

# Metallographic description of calcined titanium implants and its application as a forensic descriptor

## Descripción Metalográfica de implantes de Titanio calcinados y su aplicación como descriptor forense

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### Abstract

**Introduction:** Forensic science develops diverse technologies for the identification of corpses, but in some cases, these procedures can be very expensive and unreliable in the case of cremated bodies. This research aimed to describe the metallographic changes in a titanium implant subjected to different temperatures and the evaluation of its potential use as a forensic descriptor.

**Materials and methods:** Fifteen titanium mini implants with an identification code were made, inserted into pork jaws and subjected to temperatures of 200 ° C, 800 ° C and 1000 ° C, samples were recovered and analyzed were performed by optical microscopy and electron scanning microscopy. **Results:** It was possible to characterize the microstructure for each temperature, an increase in the oxide layer was observed with the increase of each temperature. **Conclusion:** It is possible to use dental implants as a forensic identifier.

**Keywords:** forensic dentistry; dental implants; metallography; Oxide Layer.

### Introduction

In Colombia the violence intensification in the last two decades, the degradation of the armed conflict and the appearance of drug trafficking criminal bands (BACRIM), they have led to phenomena as the forced displacement, the common proliferation graves and the corpses quartering and incineration as method to impede the identification of the victims, which does that the forensic normal methods of identification practically useless.

Rivas (2000), from the official statistics, was raising “ the violence “ as the principal problem of public health in Colombia and for the year 2008, the violent deaths manage to be the second reason for death.

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The positive identification of a person needs the authentic coincidence of the deceased's physical characteristics with the records of the same characteristics before the death. In the case of incinerated corpses, forensic odontology has been of great help in the victim's identification, since often it remains genetic material in the teeth.

Von Wurmb-Schwark, Simeoni, Ringleb and Oehmichen (2004) managed to isolate DNA but they were not successful in obtaining a positive identification; in a totally in vitro study with isolated teeth, Adserias, Ubelaker, & Zapico (2016) they reported difficulty in processes of amplification and in the obtaining DNA profile from 300 °C.

The oral cavity offers certain protections to the dental structures, nevertheless to 500 °C the inorganic components begin to deteriorate and between the 660 °C and the 825 °C presents dehydration and loss of the

organic matter, which leads to fissures, fractures, and detachment of fabric (Sandholzer, 2014).

In a fire, the peak of temperature can reach levels over 1200 °C and remain between 600 °C and 800 °C several hours (Taylor, Wilson & Lyons, 2002), according to Holk (1996) (mentioned by Taylor et al.; 2002), between the 800 and 1000 °C the dentine and the enamel lose structure and between 1100 °C and 1200 °C there is the complete decomposition of these fabrics.

The good conservation of the dental pieces after the exhibition of a body to the fire has been explained because having the corpse warmed up, the gases proceeding from the intestine and the stomach produce tongue bulge what, added to the presence of other muscles, it protects the teeth of the direct exhibition to the temperature (Blond, Sioli, Suárez, Gaitán & Martín-de-las-Heras, 2015).

Although to temperatures superior to the 1000 °C the teeth still are macroscopic identifiable, in situations where the temperature is major the simple manipulation can take to its fragmentation, which forces to arrange very careful protocols for its managing (6-7) and physical early stabilization (Reesu, Augustine and Urs, 2015).

Merlati, Savio, Danesino, Fassina, and Menghini (2004) found that the damages in the dental structure can appear earlier if the teeth present restorations.

Different authors as Moreno, León, Marín & Moreno (2008); Marin & Moreno (2004) and Vázquez, Rodríguez

& Moreno (2012), bring specific changes in the dental structures, in agreement with the range of temperature: longitudinal fissures in the enamel and cement to 400 °C, cracks in dentine and enamel to 800 °C and exhibition of pulp chamber to 1000 °C; of equal form the dental materials like the resins between the 500 °C and 700 °C.

Due to the great number of intra-ossal implants that are placed, it has been proposed the need to characterize and be evaluated by the possibility of using them as an identifier.

Authors like Sahiwal, Woody, Benson and Guillen (2002) identify "morphologic" parameters of implants by means of X-rays and Nuzzolese, Lusito, Solarino & Vella (2008) before the summit of the dental implants called the attention to have libraries that gather the information of the business firms it brings over the macroscopic designs of these devices.

The dental implants when are being elaborated alloy of titanium have a merger point superior to 1650 °C what increases the possibilities of supporting the high temperatures that are generated in an event that involves fire as a cremation (950 - 1000 °C), I inflame of vehicle (1000 °C), inflame and explosion (1093 °C) as the event of the World Trade Center (Berketa, James & Marino, 2011a) and even an experiment in tunnel of fire (1365 °C) (Berketa, James & Marino, 2011b).

An example of the application of the forensic odontology was in the forest fires of 2009 in Victory, Australia, where there was necessary the combination of numerous dental forensic technologies to manage to identify the calcined remains (Cordner, Woodford, & Basset, 2011).

In an attempt for studying the potential of the implants as a forensic identifier after an incineration, Berketa, James & Marino (2010) described the persistence of a generic identification code in a commercial type of implants to a temperature of 1125 °C, which explains why the merger temperature of the titan is top to 1650 °C (Berketa *et al.*, 2011a).

Being the dental implants produced in mass, they do not include a mechanism that facilitates the individual identification, nevertheless for an odontologist or an expert the combination of brands and geometries (lengths, diameters, steps of coil, between others) they turn it into the only and trustworthy device to identify a patient if there are previous dental records (Berketa *et al.*, 2011b),

which it might combine also with a software of radiological identification (Depalakshmi & Prabhakar, 2014), (De Marco, 2013).

The increase in the number of placed implants increases the possibility of finding dental implants in victims of disasters or crimes (Reesu *et al.*, 2015) An example of utilization of a dental implant like forensic identifier happened in the year 2004, with a victim of a tsunami, comparing X-ray photographs of the clinical history with post-mortem X-ray photographs, the comparison of the radiographic image of the implant zone allowed the accurate identification (Dostalova, Eliasova, Seydlova, Broucek, & Vavrckova, 2012).

In this investigation it was designed a dental implant marked with an individual identification code, which was implanted in jaws of pork-mortem pig seeking to have a better approximation to the conditions that would be waited in an incinerated corpse; since general aim proposed to describe the macroscopic changes and microstructural that suffers a dental implant that has been placed in jaws of pork and submitted to high temperatures and its potential use as forensic describer.

## Materials and methods

There were made 15 conical microimplants, auto screws, in titanium type the IVth, of 5 mm of length, 1,8 mm of the diameter of the apex and a platform of 5 mm of diameter, with a code of identification recorded to 0,7 mm of depth (Figure 1).



**Figure 1.** Microimplant with a number of identification in the platform  
**Source:** the authors

The implants were inserted post-mortem in jaws of pork of three months of age on the retromolar zone of the pertaining to the jaw right bone, to a crystal level of the curbing. (Figure 2).



**Figure 2.** Pork's jaw with inserted implant  
**Source:** the authors

The jaws with the included implants were incinerated in an electrical oven to different temperatures (200 °C, 800 °C, y 1000 °C) for a holding time of one hour and later allowed to cool inside the oven.

The implants were recovered and prepared for metallographic analysis in electron microscope of the sweep, for which there was encased in lucite (polymethacrylate of methyl), to a treated temperature of 140 °C for a time of 15 minutes and a pressure of 92 MP.

Later, there were realized longitudinal cuts that divided the implant into two equal parts, using a diamond disc of 0,38 mm, 2300 rpm and with an advanced speed of 1,2 mm / minute, with the flow of constant water.

The surface to study was prepared across sanded methodically, by means of sandpapers of thick grain and thin grain (sandpapers No. 240, 320, 400, 600, 800, 1000 and 1200).

After the polished thickness it was realized the thin polished, by means of a polisher of cloths, taking as an abrasive alumina agent of 1 and 0,3 microns, for the initially and finally stages, respectively. The efficiency of this process happened through an optical microscope.

Finally, the sample was treated with the kroll reagent to reveal its microstructure and to allow the observation before the optical microscopes and of electronic sweep.

## Results

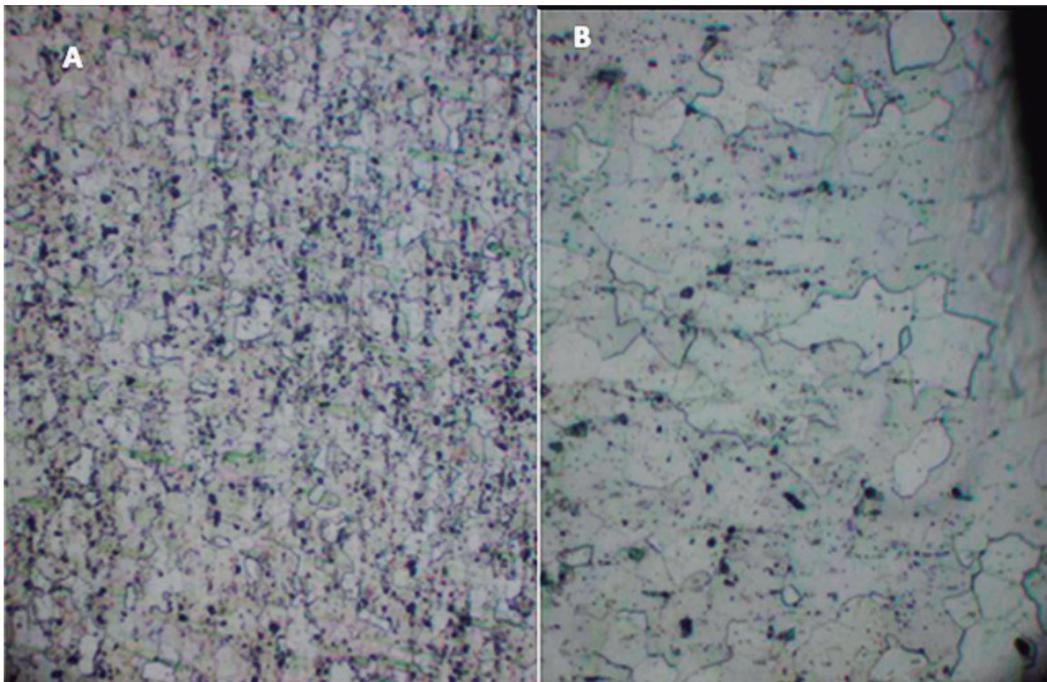
To the macroscopic examination, all the calcined implants preserved the same appearance, the only difference between groups was situated in the conservation of the marking code (Figure 1) which remained visibly to simply, in the groups of 200 °C and 800 °C but disappeared in 1000 °C.

To microscopic level, the different samples preserved equal microstructural characteristics inside every group (it is to say, to a specific temperature), but they exhibit

significant changes with the increase of temperature (200 °C, 800 °C and 1000 °C).

### Metallographic analysis to 200 °C

The metallographic analysis for these samples showed that the microstructure was constituted by phase grains to by TiH's small particles (of black color) and small sections of phase  $\beta$  (of black color), since it is possible to estimate in Figures 3 (A) and 3 (B), taken to 100 and 500 increases, respectively. It is of notice that the edges of the implants for this temperature remained intact and without changes.



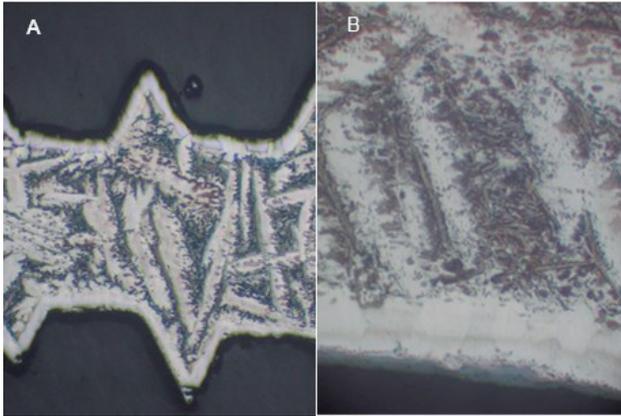
**Figure 3.** Implant calcined to 200 °C. Longitudinal section  
A) A 100X (center of the implant). B) A 500 X (edge of the implant)  
**Source:** the authors

### Metallographic analysis to 800 °C

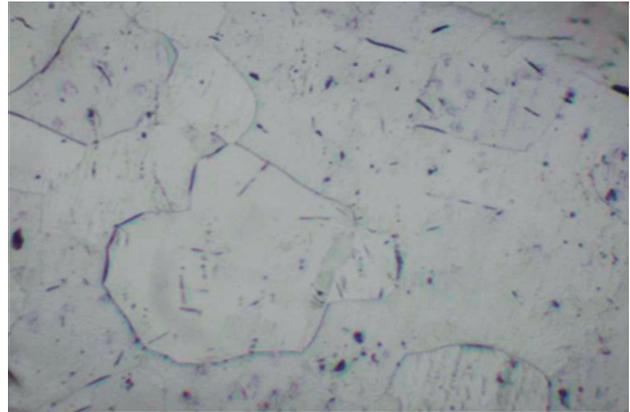
The metallographic inspection of these samples revealed that the microstructure is constituted from plates (elongated clear zones) of phase  $\alpha$  with phase  $\beta$  located in intermediate positions (dark phase), see Figure 4 (A). Additional, certain deterioration was demonstrated in the edges of the implants (irregularities in its form) and the presence of an oxide cap (of gray color) that delimits them, see Figure 4 (B).

### Metallographic analysis to 1000 °C

The microstructures of the samples submitted to 1000 °C showed an increase of grain size, with regard to the ones treated to 200 °C. On the other hand, the counterfoil was constituted from phase grains to (of clear color) with small quantities of phase  $\beta$  (needles of black color) disperse inside the grains too, see Figure 5.



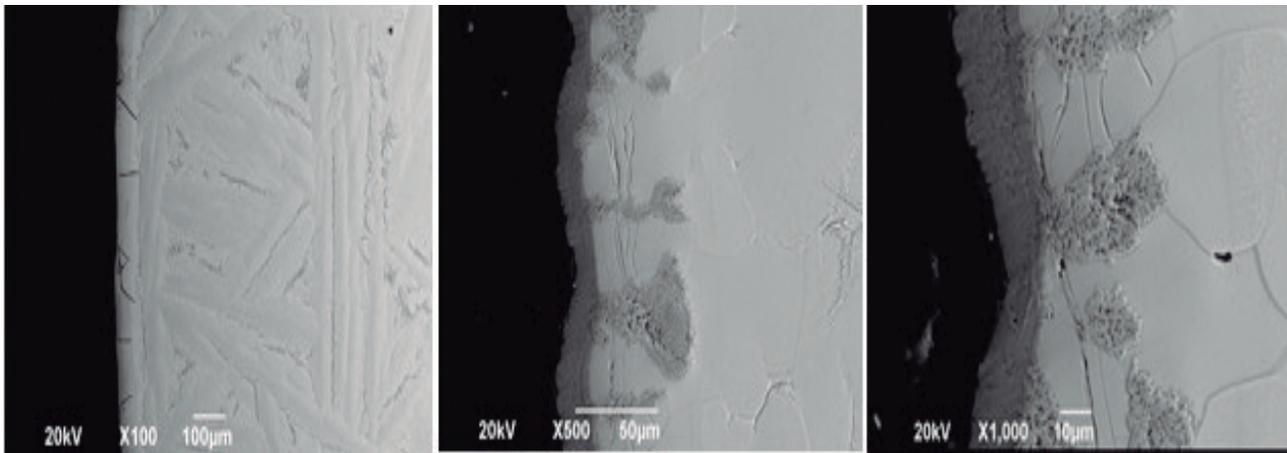
**Figure 4.** Calcined implant to 800 °C. Longitudinal section. A) A 50X (center of the implant, screw zone). B) A 500 X (edge of the implant)  
**Source:** the authors



**Figure 5.** Implant calcined at 1000 °C. Longitudinal section (center of the implant). 500X image  
**Source:** the authors

The inspection of the samples across the electronic sweep microscope (JEOL JSM 6490LV) under the way of electrons retro dispersed, put in evidence the growth of a cap of present oxide in the samples submitted to 800 °C,

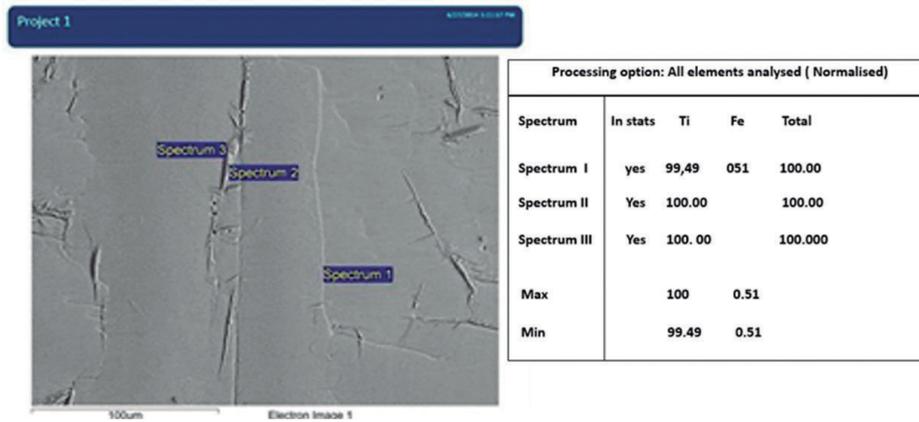
(Figure 4), this phenomenon is tied by the temperature and the time of exhibition of the implant in these conditions, to see (Figure 6).



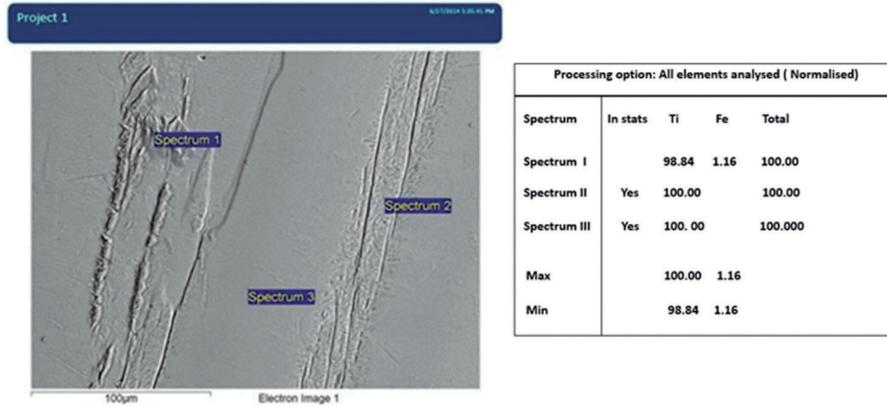
**Figure 6.** Structure submitted to 1000 °C (cap of oxide)  
**Source:** the authors

By means of analysis with spectroscopy for dispersive energy (EDS) was found that the chemical composition of the implant it did not alter in the step along with the

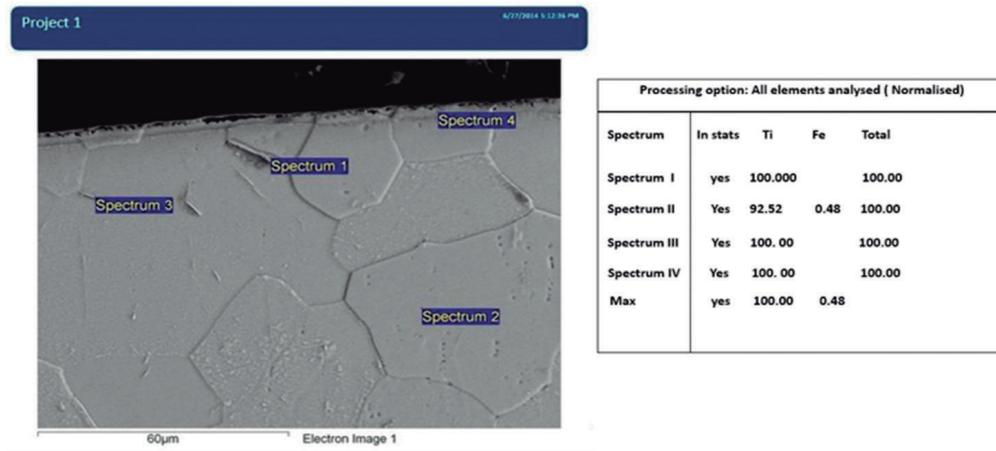
different temperatures, since it is possible to observe in the Figures 7, 8 and 9.



**Figure 7.** Spectral analysis of implant submitted to 200°C. Is the observed presence of titanium and iron, analysis for EDS  
**Source:** the authors



**Figure 8.** Spectral analysis of implant submitted to 800 °C. Is the observed presence of titanium and iron, analysis for EDS  
**Source:** the authors



**Figure 9.** Spectral analysis of implant submitted to 1000 °C. Is the observed presence of titanium and iron, analysis for EDS  
**Source:** the authors

## Discussion

Great number of implant that are placed nowadays in the world and the high resistance of the implants to the temperature converts them into an attractive candidate to be considered to be a forensic identifier, specially when the temperature of exhibition is so high that the teeth become very fragile, or alone when there are implants as props of the prostheses (Byraki, Costea, Curca & Hostiuc, 2010).

The different works realized by Berketa *et al.* (2010), (2011a), (2011b) and (Berketa, James, & Marino, 2011c) show that implants submitted directly to temperatures top to 1600 °C not only preserved the general form but even the number of identification included in its internal connection, in this work to temperatures of 1000 °C observes that the macrostructure of the implant (design of combs and valleys) and the step of coil remain, which would allow its identification by means of X-rays.

As for the code of identification recorded in the platform of the implant, this one resigned on having been submitted to 1000 °C, which explains because in the work of Berketa *et al.* (2010), (2011a), (2011b) and (2011c) the code was in the internal cavity of the implant while in the designed implant it was located in the platform and remained protected alone by soft fabric.

The oxide cap of titanium is formed in a passive way when the implant is exposed to the temperature set. This cap initially is amorphous and thin (5-10 nanometers), but it becomes thicker and changes its chemical composition on having submitted the implant to higher temperatures (Gemelli & Camargo, 2007).

Though the implants preserved his macroscopic characteristics to 200 °C, 800 °C and 1000 °C, microstructural changes could demonstrate for every implant (Figures 3 to 5), which might turn into an indicator of the temperature in which it was submitted.

In this investigation also an increase was observed in the thickness of the oxide cap of titanium by the increase of the temperature. In agreement with Berketa *et al.* (2011a) and (2011c) the exhibition of the implants to the high temperature generated changes of color attributable to the increase in the cap of oxide (approximately 0,1 mm).

The changes in the size of the oxide cap also might turn into an indication of the temperature to that incinerated the corpse, since this cap is capable of being measured and / or characterized for different technologies, such as electronic

microscopy of sweep (SEM), spectroscopy for dispersive energy of X-rays (EDS or EDX), diffraction of X-rays (DRX), between others (Gemelli and Camargo, 2007).

## Conclusions

The realized tests showed that the implants elaborated in titanium type the IV did not present macroscopic valuable changes.

Also was observed that to every temperature evaluated (200 °C, 800 °C and 1000 °C), a typical microstructure and a variation existed in the thickness of the oxide cap of titanium (present in the edge), which might allow to identify the temperature to the one that was exposed every implant.

In relation with the code of identification incorporated, one recommends to record it to a top depth to 1mm, due to the fact that the code used in this investigation disappeared on having come to the 1000 °C.

In agreement with the previous thing, the dental implants of titanium can be used as elements of forensic identification even in the case of incineration.

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