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PRELIMINARY STUDY WITH FORENSIC PERSPECTIVE OF LASER ENGRAVING OF ALPHANUMERIC CODES ON THE SURFACE OF FOUR ROSTERDENT® DENTAL IMPLANT SYSTEMS DESIGNED IN ARGENTINA.

Estudo preliminar com perspectiva forense da gravação a laser de códigos alfanuméricos na superfície de quatro sistemas de implantes dentários Rosterdent® desenvolvidos na Argentina.

Alan Diego BRIEM STAMM[1,2], Carla Georgina ARIAS[1], Mauro ANGELLI[3,4], Roberto CROSTA[4], Ornella Sofía MACUGLIA[2], Luis Reinaldo RANNELUCCI[1].

1. Chair of Legal, Forensic and History of Dentistry, Faculty of Dentistry, University of Buenos Aires, Buenos Aires, Argentina.
2. Department of Criminalistics and Forensic Studies, Gendarmería Nacional Argentina, Buenos Aires, Argentina.
3. Chair of Prosthodontics, Faculty of Dentistry, University of Buenos Aires, Buenos Aires, Argentina.
4. Rosterdent® Implant System, Laboratorio Romi S. A., Quilmes, Province of Buenos Aires, Argentina.

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Author for contact:
Dr. Alan Diego Briem Stamm
E-mail: alanbs.uba@gmail.com.

ABSTRACT
Objective: To engrave with laser technology an alphanumeric code on the surface of dental implants manufactured in Argentina by the company Rosterdent® that allows the identification of their batch number for forensic identification purposes. Method: A SMARK SHF-20 laser engraver was used to generate an alphanumeric code on the external and internal areas of the 4 Rosterdent® implant systems, external and internal connection hexagon, Trichannel and Morse Cone, totalling 8 engravings. Results: The codes engraved on the external hexagon implant system, both on the internal and external surface, were the most suitable, with a better visualization of the identification method, making it possible to read and interpret them. Conclusion: It is advisable to carry out new tests with the purpose of exposing the implants to thermal vulnerability and to consider the standardisation of Rosterdent® batches in order to provide information that contributes to human identification processes.

KEYWORDS
Forensic odontology; Dental implants; Batch numbers; Laser.

INTRODUCTION

Today's globalized world has encouraged the development of incidents of various kinds, such as violent crime, road accidents, terrorist attacks, hurricanes, floods, bombings and armed conflicts, which require the intervention of multiple agencies to assist the victims and, in the case of fatalities, to proceed with their categorical identification[1,2]. These incidents often generate very high temperatures that severely attack the integrity of the human body, resulting in carbonization and incineration, with the consequent loss of fingerprints, physiognomy and even DNA denaturation, making the identification process extremely complex[3]. Forensic dentistry is the application of dental knowledge to contribute to the enforcement of criminal and civil laws within the criminal justice system. In this context, the dental expert can play a crucial role in the identification of human remains as well as whole or fragmented bodies[2,4]. The most commonly used methodology is based on the comparison of post mortem (PM) information collected from the body and/or unidentified remains with ante mortem (AM) records recovered from the clinical history of the presumed victim, provided by dentists, family members and work institutions. Teeth represent one of the most resistant structures of the human body and, in addition to some materials used as restorative elements, they can tolerate high temperatures, preserving their physical integrity and constituting a source of distinction between individuals[4-6]. However, the loss of the organic component of teeth causes shrinkage and/or cracking above 1000° Celsius, making them very fragile[7].

Historically, the contribution of dental prosthesis to human identification has been emphasized, and in recent years the potential of dental implants in such scenarios has gained considerable relevance[8-10]. A dental implant is a prosthetic element surgically positioned in a bone bed formed inside the maxilla and/or mandible. After a period of approximately 3 months, osseointegration develops between the implant surface and the surrounding bone tissue[11]. Consequently, the implant acts as a support structure for oral rehabilitation as a fixed superstructure that can be adapted to it by different types of attachments, consisting of a crown, a bridge, a support bar for a removable partial denture, among others.

Anatomically, the implant consists of a body with coils that provides its primary anchorage, with a prosthetic connecting element at the top, the design of which may be an internal connection Hexagon (Fig. 1), external connection Hexagon (Fig. 2), Trichannel (Fig. 3) or Morse taper (Fig. 4). They are typically constructed of titanium or zirconium, or a combination of both[12]. Titanium ones have a melting point above 1650°C, while zirconium ones are in the range above 1850°C[13,14]. This physical property could contribute to the identification of victims in case of lost dental remains and in the absence of scientific evidence such as fingerprints or DNA[14,15].

Rosterdent®[16] is a company based in Argentina that manufactures 4 different designs of dental implants, so as part of a project proposed by the Chair of Legal, Forensic and History of dentistry of the Faculty of Dentistry of the University of Buenos Aires, an alphanumeric code was engraved on the surface of the implants using laser technology. In each implant model, two different locations were selected for engraving, in order to analyze which would provide an adequate reading and interpretation that would help to identify the manufacturing batch number of the implants in a forensic context.

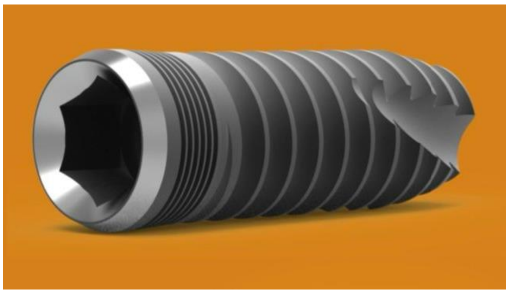

Fig. 1. Internal connection hexagon implant. Source: Rosterdent®.

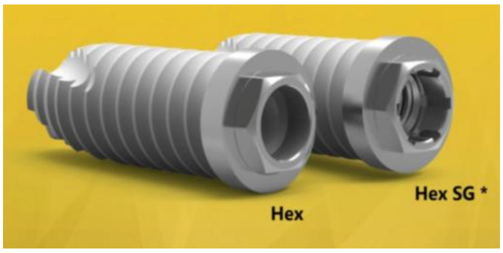

Fig. 2. External connection hexagon implant. Source: Rosterdent®

Fig. 3. Trichannel implant. Source: Rosterdent®

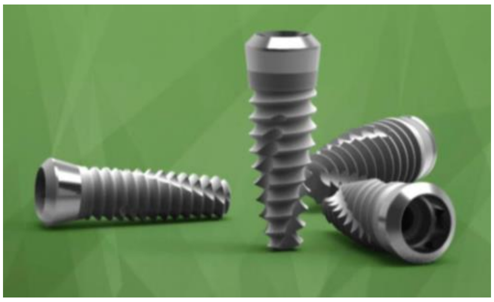

Fig. 4. Morse taper implant. Source: Rosterdent®

MATERIALS AND METHODS

The facilities of Laboratorio Romi S.A. at the Rosterdent® implant factory in the city of Quilmes, Province of Buenos Aires, Argentina, were used. A SMARK SHF-20 laser engraver was used (Figures 5a and 5b). The equipment has a 4th rotary axis that makes it possible to perform laser engraving on cylindrical surfaces at 360º, with a smaller engraving surface area of 3,000 mm. This technology is linked to a software that, through a digital computer system, allows configuring the design of the alphanumeric code that will be transferred by the laser engraver to the surface of the implant. The smallest letter size to be engraved has a width of 1.000 mm x height of 0.010 mm (flat surface and 4th rotary axis) (Fig. 6).

Auxiliary equipment was also available, consisting of a 200 x 130 mm hat square, a 0 to 150 mm digital caliper, a clamping device for implants (flat engraving) and a 0 to 15 cm ruler (Fig. 7).

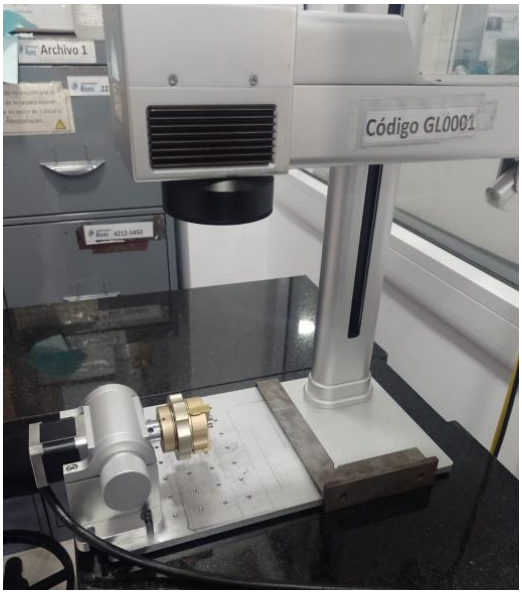

Fig. 5a. Laser engraver SMARK SHF-20. Source: Laboratorio Romi S.A., Quilmes, Argentina.

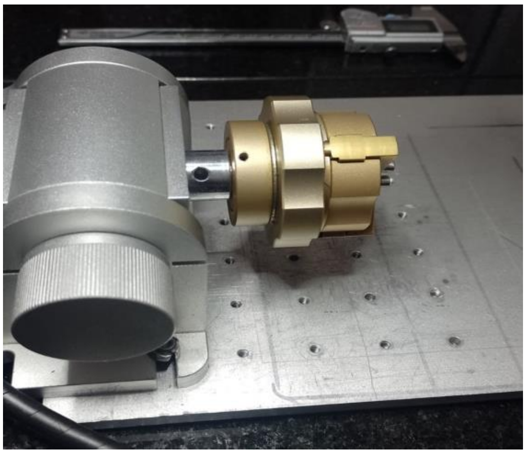

Fig. 5b. Laser engraver SMARK SHF-20. Source: Laboratorio Romi S.A., Quilmes, Argentina.

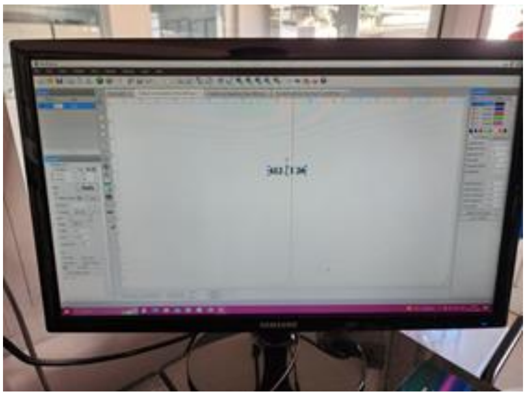

Fig. 6. Selection of the design and size of the code to be engraved. Source: Laboratorio Romi S.A., Quilmes, Argentina.

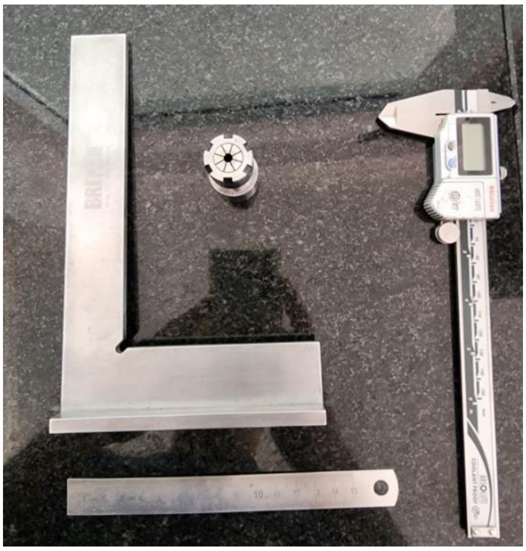

Fig. 7. Auxiliary equipment. Source: Laboratorio Romi S.A., Quilmes, Argentina.

Laser engraving of the alphanumeric code was performed on the 4 types of dental implants manufactured by Rosterdent®, selecting 2 different locations for each of them, with the aim of evaluating which would be the most suitable to facilitate their reading and interpretation. We started with external hexagon dental implants, first engraving the outside of the implants (Fig. 8a and 8b). On the chosen surface, the code could be read and interpreted (Fig. 8c).

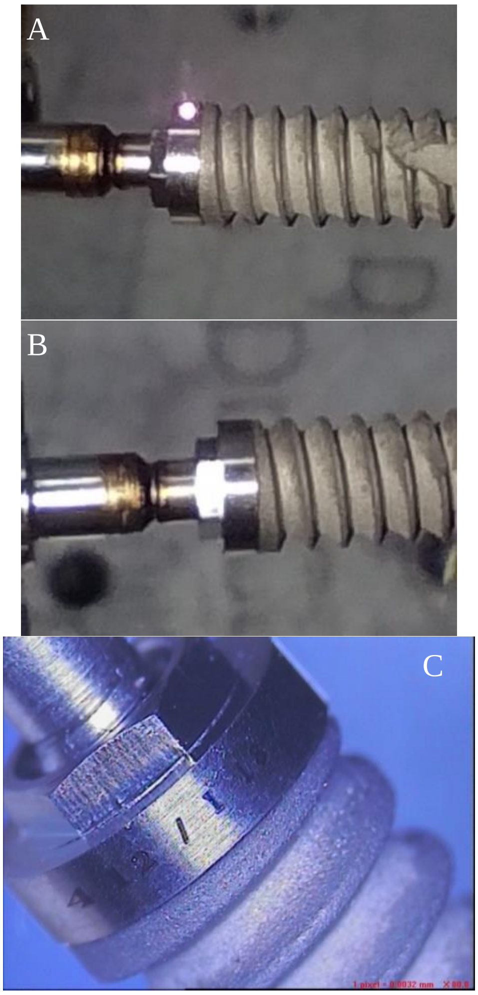

Fig. 8a. 8b. External hexagon implant on the outside, pre-engraved and during engraving. **Fig. 8c**. External hexagon implant on the outside, post-engraving. Source: Laboratorio Romi S.A., Quilmes, Argentina.

The externally connected hexagonal dental implants were continued, but engraved in the internal area. (Fig. 9a and 9b). On the chosen surface, the code could be read and interpreted (Fig. 9c).

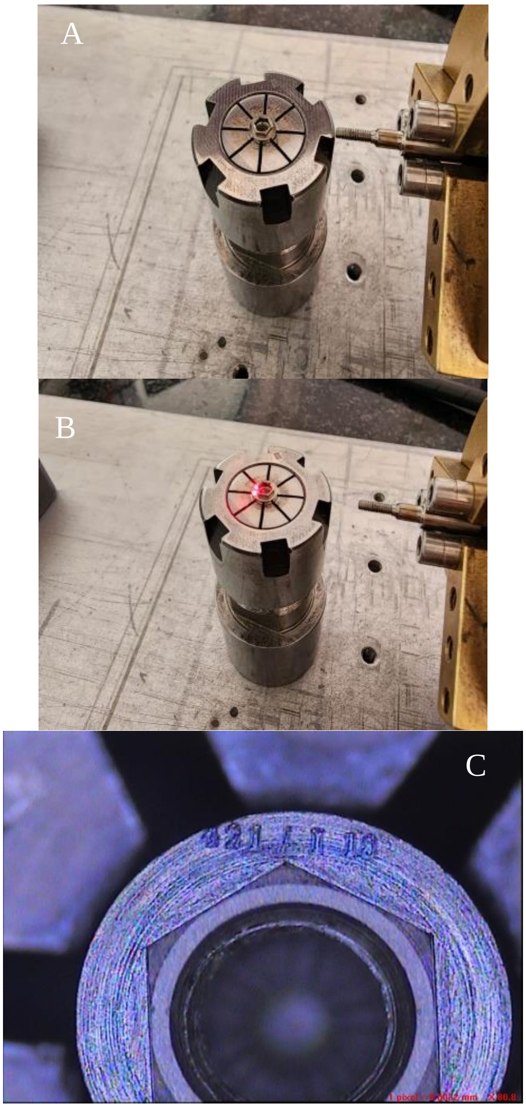

Fig. 9a. 9b. Pre-engraved internal surface of external connection hexagon implant and during engraving. **Fig. 9c**. Inner surface hexagon implant, post-engraving. Source: Laboratorio Romi S.A., Quilmes, Argentina.

The next step was to work with the internal hexagon implants, specifically on the polished external surface (Figures 10a and 10b). In the selected area, it was possible to read and interpret the code (Figure 10c).

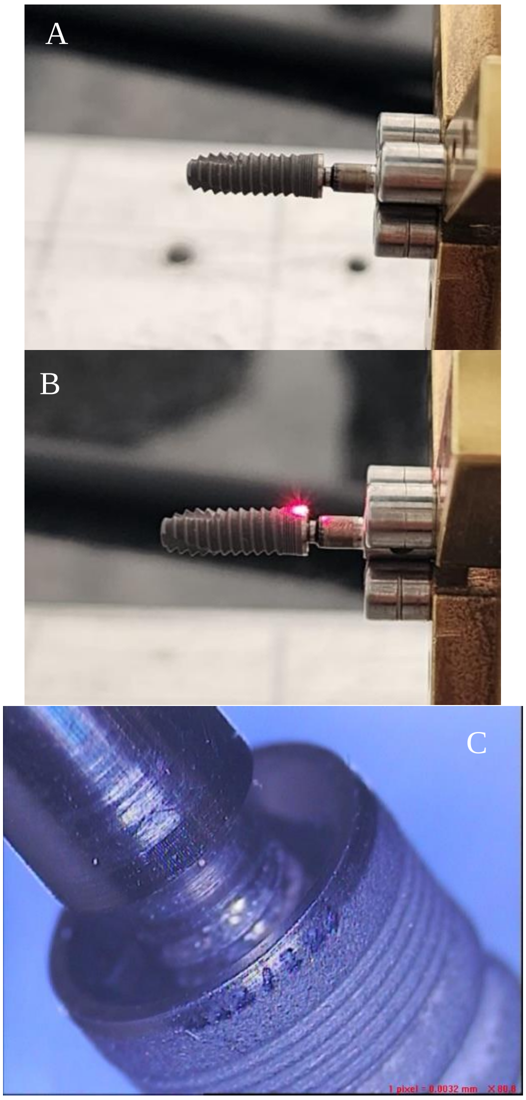

Fig. 10a. 10b. Internal connection hexagon implant pre-engraving and during engraving. **Fig. 10c.** Internal connection hexagon implant with polished exterior, post engraved. Source: Laboratorio Romi S.A., Quilmes, Argentina.

Subsequently, the internal hexagon implants were engraved, specifically on the polished inner surface (Fig. 11a and 11b). On the chosen surface, the code could be read and interpreted (Figure 11c).

Next, Trichannel implants were used, specifically in the outer bevel (Fig. 12a and 12b). On the chosen surface, the code could be read and interpreted (Fig. 12c).

Engraving was also applied to the inside of the trichannel implants (Fig. 13a and 13b). It was possible to read and interpret the code in the selected structure (Fig. 13c).

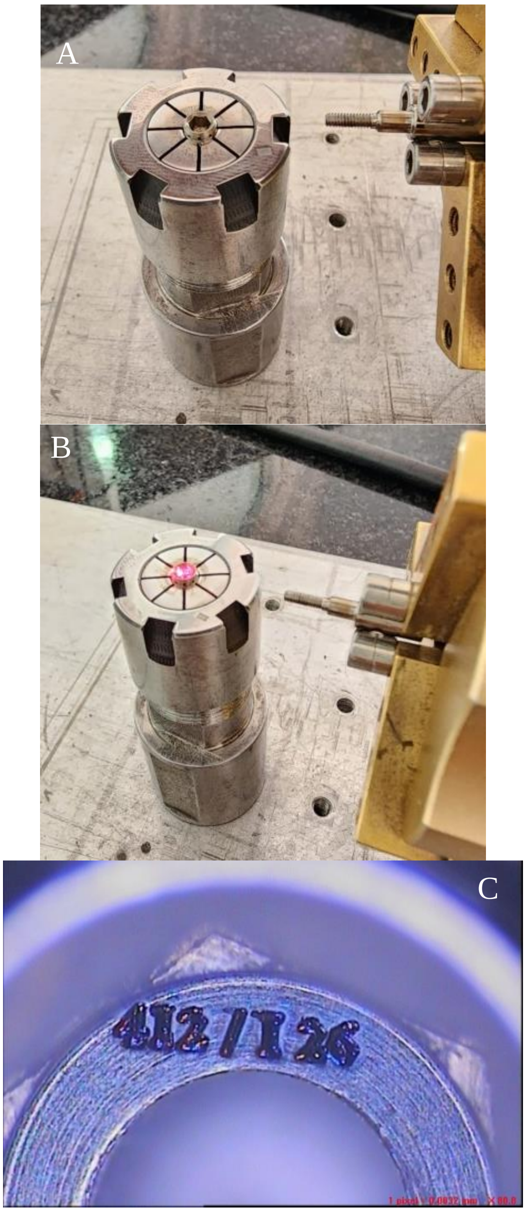

Fig. 11a. 11b. Inner surface of Internal hexagon implant, pre-engraved and during engraving. **Fig. 11c**. Internal hexagon implant on the inside surface, post engraved. Source: Laboratorio Romi S.A., Quilmes, Argentina.

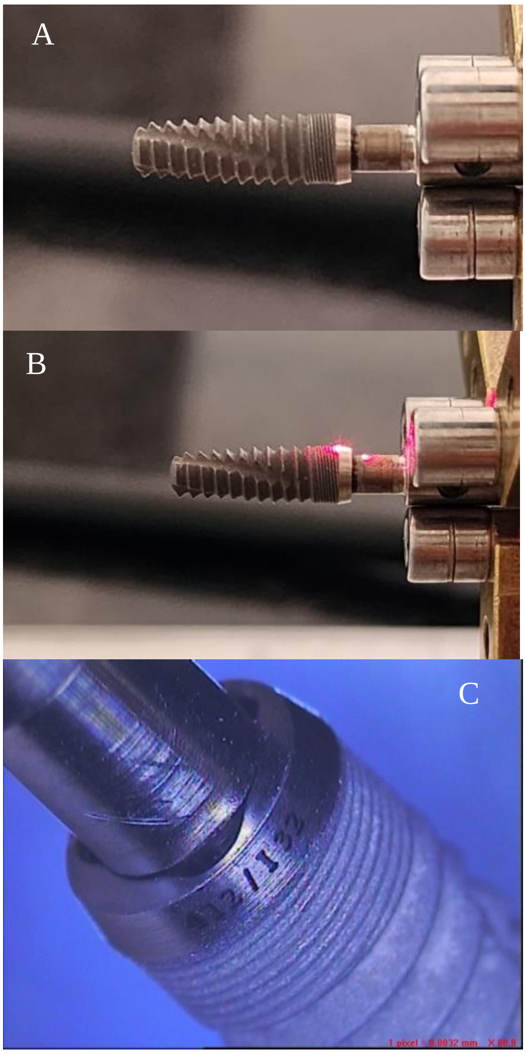

Fig. 12a. 12b. Trichannel implant outer bevel, pre-engraved and while-engraved. **Fig. 12c**. Trichannel implant with polished outer bevel, post-engraved. Source: Laboratorio Romi S.A., Quilmes, Argentina.

Work was then performed with Morse taper implants, specifically on the outside of the implant (Fig. 14a and 14b). On the chosen surface, the code could be read and interpreted (Fig. 14c).

Finally, the Morse taper implants were engraved on the inside (Fig. 15a and 15b). On the chosen surface, the code could be read and interpreted (Fig. 15c).

Fig. 13a. **13b.** trichannel implant inner surface, pre-engraved and while engraving. **Fig. 13c**. Trichannel implant inner surface, post-engraving. Source: Laboratorio Romi S.A., Quilmes, Argentina.

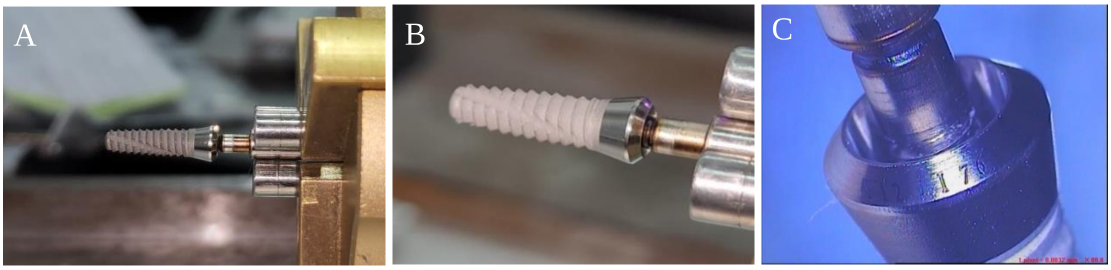

Fig. 14a. **14b.** Implant Morse taper with external polish, pre-engraved and while engraved. **Fig. 14c**. Morse taper implant polished exterior surface, post-engraved. Source: Laboratorio Romi, S.A. Quilmes, Argentina.

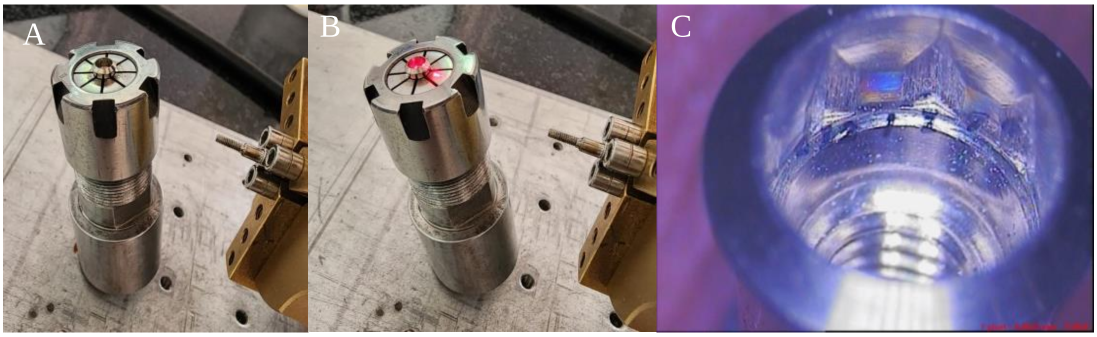

Fig. 15a. **15b.** Morse taper implant inner surface, pre-engraved and during engraving. **Fig. 15c**. Interior of Morse taper implant, post-engraved. Source: Laboratorio Romi S.A., Quilmes, Argentina.

RESULTS

The four implant designs manufactured by Rosterdent® could be engraved with laser technology at the planned locations. However, taking into account the main objective of this project, i.e. the possibility of reading and interpreting the alphanumeric code that confirms which manufacturing batch the implant belongs to and, in view of possible expert contexts with severe destruction and/or carbonization of the human body, the design, the tests showed that the codes engraved on the external hexagon implant system, both on its inner and outer surface, were the most suitable, with a better visualization of the identification method. This would mean that, once the implant has been recovered, it would be easier to locate, read and interpret, limiting the forensic search and speeding up the processes aimed at assisting the justice system.

It is necessary to consider that the second stage of the project will expose the implants with the engraved code to thermal stress, so these results are awaited in order to obtain further conclusions aimed at standardizing the batches of implants manufactured by Rosterdent®.

DISCUSSION

The analysis of dental implants with forensic implications has increased significantly due to the increasing demand as a treatment option for patients worldwide, increasing the likelihood of finding them in deceased victims, with post-mortem imaging resources contributing to their detection[17-19]. Being made of pure titanium and/or titanium alloy, the concrete possibility of the implants surviving thermal shock is obvious[13,15,20]. If the fatality is unknown, analysis of the brand, design type and size of the implants could contribute to their unequivocal identification. It has been reported that there are more than 463 different types of implants worldwide, so the possible presence of sales representatives in nearby districts and/or cities where an adverse incident with multiple victims has occurred could provide relevant data on morphological and design details of the implants that could be recovered during the oral cavity time inherent to the medico-legal autopsy[10]. Such an aspect would allow confirmation of identity or perhaps an exclusion of the body from a missing persons list[9].

Recent research results suggest that dental implants are still recognizable after incineration, although currently no published articles have been found regarding the identification of incinerated implants that have been osseointegrated within human tissue. There are companies that develop their implants with different lengths and widths, and these dimensions should be compared with designs published on websites[20,21] or by scanning company brochures, in order to establish possible points of comparison in forensic approaches. In addition to the implant models and their sizes, the differential diagnosis extends to the type of superstructure (gold alloy, titanium, chrome, zirconium or combinations of other elements), the top design (gold, titanium, zirconium, cast or preformed) and, most importantly, whether the crown structure could be retrieved and of what material it is designed (porcelain, zirconium, porcelain bonded to metal or gold)[21,22]. Another instructive piece of information is whether the crowns were screw-retained or cemented. In this regard, analyses of the implant surface texture have been carried out using software called SEM[5,9,12].

While it has been explained that dental implants lack the individuality of dental restorations because they are produced in large quantities, Straumann™ Company (Waldenburg, Switzerland)[23] has reported that their implants have laser engraved batch numbers on the inside[24]. The batch of implants with identical batch numbers varies between 24 and 2400[23]. It is reasonable to think that, although this number is still quite high, it would considerably reduce the frequency of possible victims carrying implants, and could provide relevant information in extreme incineration situations by visualizing the manufacturing batch number of the implants.

The examination of dental implants for identification purposes arose during the tsunami that devastated Southeast Asia in 2004[25], with more than 20,000 fatalities. It is necessary to consider that it is still a challenge to reach a consensus with the manufacturers regarding the incorporation of elements in their surface structure that enable their individualization. Experimental work reported in the scientific literature has demonstrated the ability to identify the engraved batch number after exposure to an oven at 1125ºC[25]. One aspect to bear in mind is that the studies carried out were performed with implants that were free inside the oven, i.e. they were not included in the bone structure, which merits further studies to observe how the behavior of the etching on the implants would be in such situations.

Dental implants have become an excellent alternative to replace lost natural teeth. Their high structural strength, together with their high melting point, gives them great protection against injury from deleterious physical agents. Titanium implants have become widespread throughout the world in a variety of designs, so it would be advisable to mark them for forensic identification purposes. The Chair of Legal, Forensic and History of Dentistry of the University of Buenos Aires, together with the dental implant company Rosterdent®, have generated an integral project with the purpose of investigating strategies to engrave with laser technology an alphanumeric code on the surface of dental implants to identify the lot number to which it belongs.

CONCLUSION

The four implant designs manufactured by Rosterdent® could be engraved with laser technology at the planned locations. However, taking into account the main objective of this project, i.e. the possibility of reading and interpreting the alphanumeric code that confirms which manufacturing batch the implant belongs to and, in view of possible expert contexts with severe destruction and/or carbonization of the human body, the design, the tests showed that the codes engraved on the external hexagon implant system, both on its inner and outer surface, were the most suitable, with a better visualization of the identification method. This would mean that, once the implant has been recovered, it would be easier to locate, read and interpret, limiting the forensic search and speeding up the processes aimed at assisting the justice system.

It is necessary to consider that the second stage of the project will expose the implants with the engraved code to thermal vulnerability, so these results are awaited in order to obtain further conclusions aimed at standardizing the batches of implants manufactured by Rosterdent®.

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RESUMO

Objetivo: Gravar com tecnologia laser um código alfanumérico na superfície de implantes dentários fabricados na Argentina pela empresa Rosterdent® que permita a identificação do número do lote para fins de identificação forense. Método: Foi utilizado um gravador a laser SMARK SHF-20 para gerar um código alfanumérico nas áreas externa e interna dos quatro sistemas de implantes Rosterdent®, hexágono de conexão externa e interna, Trichannel e Cone Morse, totalizando 8 gravações. Resultados: Os códigos gravados no sistema de implantes hexágono externo, tanto na superfície interna quanto externa, foram os mais adequados, com melhor visualização do método de identificação, possibilitando sua leitura e interpretação. Conclusão: É aconselhável realizar novos ensaios com a finalidade de expor os implantes à vulnerabilidade térmica e considerar a padronização dos lotes Rosterdent® para fornecer informações que contribuam para os processos de identificação humana.

PALAVRAS-CHAVE

Odontologia legal; Implantes dentários; Números de batch; Laser.

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