# IN VITRO BEHAVIOR OF INTERFACES IN HUMAN MOLARS WITH AN IMPLANTED PASSIVE RFID MICROCHIP AND SUBJECTED TO COMPRESSION FORCES

# COMPORTAMIENTO IN VITRO DE LAS INTERFASES EN MOLARES HUMANOS CON UN MICROCHIP RFID PASIVO IMPLANTADO Y SOMETIDOS A FUERZAS DE COMPRESIÓN

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**ABSTRACT:** In this "in vitro" study we evaluated the physical behavior of the interfaces of dental tissue of a restoration in resin composite (Filtek P90™ Silorane 3M-ESPE®) and a passive RFID microchip (VeriChip™) implanted in human molars, using a scanning electron microscope (SEM), to determine the clinical and technical possibilities of the implant and the viability to withstand compression forces exerted by the stomatognathic system during mastication. Through the ANOVA test, it was found that teeth in which a microchip was implanted present great resistance to compression forces, evidenced in the behavior of the interfaces between dental tissues, restoration in resin composite, and the microchip. From the bio-mechanical point of view, the interfaces observed present great in vitro resistance to compression forces and only evidence adhesive failure at extreme values that exceed the forces of the stomatognathic system during mastication.

**KEYWORDS:** Interfaces, resin composite, passive RFID microchip, compression tests, forensic dentistry, odontological identification.

**RESUMEN:** Estudio experimental in Vitro que evaluó a través de microfotografía electrónica de barrido (MEB) el comportamiento físico de las interfases de los tejidos dentales, de una restauración en resina compuesta (Filtek P90™ Silorane 3M-ESPE®) y un de microchip RFID pasivo (VeriChip™) implantado en molares humanos, con el fin de determinar las posibilidades técnicas y clínicas de la implantación y la viabilidad para resistir las fuerzas de compresión ejercidas por el sistema estomatognático durante la masticación. La prueba ANOVA determinó que los dientes en los que fue implantado un microchip presentan gran resistencia a las fuerzas de compresión, evidenciado en el comportamiento de las interfases entre los tejidos dentales, la restauración en resina compuesta y el microchip. Desde el punto de vista bio-mecánico, las interfases observadas presentan gran resistencia in Vitro a las fuerzas de compresión y solo evidencian fallas adhesivas a valores extremos que superan la fuerzas del sistema estomatognático.

**PALABRAS CLAVE:** Interfases, resina compuesta, microchip RFID pasivo, pruebas de compresión, odontología forense, identificación odontológica.

## 1. INTRODUCCIÓN

In Colombia, increasingly there are more deaths whose procedure of identification is made difficult by the state of the corpse or of the human remains (advanced state of decomposition, skeletonization, burns, carbonization, incineration, mutilation, among others), where there is alteration of soft tissue, elimination of finger prints, poor quality of tandem repeat DNA sequences susceptible to being interpreted and analyzed, or the lack of other elements leading to a positive or reliable identification of an individual. This is why institutions in charge of said identification processes must have more efficient methods that permit rapid recognition of an individual, to comply, not merely with the social work with respect to the family members, but also to expedite the case from the legal point of view. Currently, the use of passive RFID

microchips implanted in humans is becoming popular with different medical and economic objectives, whose main function is to identify and provide certain information of an individual. Said implant is sub-dermal (back of the hand and on the forearm) and it has been approved by the Department of Health and Human Services of the United States Food and Drug Administration (FDA), and regulated by ISO norms.

We found several reports in specialized literature of mechanisms for marking the different oral rehabilitation apparatus for identification purposes like those by Harvey [1], Turner et al. [2], Ryan et al. [3], Berry et al. [4], Cross and Wolfaard [5], Ling [6], Reeson [7], and Moya et al. [8]. Likewise, the American Dental Association (ADA) developed an acrylic micro-disc (blue for men and pink for women) measuring 3 to 4 ml in diameter, cemented on the vestibular surface of the upper right first molar. This devise has a unique alphanumeric code engraved that could identify each individual [9,10]. Rajan and Julian [11] indicated the use of microchips for these purposes for which Millet and Jaeannin [12] conducted a study incorporating a microchip to full acrylic prosthesis (dentures) through the scanning or reading system of passive RFID. Currently, the company Dentalax® commercializes a microchip and its reader to label removable partial or total dentures containing acrylic [13]. Regarding the implant of microchips within teeth, Theviessen et al. [14,15] conducted an in vitro study where they implanted several veterinary use passive RFID microchips (EasyTrac-ID®) in human molars concluding that these types of systems are quite useful for the identification of an individual within the forensic context. Nevertheless, more research is needed about implanting these microchips in teeth, a situation that would provide greater protection to the mechanism given the great resistance of the teeth against high temperature, acid attack, and humid and saline environments; likewise, this would be very useful in case of inhumation of several cadavers from a common grave, or the dismembering of several individuals, the latter employed by perpetrators to hinder identification processes, given that the microchip would remain where implanted after the latent cadaveric phenomena and reduce the possibility of confusion among several microchips and their loss in the place where the corpse or human remains were found. This is why this research evaluated the in vitro physical behavior of a passive RFID microchip (VeriChip™) implanted in human molars.

Microchips, electronic labels, RFID tags or passive electronic identification transponders consist of an electric resonance artifact conformed by a capacitor circuit, a reception and transmission antenna, and an electronic microchip, which, upon coming into contact with an antenna at a distance of about 10 cm with a specific low-power and amplitude modulation (AM) electromagnetic field generated by the scanner, which is fed with the voltage induced in the resonance circuit (using a frequency going from 125 kHz to the Industrial Scientific and Medical (ISM) band of 2.4 gHz, and even further), triggering the microchip to send the unique identification code to the scanner; once there, the code is amplified and converted to digital format, thus, deciphering it and introducing the sole identification number on the scanner's LCD screen. The tag consists of the microchip, which stores a 16-digit identification code, also laser engraved on the surface unalterably prior to its assembly; the antenna is a copper wire coil around a ferrite core, which receives and transmits the different signals to and from the reader; and the capacitor receives the necessary voltage from the scanner to allow the microchip to activate and transmit the identification code (Table 1).

## 2. MATERIALS AND METHODS

An experimental in vitro study was conducted to evaluate via scanning electron micrograph (SEM) the physical behavior of the interfaces between the dental tissues, a restoration in resin composite, and a passive RFID microchip (VeriChip™), implanted in 10 human molars subjected to compression forces, for the purpose of determining the technical and clinical possibilities of implantation and of creating a protocol, with respect to the diagnosis of the host tooth, the size and depth of the cavity, the selection of the dental restoration material and the possibility of producing adhesive failure among said interfaces. Currently, these devices are designed for sub-dermal implantation, for this reason this study evaluated the possibility of dental implantation.

### 2.1. Sample collection

Upon obtaining endorsement from the Human Ethics Committee of the Health Faculty at Universidad del

Valle, according to Resolution 8430 of the Ministry of Social Protection [16] and to the Helsinki Declaration [17], and verifying the minimum risk entailed in this study, we proceeded to collect a sample of 10 molar teeth, obtained from the patients who attended the Oral Surgery Clinic of the Dental School at Universidad del Valle, who required extraction of molars because of periodontal or orthodontic reasons and who signed an informed consent form.

### 2.2. Handling and preservation of the sample

Once the teeth were extracted, we proceeded to wash them profusely with tap water to eliminate traces of blood and tissue, and they were thereafter placed in a dark, tightly sealed container with the Chloramine T fixative solution at 5%. The teeth remained in Chloramine T for a week and were then placed in saline solution at room temperature according to ISO/DIS 11405:2003 Norm [18].

### 2.3. Sample distribution

Two groups were formed. The five teeth from group 1 received a class I cavity, then they were implanted with a microchip and restored with resin composite. The five teeth from group 2 received a class V cavity, then they were implanted with a microchip and restored with resin composite (Table 1).

**Table 1.** Results of compression tests

| Sample | | Type of cavity | Maximum Load (N) | Maximum Extension (mm) | Microchip operation |
|---|---|---|---|---|---|
| Group | Tooth | | | | |
| 1 | 2 | I | - | - | - |
| | 4 | I | 1318 | 1.08 | ☒ |
| | 8 | I | 1584 | 1.14 | ☑ |
| | 18 | I | 1678 | 0.92 | ☑ |
| | 13 | I | 1178 | 1.11 | ☑ |
| 2 | 1 | V | 3488 | 1.04 | ☑ |
| | 6 | V | 1708 | 0.80 | ☑ |
| | 7 | V | 2193 | 0.90 | ☑ |
| | 9 | V | 1904 | 1.08 | ☒ |
| | 20 | V | - | - | - |

### 2.4. Preparation of the passive RFID microchips

Given the size of the microchip (VeriChip™) used in this study, it was necessary to reduce its dimensions to create a dental cavity that would have sufficient remaining resistant dental material; to keep the microchip from coming into contact with the cavity walls (dental tissue) so that the restoration material could cover the entire microchip and fulfill its physical, biological, and aesthetic functions. To accomplish this, and according to indications by Thevissen et al. [14,15], the polypropylene porous polymer coating the end of the microchip was removed with a No. 15 scalpel and the scanned-glass capsule (VeriChip Pocket Reader™) was eliminated with diamond burs, because the glass is very fragile and has low resistance to compression and tension [19], constantly scanning the microchip to monitor its operation. These procedures diminished the microchip dimensions from 13 to 9 mm length and from 2.5 to 1.5 mm diameter.

### 2.5. Preparation of the dental cavities

The 10 teeth received the respective cavities with a high-speed, high torque dental hand-piece with four water outlets (Kavo 7000c®) with constant refrigeration and medium grain diamond cylindrical burs for operatory (Intensive Swiss®). The cavities were created from the occlusal and buccal midline, respectively, controlled through silicon caps placed on the bur and corroborated with an electronic gauge (Figure 1).

### 2.6. Obturation of cavities

Prophylaxis procedure was performed with a prophylaxis brush and a sodium bicarbonate solution; the surface was dried with absorbent paper and a P90® 3M-ESPE® adhesive system was applied (the primer was applied for 15 seconds, it was aerated and photo-cured for 15 seconds; then the adhesive was applied for 10 seconds, it was aerated and resin was photo-cured for 10 seconds). Thereafter, we placed a first layer of resin (Filtek P90™ Silorane 3M-ESPE®) at the bottom of the Class I and Class V cavities; the microchip was set in place and it was photo-cured for 20 seconds.

Finally, obturation of the cavity was completed through two increments – each photo-cured for 20 seconds; the restoration was polished and shined with disks (Soflex® 3M-ESPE®) and a sealing agent (Concise White Sealant 3M-ESPE®) was applied to the restorations of the Class I cavities to seal the cusp union. For the restoration process, we followed the manufacturer's indications [20] and the microchip was constantly scanned (VeriChip Pocket Reader™) to test its proper

operation (Figure 2). The teeth were preserved in saline solution and labeled with the microchip serial until the application of the compression tests.

### 2.7. Application of physical compression tests

A self-polymerization (New Stetic®) acrylic resin base was made for each sample from the two both groups the resistance to the compressive forces was greater than those generated by the stomatognathic system during mastication [21-25].

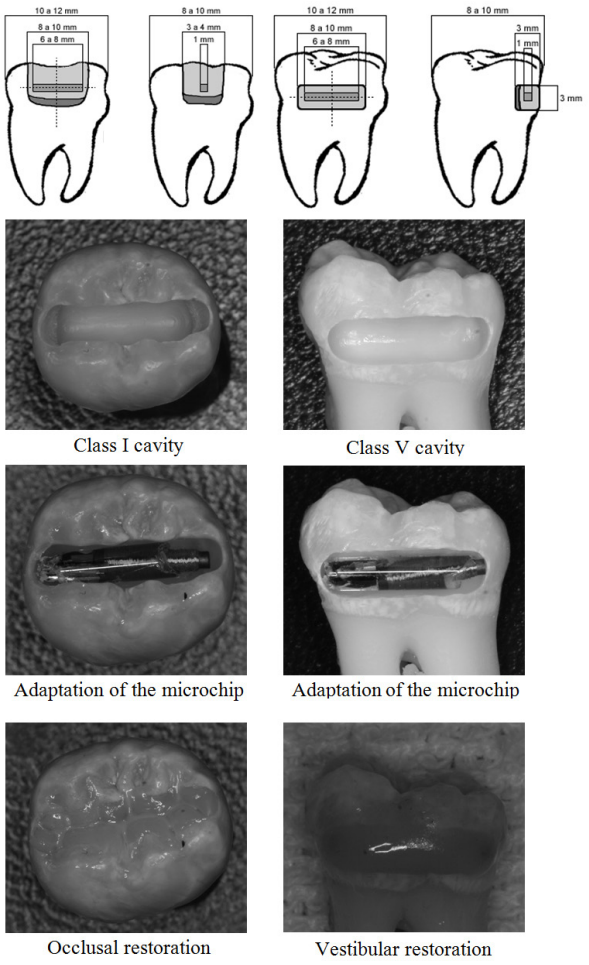


**Figure 1.** Preparation of the cavities, implantation of the microchip and restoration of the cavity

Theviessen et al. [15] implanted veterinary use microchips in class I cavities done in molar teeth and subjected them to compression forces, finding that in all the samples tested, the maximum resistance without microchip failure reached 2200 N. Moreno et al. implanted passive RFID microchips in class I and class V cavities of human molars and subjected them to compression forces, concluding that given the major resistance to compression (from 1318 N to 3488 N), it is viable from the mechanical point of view to implant microchips in teeth, with it being more plausible to perform said implantation in class V cavities [26]. However, the authors state that from the biological point of view (conservation of the quantity and quality of the dental tissue), the dimensions of the microchip must be reduced.

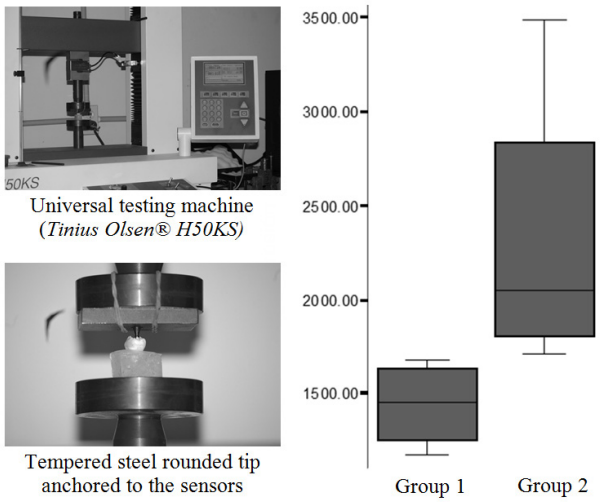


**Figure 2.** Compression tests. Universal testing machine. Rounded tip and graphic of specimen dispersion within each group

In this study, via SEM, we observed cohesive failures in dental tissue, in resin composite restoration, and in the microchip, but only two ceased operating correctly. Likewise, adhesive failure was noted in the interfaces between the dental tissues and the resin composite restoration, and between the resin composite restoration and the microchip. Nevertheless, it is not possible to associate these types of failures to a given group of teeth because there are individual variations in tooth morphology (size, shape, and inclination of the cuspids), on the size of the teeth, on the conformation of the cavities, and on the point of contact of the rounded tip during the physical tests, which may contribute to the standard deviation in the behavior of the resistance to compression. But it may be explained why the teeth from group 2 had the greatest resistance, given that there is greater dispersion in the compressive resistance of the specimens, which is associated with the area of the occlusal table, the vestibular-lingual width of the

teeth, and to the proximity of the cavity to the axial force axis, a situation that was not

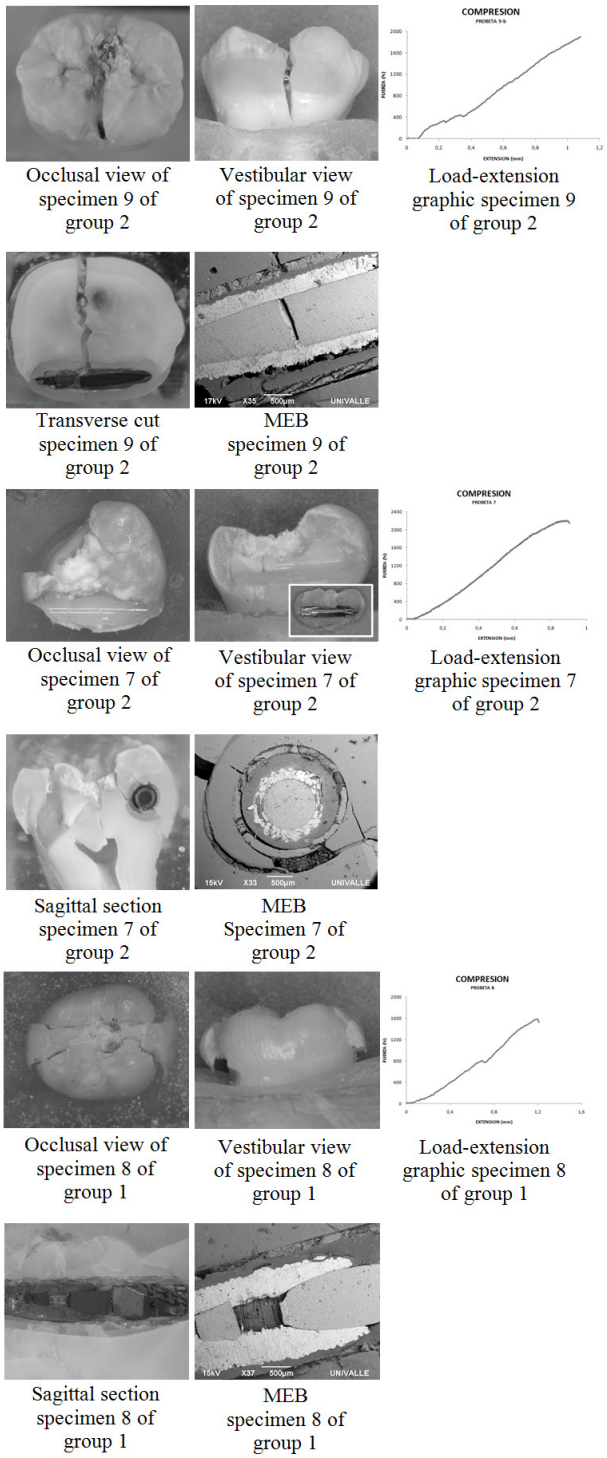


**Figure 3.** Compression tests results

present in the teeth from group 1, where the restorations in the resin composite received the force directly (Figure 3).

## 3. CONCLUSIONES

The Filtek P90™ Silorane 3M-ESPE® restoration material turned out ideal for implanting microchips in teeth, given that the cohesive and adhesive failures upon application of compressive forces are found above the forces produced by the stomatognathic system. Only two microchips stopped functioning after the compression tests because of their fracture.

From the bio-mechanical point of view, and according to the statistical tests, it is more plausible to implant a microchip in a class V cavity than in a class I cavity, although in both groups the resistance to the compressive forces was greater than those generated by the stomatognathic system during mastication.

## 4. ACKNOWLEDGMENTS

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