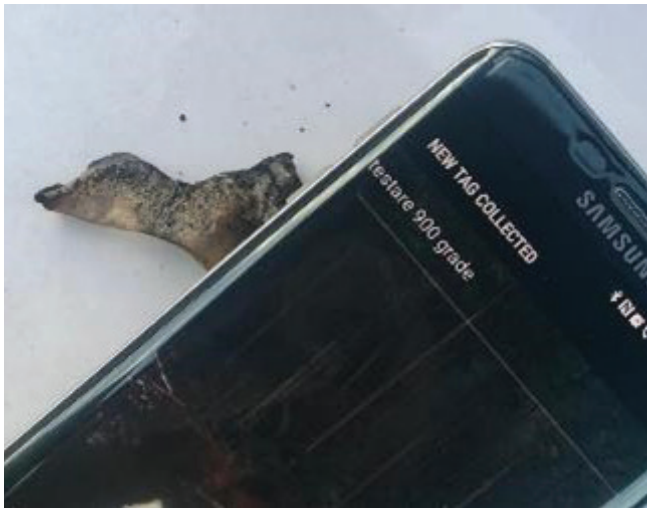

Figure 11. Remainder of prosthesis NFC reading test; the data is readable, signifying that the Aerogel protects the NFC tag at extreme temperature, own research.

RESULTS

The experiment proved that using NFC-only marked prostheses is not a reliable method of identification in combustion accidents, given that the data can only be preserved up until a temperature of 200°C, beyond which the materials used were completely charred.

Conversely, the Aerogel used to protect the NFC tag, and inherently, the data written on it, remained undamaged at high temperatures of 900°C for up to 5 minutes (Figs 9-11).

This result allows us to state that no matter the temperature involved, taking into account the cases most encountered in the medico-legal field(house fires) in which cadavers may be carbonized completely, inserting Aerogel and NFC tags in dental prostheses can have a great benefit in medico-legal odontological identification.

DISCUSSION

- This study represents a novelty in Romanian and International legal medicine. It is the only study that, based on argumentative and experimental findings, endorses the use of Aerogel in legal medicine, with clear benefits in medico-legal odontological identification.

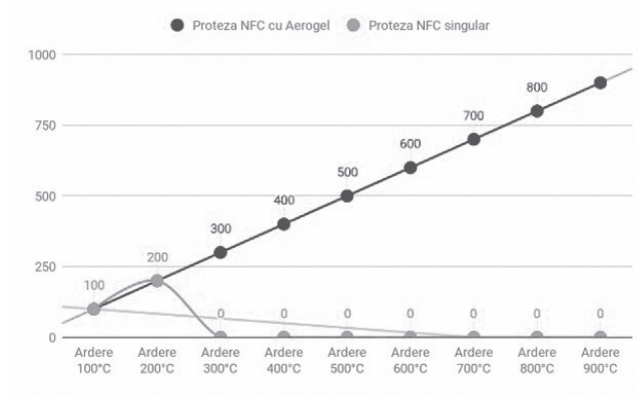

Figure 12. Graphic representation of temperatures at which the prostheses(NFC only and Aerogel-NFC) were scanned.

	Temp. 100	Temp. 200	Temp. 300	Temp. 400	Temp. 500	Temp. 600	Temp. 700	Temp. 800	Temp. 900
Citire NFC Aerogel	✓	✓	✓	✓	✓	✓	✓	✓	✓
Citire NFC	✓	✓	X	X	X	X	X	X	X

Figure 12. Types of marked complete acrylic prostheses and the maximum temperature at which they were scanned.

- It is the first study of its kind which proves the importance of the dental prosthesis marking techniques, coupled with resistance testing.

- Brings forth the use of intelligent materials, previously neglected in medicine, which can augment current identification techniques, opening up a whole new array of possibilities in this regard.

- It is the only medical study that researches the Aerogel and NFC's resistance in different liquids and combustion(100-900°C).

In conclusion, NFC-marked dental prostheses provide patients with comfort and esthetic benefits due to the reduced size of the NFC tags and Aerogel and their placement in the unseen areas of the prosthesis, thus being virtually undetectable.

The test carrying paramount importance in medico-legal identification – combustion test– substantiated the use of Aerogel under the form of a protective film over an NFC tag containing personal data, proved to be a necessity in assisting the progress of identification technique.

Neither of the other known marking agents, as found in current literature, does not withstand high temperatures.

This study attempts to emphasize the importance of researching new regulated identification methods, both dental and medico-legal, thus improving the current approach regarding medico-legal odontological identification.

Conflict of interest

The authors declare that they have no conflict of interest.

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