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ID in War Times- Forensic Identification of 3 Major Types of Dental Implants Incinerated

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Abstract

Teeth remains are often the only means of positive identification in an unidentified body after being subjected to high temperature injury. The routine use of dental implants made them as an active contributing element to the identification of unidentified cadavers. Their resistance to prolonged high temperature might make them a substantial contributor to the identification of high temperature burned bodies. The aim of the study was to observe the effects of high temperature on three dental implants of distinct elemental composition: C1-MIS®, made of Ti grade 23; BL- Straumann®, made of Ti grade 4 and of a Titanium-Zirconium alloy; Roxolid-Straumann®, by detecting the changes of their microstructural and elemental composition. Scanning Electron Microscopy and Electron Dispersive Spectroscopy were used to characterize the surface structure and elemental composition of the implants before and after implants being subjected to a high temperature protocol of 1375 for 30 minutes. Macroscopic and microscopic changes in the samples after exposure to the high temperature. Dental implants demonstrated specific macroscopic changes and microstructural deteriorations, after exposure to high temperature. After exposure to high temperature, dental implants demonstrated specific macroscopic changes and microstructural deteriorations. Although several changes occurred in the elemental content of the materials, the original elemental composition was preserved. The ability to discriminate between dental implants by elemental analyses can have a determinant impact on the identification process of burned bodies.

Keywords: Forensic dentistry • Human identification • Dental implants • High temperatures • Postmortem

Introduction

The Ukraine-Russia and Israel-Hamas conflicts have returned war to the highlights; forensitic identification of humans rests following high temperature burning due to powerful explosives has knocked back to our doors. In addition to wars, there is an increasing number of reasons for human beings to die by fire (forest fires, air diasters, traffic accidents, electric vehicles that catch fire, war and terrorism). Personal Identification (ID) can be defined as scientific and technical procedures dedicated to examine and analyze the dental evidence on the interest of justice [1]. A positive identification is vital to help family members progress through the grieving process, providing some sense of relief in knowing that their loved one has been found.

There are five Forensic Dentistry general methods (visual, fingerprint, DNA analysis, anthropologic/radiology and dental comparison) used to identify human remains, as settled by the American Board of Forensic Odontology (ABFO) [2], of which most require a presumptive identification in order to allow for the direct comparison of Antemortem (AM) and Postmortem (PM) biometric evidence [2], such as happened in the World Trade Center (WTC) disaster [3].

The interest of the present study derives from the fact that implantology techniques are increasingly widespread, and so, the possibility of facing victims with dental implants is increasing [4]. It was possible to trace back the identity of the unknown victim following severe incineration to a prosthesis structure supported by dental implants.

Scanning Electron Microscopy (SEM) and Energy-dispersive X-ray Spectroscopy (EDS) can be used in Forensic Dentistry ID, after radiographic image examination of the incinerated implants recovered from the victim. By comparing with AM and PM records, it is then possible to ascribe the found implants to an alleged victim [5,6].

The application of this technology in Forensic Dentistry is recent and we intend to first describe its application to three novel dental implants. The present proposal also has the objective to contribute to increase the knowledge in forensic dentistry regarding the ID of carbonized victims through their incinerated dental implants.

The main hypothesis of the present work was that by using SEM and EDS, the incinerated implants can still be identified as belonging to a certain carbonized victim.

We intended to characterize the alterations in dental implants exposed to high temperatures and determined the possibility to identify and differentiate between the different groups of implants.

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With the results obtained we expected to improve considerably the assistance to the experts in Forensic Dentistry and thus contribute to a faster human identification in the case of corpses whose cause of death was the action of fire.

Materials and Methods

We selected 3 groups of dental implants (n=6), with different surface roughness, topography and composition: Group 1 (C1-MIS®) included dental implants (n=2) with a circular neck (3.9 × 8 mm) made of titanium (Ti), surface airborne- particle abraded with medical grade alumina, and etched in hot acids (C1-MIS®) [7]; Group 2 (BL-Straumann®) included dental implants (n=2) with a circular neck (3.3 × 8 mm) made of cold-worked commercially pure Ti (cpTi), surface airborne particle abraded with large grit (0.25-0.50 mm) medical grade alumina, and etched in hot acids (SLA®) (BL- Straumann®, SLA®) [8]; and Group 3 (Roxolid-Straumann®) included dental implants (n=2) with a circular neck (3.3 × 8 mm) made of titanium-zirconium (Ti-Zr), also SLA® treated (Roxolid-Straumann®,SLA®) [9]. For each dental implant group, dental implants were submitted to 1375 °C for 30 minutes. The morphological examination and the chemical composition of the implants was determined before (control) and after incineration (Table 1).

We used a sintering furnace Naberthem Inc/LHT117PN2 (Lilienthal, Germany), a high technology CAD/CAM equipment (computer-aided design/ computer-aided manufacturing) designed to sintering zirconia. Dental implants were placed in the furnace until reaching the temperature of 1375 °C. Furnace was monitored with an incorporated digital thermomete (Lilienthal, Germany).

After a 30 minutes exposure at 1375 °C, the kiln was switched off and the door of the kiln left open for the implants to cool slowly. Implants were photographed before and after incineration (Figures 1 and 2).

Implant surface roughness, surface topography, and elemental and surface composition were determined with SEM and EDS. The Scanning Electron Microscope (Phenom XI G2; Thermo Scientific, USA) was operated at 20 kV in the Secondary Electrons (SE) and Back-Scattered Electrons (BSE) modes EDS, with a silicon drift detector (Thermoelectrically cooled (LN2 free; Bruker Nano) (Mn Kα ≤132 eV).

Results

The gross external inspection by photography of the implants before (in Figure 1) and after (in Figure 2) incineration, evidenced a color change, C1-MIS® implants turned black, BL-Straumann® implants turned yellow and Roxolid-Straumann® implants turned pink.

The SEM images of the control C1-MIS® implants revealed a sandblasted and etched surface, which appeared as a FW: 115 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:45 PM. Afer incineration, the surface of the C1-MIS® implants apeared as FW: 115 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:13 PM. The SEM images of the control BL-Straumann® implants revealed a Ti (Titanium) surface, which appeared as a FW: 146 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:50 PM. Afer incineration, the surface of the BL-Straumann® implants apeared as FW: 115 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:31 PM. The SEM images of the control Roxolid-Straumann® implants revealed a O, Ti, Zirconium (Oxygen, Titanium, Zirconium) surface, which appeared as a FW: 115 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:34 PM. Afer incineration, the surface of the Roxolid-Straumann® implants revealed a O, Si, Ti (Oxygen, Silicon, Titanium) surface apeared as a FW: 97 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:38 PM (Figures 3-8).

The elemental analysis by EDS revealed that the majority of the surface consisted of titanium oxide. Small areas of Carbon (C) were observed and serum salts Cesium (Cs) in Figure 10 (Figures 9-14).

EDS analysis of the control C1-MIS® implants revealed a chemical composition of Titanium (Ti) 82.716, Vanadium (V) 4.817 and Aluminum (Al)

Table 1. Brand, model, chemical composition, surface type and implant measures of three types of dental implants: commercially pure Titanium (cp Ti), Titanium (Ti), Aluminum (Al), Vanadium (V), Zirconium (Zr).

Groups	Brand	Model	Chemical Composition	Surface Type	Implant Measures (diameter × length)
1	MIS®	C1®	Titanium alloy (90% Ti, 6% Al, 4% V)	Airborne-particle abraded with medical grade alumina	3.3 × 8 mm
2	Straumann®	BL®	cp Ti	SLA®	3.3 × 8 mm
3	Straumann®	Roxolid®	Ti-Zr (85% Ti, 15% Zr)	SLA®	3.3 × 8 mm

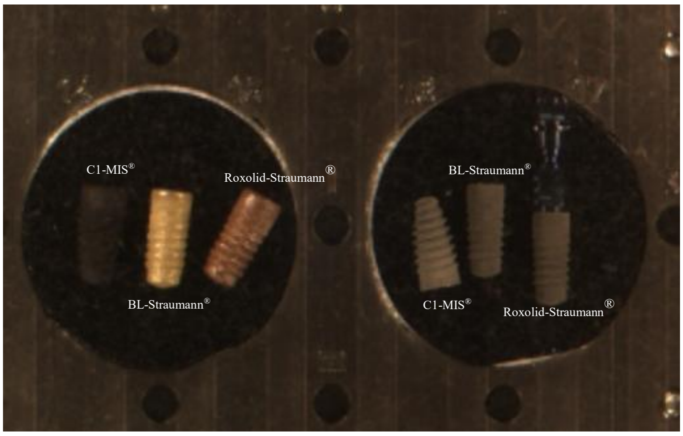


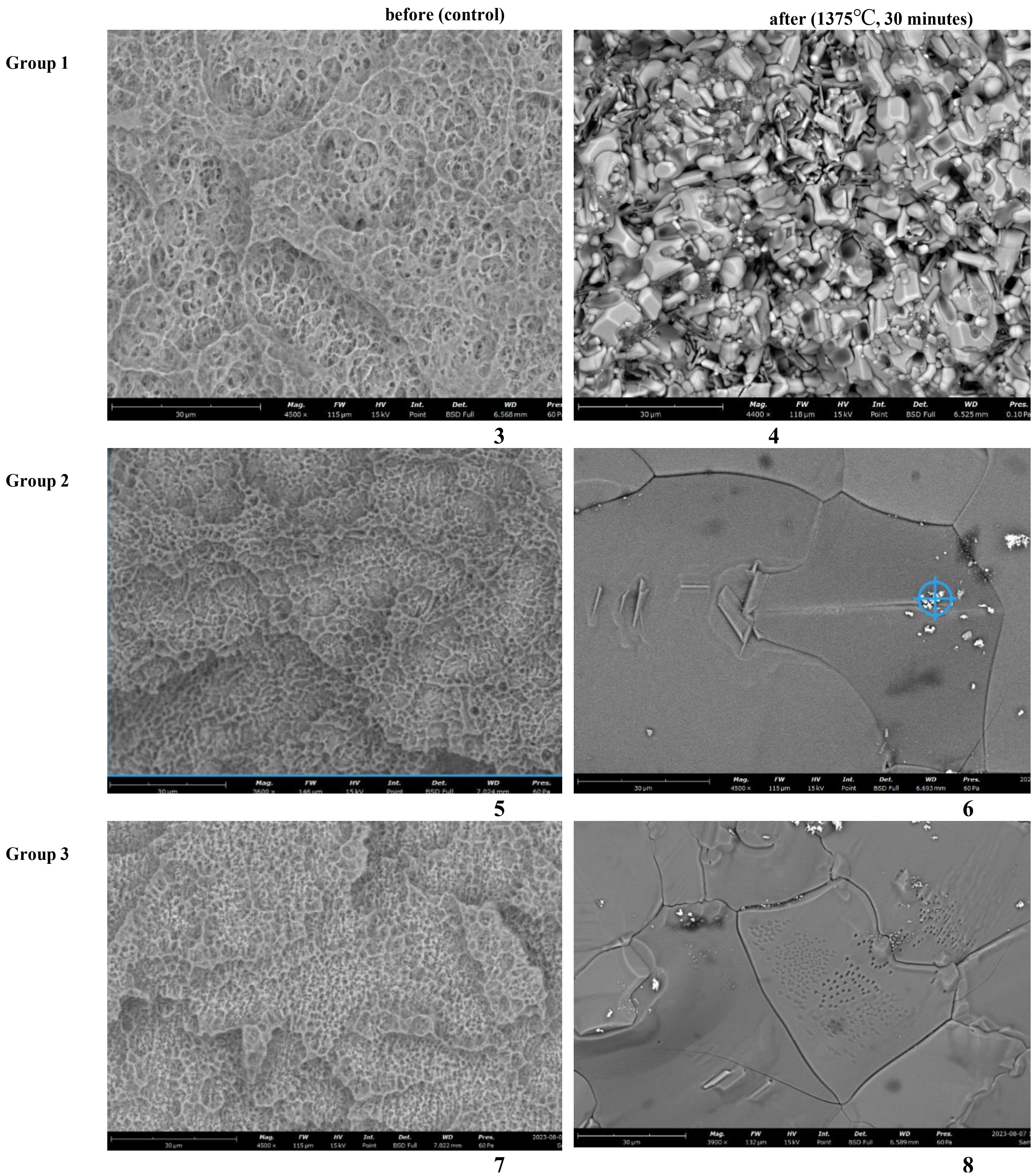
Figure 1. Photograph of the 3 groups of dental implants in the furnace, before (right) and after incineration (left).

Figure 2. Enlarged photograph of the 3 groups of dental implants, after incineration. The C1-MIS® implant turned black, the Roxolid-Straumann® implant turned pink and the BL-Straumann® implant turned yellow.

12.476 atomic concentration (%) (Figure 9). After incineration the chemical composition of the C1-MIS® implants was made of Titanium (Ti) 16.372, Vanadium (V) 2.669 and Aluminum (Al) 13.774; Oxygen (O) 63.734; Cesium (Cs) 0.621 atomic concentration (%) (Figure 10).

EDS analysis of the control BL-Straumann® implants revealed a chemical composition of Titanium (Ti) 100.0 atomic concentration (%) (Figure 11). After incineration the chemical composition of the BL-Straumann® implants was made of Titanium (Ti) 31.745, Oxygen (O) 68.255 atomic concentration (%) (Figure 12).

EDS analysis of the control Roxolid-Straumann® implants revealed a chemical composition of Titanium (Ti) 92.245 and Zirconium (Zr) 7.755 atomic concentration (%) (Figure 13). After incineration the chemical composition of the Roxolid-Straumann® implants was made of Titanium (Ti) 33.637, Oxygen (O) 63.028, Silicon (Si) 0.413 and Zirconium (Zr) 2.923 atomic concentration (%) [10,11] (Figure 14).

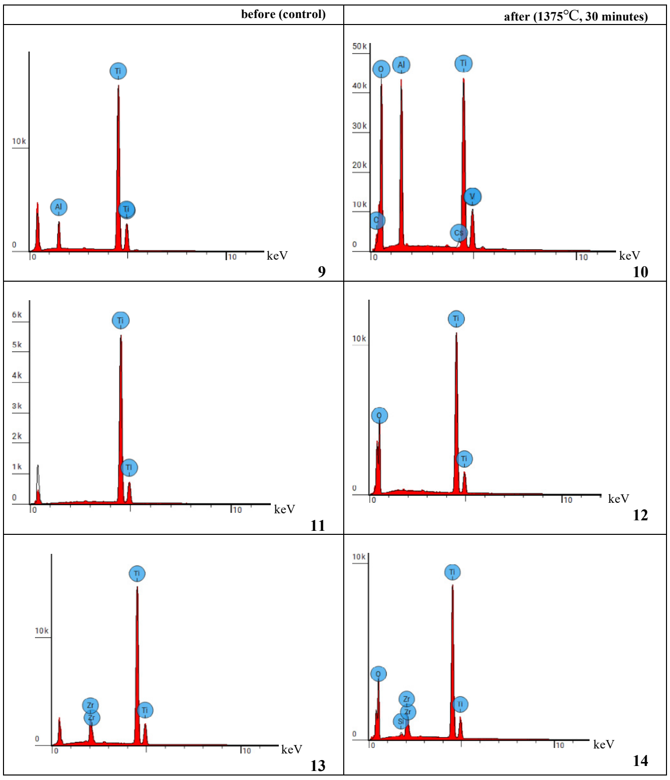


Figures 3-8. SEM analysis of the Group 1, 2 and 3, before and after incineration, at 1375°C, during 30 minutes. SEM analysis of the surface shade of the control C-MIS® implant (Figure 3). It is observed a FW: 115 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:45 PM. SEM analysis of the surface shade of the C1-MIS® implant after incineration (Figure 4). It is observed a FW: 115 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:13 PM. SEM analysis of the surface shade of the control BL-Straumann implant (Figure 5). It is observed a FW: 146 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:50 PM. SEM analysis of the surface shade of the BL-Straumann implant after incineration (Figure 6). It is observed a FW: 115 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:31 PM. SEM analysis of the surface shade of the control Roxolid-Straumann implant (Figure 7). It is observed a FW: 115 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:34 PM. SEM analysis of the surface shade of the Roxolid-Straumann implant after incineration (Figure 8). It is observed a FW: 97 µm, Mode: 15 kV - Point, Detector: BSD Full, Time: 8/7/23 4:38 PM.

Discussion

The increase in the number of elderly people with high quality of life is a fact throughout the world, due to advanced science and technology applied in the health sector. Mauro Gillen wrote that, in China, around 54,000 people celebrate their sixtieth birthday every day. In 2030, this age group, which currently comprises 1 billion people, will constitute around 1,400 millions persons. The United States (US) will add another 14 million, for a total of 90 million persons at this age [11].

Worldwide, there are a total of 32,237 brands of dental implants [12] and each year, an estimated number of more than 5 million implants are placed in the US and United Kingdom (UK). In Brazil, this figure has risen to approximately 800,000 implants and 2.4 million prosthetic components [12] witch play a major role in oral rehabilitations, undergo crown and bridge replacements for missing teeth annually, contributing to the demand for dental implants.



Figures 9-14. Elemental analysis by EDS of the Group 1, 2 and 3, before and after incineration, at 1375 °C, during 30 minutes. EDS analysis of the control C1-MIS® implant revealed a chemical composition of Titanium (Ti) 82.716, Vanadium (V) 4.817 and Aluminum (Al) 12.476 atomic concentration (%) (Figure 9). Elemental analysis by EDS after incineration the chemical composition of the C1-MIS® implants was made of Titanium (Ti) 16.372, Vanadium (V) 2.669 and Aluminum (Al) 13.774; Oxygen (O) 63.734; Cesium (Cs) 0.621 atomic concentration (%) (Figure 10). EDS analysis of the control BL-Straumann® implants revealed a chemical composition of Titanium (Ti) 100.0 atomic concentration (%) (Figure 11). Elemental analysis by EDS of the BL-Straumann® implant after incineration (Figure 12), depicting a peak of Titanium (Ti) and Oxygen (O) atomic concentration. Elemental analysis by EDS of the control Roxolid-Straumann® implant (Figure 13), depicting Titanium (Ti) 92.245, Zirconium (Zr) 7.755 atomic concentration. Elemental analysis by EDS Roxolid-Straumann® implant after incineration (Figure 14), depicting a peak of Titanium (Ti) 33.637, Zirconium (Zr) 2.923, Oxygen (O) 63.028 and Silicon (Si) 0.413 atomic concentration.

It is thus possible to trace back the identity of an unknown victim following severe incineration to a prosthodontist structure with dental implants osseointegrated [13].

The team that will work in the forensic dentistry identification, must be aware that the calcinated bone, teeh and dental implants elements are fragile, and care must be taken when handling it to search and collect in the crime scene, because they can contribute to positive identification.

There are more and more cases of death by carbonization, due to aviation accidents, traffic accidents, theaters of war, crime by homicide. Identification in Forensic Dentistry can be defined as scientific and technical procedures dedicated to the examination and analysis of medico-dental evidence/traces in the interests of Justice. Positive identification is vital to help family members progress through the grieving process and providing a sense of relief in knowing their loved one has been found [14].

The temperature used in the present experiments was 1375 °C, bellow the titanium melting point used in dental implants (1650 °C) [10,15], but abovet he maximum temperature reached in cremations [16], the maximum temperature (1365 °C) observed during a tunnel fire in Sweden [17-19] or the maximunm temperature attained during the 9/11 WTC terrorist attack (1093 °C) in the US.

Berketta J, et al. study elemental analysis of StraumannTM implant crust subjected to temperatures up to 1125 °C. At the head of the implant showed the presence of Oxygen (O) and Titanium (Ti); at the middle thread of the implant, Oxygen (O), Aluminum (Al) and Titanium (Ti), but didn't refer the atomic concentration of the elements [10].

Due to its relevance and the fact that it doesn't exist and due to the growing number of cases of identification through dental implants, we suggest to insert the letter I (Implant) as a new code, in the Dental Codes Terminology, in the INTERPOL DVI Missing Persons and Unidentified Human Remains [20] (which uses the FDI Numbering System) [21], and also in National Center Information Citizen (NCIC) [22,23] Missing and Unidentified Persons Form (which use the Universal Numbering System).

We found many studies with SEM/EDS, that have been done to analyzing the changes in incinerated restorative materials [24], root canal filling materials [25] or ceramic crowns [26] and also comparing with color changes by visual examination, and EDS was employed for analyzing elementar composition of the elements more accurately.

In our study, like others, the SEM examination showed the chemical composition of the analyzed implants, which is of great value, and helps to confront information obtained AM with PM in the process of identification. It's a supporting method that, even though it does not establish the identity, elemental analysis of the specific material proves to be essential and it could be an effective tool in the process of human identification by forensic dentistry.

Conclusion

All available methods must be used to add the Forensic Dentistry Experts in Human Identification. The present observations further indicate that SEM and EDS allowed us to characterize the type of implant used and its composition. Although SEM and EDS are only a supporting method, as isolate they don't allow to establish identity, they nevertheless help in the identification process.

Further studies must examine the effects of high temperatures on the physical properties of implants threaded in mandibular or maxillary bone. A broader range of implants may also further verify the findings. The project aims to contribute to increasing knowledge in Forensic Dentistry regarding the identification of charred victims through dental implants.

It was our intention with this preliminary short report to add new information on the debate about carbonized victim identification, in order to increase knowledge in Forensic Dentistry regarding the identification of charred victims through dental implants. Further studies must examine the effects of high temperatures on the physical properties of implants threaded in mandibular or maxillary bone. A broader range of implants should also be included to confirm the present findings.

Author Contributions

LSA, conceived, designed and performed the experiments of the work, and write the draft of the manuscript. All authors read critically and approved the final manuscript.

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CAM equipment designed to sintering zirconia. We also acknowledge to the Histology and Electron Microscopy Department (HEMS) – Instituto de Investigação e Inovação em Saúde da Universidade do Porto (i3S), for the use of SEM and EDS facilities.

Conflicts of Interest

All authors disclose any financial interests and personal relationships which may be considered as potential competing interests.

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