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# First Seccioned and Plastinated Human Body in Latin America and its Applications: a Pioneering Effort of the Life Sciences Museum

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**ABSTRACT**

**Introduction:** plastination is an anatomical technique for the preservation of biological tissues whose principle is the replacement of body fluids by a curable polymer. Plastination with silicone, one of the polymers that can be used in this process, allows the conservation of tissue fragments, whole organs, and even large animals. The literature lacks detailed protocols for silicone plastination of sliced full human body. In this sense, the main objective of the work was to execute the first plastination of a full and sectioned human body in Latin America and detail the entire process. For this, a male cadaver with a length of approximately 1.65 meters and aged between 60 and 65 years was selected. The cadaver was part of the collection of the anatomy sector at the Federal University of Espirito Santo. The following steps were then taken to obtain the slices from the human body: positioning of the cadaver previously fixed in an anatomical position, its freezing, slicing, and the cleaning of the cuts. After that, the standard protocol for plastination was performed: dehydration in acetone, forced impregnation with silicone and curing. As a result, a total of 192 slices were plastinated. These slices were dry, odorless, non-toxic, manageable, easy to maintain and are being used in practical anatomy classes for healthcare degrees and for exhibitions at the Life Sciences Museum (MCV – *Museu de Ciências da vida*) at the Federal University of Espirito Santo in Brazil.
**Keywords:** Plastination; Silicone; Method; Seccioned.

## Introduction

The plastination method is an embalming process developed by the German physician and professor Gunther von Hagens in 1977 as an innovative technique for the preparation of anatomical parts. In this technique, the biological tissue is preserved inert, realistic and without decomposition for an indeterminate time (HAGENS; TIEDEMANN; KRIZ, 1987).

Plastination is one of the most recent and ideal tissue preservation methods (SORA *et al*., 2019). The greater durability of the parts and the possibility of handling are extremely useful characteristics for educational activities in anatomy, whether in the academic environment or not (HENRY, 2007). In addition, an advantage of the technique is that the plastinated part does not require glass vats for accommodation in exhibition spaces and also avoids the use of toxic preservative solutions with unpleasant odor for the maintenance of anatomical specimens, such as formaldehyde. These benefits have made it popular and sought after by numerous educational institutions such as Universities, colleges, and museums around the world (JONES; WHITAKER, 2009).

The principle of conservation of this technique is the replacement of tissue fluids by a curable polymer, and is achieved, according to von Hagens, Tiedemann and Kriz (1987), through a process consisting basically of four fundamental steps: chemical fixation with the use of formaldehyde for tissue stabilization, dehydration in acetone, forced impregnation of the polymer by application of vacuum to replace the acetone and chemical or photochemical catalysis to harden this polymer (MONTEIRO, 2020).

There are three main classes of polymers that can be used in plastination: epoxy, polyester, and silicone. Epoxy and polyester are best suited for thin serial cuts (3-5 mm thick), being useful for histology and diagnostic imaging, while polyester is more used for cuts in the central nervous system, as it allows greater differentiation between white and gray matter. Silicone is ideal for organ preservation, whole parts, and thicker cuts (> 1 cm thick), (SORA; COOK, 2007; HENRY; LATORRE, 2007) and is the most used in the world, due to its versatility and possibilities of use.

The literature lacks protocols for the preparation of an entire human body sectioned and plastinated with silicone, whose plastination is a complex process with many details, requiring some knowledge to produce


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high quality specimens. Detailing a protocol that seeks to make the process more affordable would facilitate its reproduction and, therefore, could be carried out in other laboratories. Furthermore, in a pioneering way in Latin America, the preparation of a specimen such as this one would serve as a complementary teaching tool in anatomy, especially in sectional anatomy, for degrees in the health area, research, and museum exhibitions.

The aim of this study was to describe the entire process in the preparation of an entirely sliced and silicone-plastined male human body in 13-15 mm thick slices for the use in higher education practical classes and museum exhibitions.

## Materials and Methods

The human cadaver used in the research was part of the collection of the Department of Anatomy of the Department of Morphology, located at the Health Sciences Center of the Federal University of Espírito Santo, with all documentation of receipt of unclaimed body regularized, according to the Federal Law of No. 8.501 (November 30, 1992) which authorizes its use for teaching and research purposes. The chosen cadaver was male and approximately 1.65 meters tall, aged between 60 and 65 years (Figure 1). The body had already been fixed and preserved in 10% formalin for approximately 5 years.

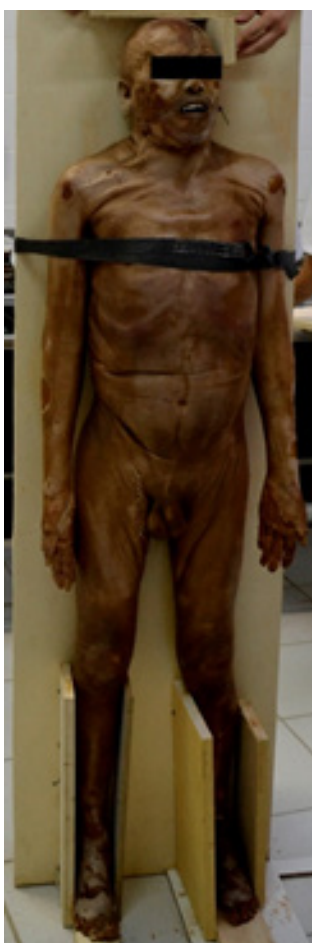

**Figure 1.** Adult human corpse already fixed and positioned for freezing and subsequent packing for slicing and plastination.

Initially, the body was washed in water for one day to remove excess of formaldehyde. Then, it was frozen on a wooden plate in anatomical position in a horizontal freezer at -25ºC for 48 hours. After freezing, with a hand saw, the feet were cut at the ankle level, the hands at the level of the wrist and the head with the neck. These segments were removed to be processed separately in order to facilitate the performance of the following steps. After that, the body was packed in polyurethane resin (PU) in a custom-made box a few centimeters larger than the specimen, where the body was positioned really close to the walls and bottom. In order to leave the corpse some centimeters suspended, Styrofoam strips were used at the bottom of the box. Then, the mixture of components A and B of the PU resin was prepared and was quickly poured around the body in the box, which was immediately closed (Figure 2). After the complete expansion of the PU foam, which lasted a few seconds, a rectangular pack was formed with the specimen, that was removed from the box and transferred to a horizontal freezer for another seven days at -25 ºC. Some authors (SORA, M-C; COOK, P, 2007; LATORRE; HENRY, 2007) suggest freezing at -80ºC for later slicing, but a temperature of -25ºC was used due to the unavailability of a large freezer that would reach lower temperatures and to propose a simpler and less expensive method. The packing and freezing served to facilitate the subsequent slicing in an aligned manner, reducing the risk of losing the cutting plan. The head was packed and sliced separately, and the hands and feet were cut without the PU pack.

**Figure 2.** Frozen corpse positioned in the wooden box during expansion of the polyurethane foam for its encasing and subsequent slicing to plastination.

The slicing was performed with the aid of a Skymsen band saw, type SSI nº 1974, in the transversal plane of the cadaver, cutting slices between 13 and 15 mm thick (Figure 3). The cutting tape used was indicated for bones and soft tissue and slicing should be slow to avoid excessive pressure on the cutting tape and consequently deviation. This step lasted approximately

seven days, since when the body and head blocks started to unfreeze, it was necessary to interrupt and repeat the freezing procedure for another 24 hours in order to maintain the quality and integrity of the slices cut. During the step, the cuts already made were stored in the freezer (-25º) inside a plastic container in the order of slicing. At the time of slicing the left leg, it was suspected that it had an intramedullary metallic rod in the tibia, since there was resistance to cut. This hypothesis was later confirmed with x-ray examination and, therefore, this segment could not be sliced, and a dissection preparation was performed to show the metal rod. To amplify the use and the anatomical content of the slices, the hands and feet were cut in different planes, without prior PU packing. One hand was cut in half in the frontal plane (coronal) and the other in the middle of the fingers in the sagittal plane. On the feet, one was cut in the transverse plane, following the body, and the other in the sagittal plane, having as reference the middle of the toes.

**Figure 3.** Band saw process of slicing the frozen body embedded in polyurethane for plastination.

Once the slicing step was completed, all slices were labeled with a numerical identification to locate the position of the slices. In addition to the number, the upper and lower limbs were identified by the letters D or E for right or left (direita and esquerda, in Portuguese), respectively. After identified, the cuts were sequentially and carefully washed in cooled acetone (-25°C) with the aid of a brush to remove ice, fragments and dirt from the slicing (Figure 4). Then they proceeded to the plastination process.

The plastination technique was basically performed according to the protocol proposed by von Hagens, Tiedemann and Kriz (1987), divided into 4 main stages: fixation, dehydration, forced impregnation and chemical cure/catalysis. Fixation had already been performed previously using a 10% formalin solution for tissue stabilization. Immediately after cleaning the cuts, as already described, the slices were placed in the vertical position in a plastic basket, separated from each other by perforated plastic screens to facilitate handling between the plastination steps, and then, the dehydration at low temperature (-25ºC), being carried out with 4 baths per week and immersed in acetone at concentrations 95, 95, 100 and 100% volume/volume (v/v), consecutively, inside a freezer.

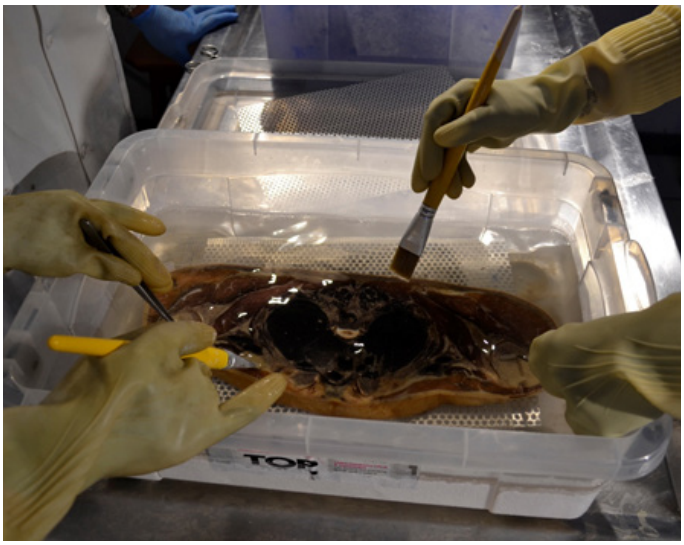

**Figure 4.** Washing process in cooled acetone (-25ºC) of the slices of the male human body destined for plastination.

The vertical accommodation of the slices separated by plastic screens aims to increase the contact surfaces of biological tissues in the dehydration and impregnation stages. Concomitantly with the first weekly dehydration bath, hydrogen peroxide was added to the cooled acetone to whitening the slices, with the final concentration of peroxide being 10 volumes (3% v/v). The bleaching was carried out at the same time as dehydration to avoid thawing of the cuts and possible loss or displacement of small structures. At the end of each bath, the purity of the acetone was checked by an acetonometer, considering that the dehydration step with acetone was concluded, having reached a purity greater than 99% v/v. Since then on, the cuts inside the baskets were immersed in the cold impregnation reactive mixture (-18°C), composed by a silicone PDMS (polydimethylsiloxanes) and the catalyst Dibutyltin dilaurate (DBTL), in the proportion of 100:1 mass/mass (m/m), respectively, already inside the vacuum chamber for 24 hours. After this period, the vacuum was applied slowly and progressively, having as a vacuum adjustment parameter the pattern of bubbles with one bubble/second at the same observation point (JONG; HENRY, 2007). Vacuum progression was measured with a digital and mercury manometer. When the appearance of bubbles on the silicone surface ceased and the maximum vacuum was reached by the pump, the step was considered complete. Thereby, the forced impregnation step lasted 26 days, reaching a minimum pressure (maximum vacuum) of 8 mmHg. Then, the slices were placed for drainage of excess silicone suspended in the chamber itself for 3 days (Figure 5)

and then mechanical drainage was also performed with absorbent paper for another 5 days. The removal of excess silicone with absorbent paper is extremely important so that the final specimens do not have an undesirable glowing appearance.

**Figure 5.** Silicone draining process immediately after low temperature (-18°C) impregnation of male human body slices destined for plastination.

Before hardening, some structures were positioned and finalized, and some adjustments were made, such as the opening of collapsed blood vessels, and repositioning and filling with cotton of the intestine fragments. In addition, some suture stitches were determined in certain tissues and organs to keep them in the desired position. In the next step, the chemical curing, the crosslinker tetraethyl orthosilicate (TEOS) was vaporized in a closed bag containing the pieces disposed for the hardening of the silicone (Figure 6). After two days of hardening, the specimens were finished. For greater stabilization and security, for some organs such as the heart and liver, headless pins were used to completely traverse the skin towards the structure, not being visible to the eye. The entire plastination process was carried out at the Plastination Laboratory at the Federal University of Espirito Santo.

**Figure 6.** Process of chemical curing of human body slices impregnated with silicone, which is performed by volatilizing the crosslinker in a closed plastic chamber.

## Results

A total of 192 slices of the anatomical segments were obtained, being 12 cuts from the head/neck, 15 from the chest, 20 from the abdomen, 9 from the pelvis, 76 from the lower limb (MI) and 60 from the upper limb (MS). Figures 7 and 8 show some plastinated slices from different anatomical segments.

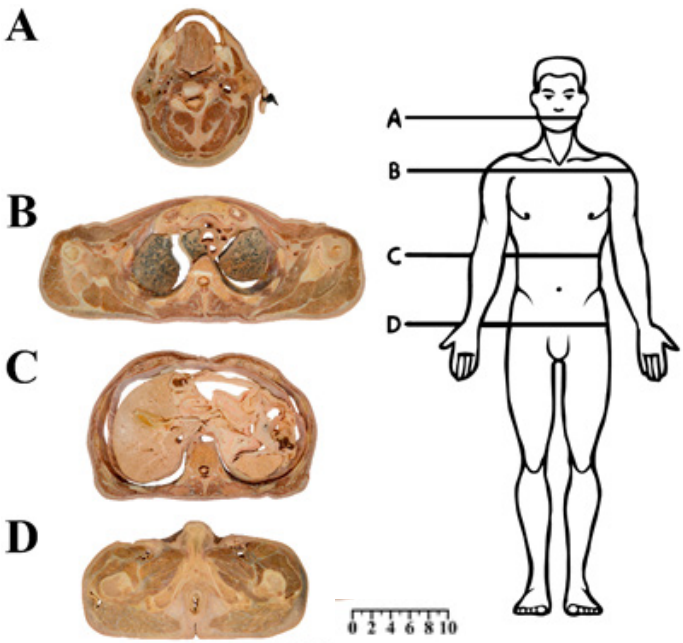


**Figure 7.** Examples of plastinated human body slices relative to different segments in lower view and legend of anatomical plane of the slices. A = head; B = thorax; C = abdomen, D = Pelvis. Scale in centimeters.

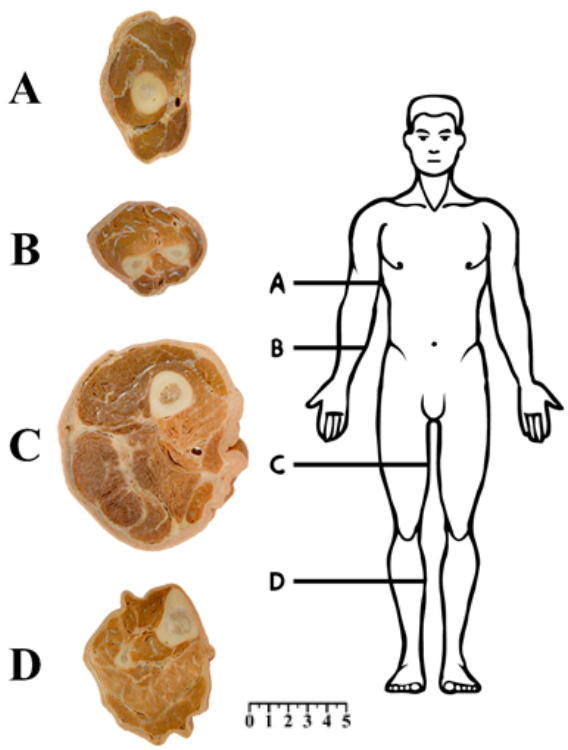


**Figure 8.** Examples of plastinated human body slices relative to the right upper and lower limbs in lower view and legend of anatomical plane of the slices. A = arm; B = forearm; C = thigh, D = leg. Scale in centimeters.

The left leg was dissected to expose the intramedullary rod, with part of the skin, subcutaneous tissue, muscles, and tibial bone opening, as shown in Figure 9.

**Figure 9.** Left leg dissected and plastinated to demonstrate the metallic intramedullary rod and the bone callus.

There were no visible changes in the colors of the slices when comparing the specimens before and after plastination. The final specimens were dry, more resistant, and durable, and could be handled with safety due to the elimination of toxic preservative agents, such as formalin.

Some adaptations made in the plastination process of the body to reduce costs while maintaining the high quality of the final product were: freezing the specimen in a conventional horizontal freezer at a temperature of -25 °C for slicing, use of materials for positioning the body such as wood, screws and tools in general, creation of a simple wooden box for the PU packing of the specimen, preparation of the individual screens to protect the slices from a larger aluminum plate and preference for the use of common materials to aid in the process, such as plastic baskets for moving the slices in the dehydration and forced impregnation stages.

After plastination, half of the cuts produced were allocated to the collection of the Department of Morphology at Ufes to be used in practical classes of courses in the health area (Figure 10), and the other half was displayed at the Life Sciences Museum of Ufes (MCV) (Figure 11). The specimens are also being used in scientific research.


**Figure 10.** Human sections being used in practical classes in an undergraduate course.

**Figure 11.** Specimen called "tomography" ("*Tomografia*") on display at the Life Sciences Museum, consisting of 80 horizontal, coronal (right hand) and sagittal (hand and left foot) 13-15 mm slices of an adult male body plastinated with silicone.

## Discussion

The sliced specimen will be used as a teaching tool in practical anatomy classes, mainly for the study of sectional anatomy and its correlations with medical diagnostic imaging exams. This type of anatomical specimen allows a detailed and high precision in learning about anatomical structures present in the slices (OTTONE *et al.*, 2017; JAMES *et al.*, 2019). During the study only in textbooks, the spatial notion is restricted to a two-dimensional perspective, and plastinated sections, on the other hand, form an invaluable bridge between cadavers and radiological images, allowing a better 3D spatial understanding of organs and structures and manipulation at any angle (DIBAL *et al.*, 2018). With this, the specimens can be viewed by students without the need to use protective equipment (glasses and gloves), since there is no presence of toxic substances such as formaldehyde and can be shown in environments outside the anatomy laboratory without difficulties, such as in lectures and theoretical classes. To expand access to the work developed in the plastination laboratory, an atlas of sectional anatomy is being developed from the slices produced, which will be available online and free of charge.

In addition to teaching, the product of this research will contribute to university extension since part of the slices will remain on display at the MCV for thousands of students and the general community public who will have access to this very high-quality material. The assembly in the museum was called "Tomography" (Figure 9), being the first human body sliced and plastinated with silicone produced in Latin America on display. The specimen is more than 4 meters long and has approximately 80 slices didactically exposed representing a tomographic exam.

Besides, scientific research is being developed with the slices for different evaluations, mainly in the area of scientific education.

The plastination of the sectioned body promoted an innovation not only for Brazil, but also for Latin America, in the context of anatomy teaching and in the area of museums. The pioneering spirit of the Museum of Life Sciences of the Federal University of Espirito Santo with the production of a specimen of high complexity and quality took place with a protocol that sought adaptations in order to make the processes less expensive and to make their reproduction more accessible for laboratories of smaller size, aiming at the diffusion of plastination technology and the improvement of teaching tools.

## Conclusion

The plastination protocol used in this work show us that is possible to produce high-quality plastination of the slices with a modest cost and infrastructure.

The present work showed that the production of a sliced specimen can bring great benefits in teaching, research, and especially in biological sciences area as anatomy, pathology and health care degrees.

With plastination technology, the cuts of the body are more resistant, dry, odorless, easy to store and safer for the handlers, and, therefore, extremely advantageous for use in the activity of academic and museal education.

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## Mini Curriculum and Author's Contribution

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