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Manuscripts and figures intended for publication in The Journal of Plastination should be sent via e-mail attachment to:  
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On the Cover: Human pelvis containing 3D printed models generated from plastinated specimens from the article “Method for Creating Interactive Plastinated Models of the Male and Female Pelvis for Medical Anatomy Education” by M.S. Cook and P. Hill published in this issue pages 25-33.
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Letter from the President of the International Society for Plastination

Dear Friends and Plastinators:

It is with great pleasure that I present to you Volume 31, Issue 1, of the Journal of Plastination. I want to thank the authors of the papers who have chosen our journal to publish their results. These articles allow us to know new applications of plastination techniques, and open new work options in our laboratories.

I would like to thank the reviewers for taking their time to review the manuscripts.

This issue presents five remarkable papers. The first paper from Drs Cook and Hill is about how to create interactive plastinated models of the male and female pelvis for medical anatomy education. These specimens from the pelvis, a challenging region of the human body, can be manipulated to allow students to remove organs, blood vessels and nerves from the pelvis. The second study is about the microbiological safety of specimens plastinated with the S10 cold temperature technique, from Dr. Komarnitki et al. The authors did not observe any bacterial or fungal growth on plastinated samples. However, they recommend a continuous monitoring of temperature and humidity of the plastinate storage rooms. The third paper, presented by Dr. Nguyen et al., shows the students’ and residents’ opinion and performance in anatomy learning, with cadavers or plastinated specimens. They found interesting results about plastinated resources. The fourth paper of this issue is presented by Dr. Owolabi et al. In this work, the authors compare results of whole brains impregnated at cold temperature or at room temperature. The last paper, about impregnation of samples completely in paraffin wax as an alternative preservation method to plastination, by Dr Sultana et al., presents curious results.

As most of you know, the XX International Conference on Plastination (https://www.icp2020chile.com) will be held in Temuco, Chile, next July. The host is Prof. Nicolás Ottone and his team from Universidad de La Frontera. The dates are July 20-24th, 2020. As president of the ISP I would like you all to become actively involved in this conference, sending communications and attending it personally. It will be a great opportunity to share new experiences about innovation and to establish future collaborations for the advancement of plastination. I hope I can meet all of you in Temuco.
I have to remind the different groups, that to attend this Congress, the General Assembly of the ISP approved three travel grants for postgraduate students, working in plastination, and members of the International Society for Plastination.

I would like to welcome all new members of the International Society for Plastination and to invite all of you to participate in the Journal of Plastination. Please, share with us your results, your expertise in plastination and other anatomical techniques.

With best regards from Murcia, Spain

Rafael Latorre
Dear Colleagues,

This issue marks a significant step forward in the history of The Journal of Plastination: papers published from here on will be indexed on SCOPUS. Scopus is Elsevier’s abstract and citation database. It covers nearly 36,377 titles from approximately 11,678 publishers, of which 34,346 are peer-reviewed journals in top-level subject fields: life sciences, social sciences, physical sciences and health sciences. All journals covered in the Scopus database are reviewed each year to ensure high standards are maintained.

I have pasted below, for your information, the relevant email from Elsevier in Amsterdam:

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Note that our continued coverage depends on maintaining our commitment to the highest possible publishing standards. Now that contributions are going to be indexed, I am confident that the Journal of Plastination will attract more high-quality submissions from all round the world, reflecting the significance of plastination in research and education, and the truly global reach of the technology.

Philip J. Addis, MSc, FAS, FIBMS, SFHEA
In this issue, we present two papers discussing aspects of education, a paper on the bacteriological safety of plastinates, and two papers on alternative techniques of tissue preservation from institutions in countries where access to the necessary resources for *bona fide* plastination is likely to be challenging.

With best wishes,

Philip J Adds
Editor-in-Chief
References

Dental Students’ and Residents’ Opinions and Performance of Anatomy Learning via Cadavers or Plastinated Specimens

ABSTRACT:
For centuries, cadavers have been the traditional model of teaching gross anatomy. However, with the large time investment and high cost of maintenance associated with cadavers, studying anatomy via plastinated specimens has become increasingly attractive. Plastination is a novel technique for preservation of the human body by replacing water content with polymers, creating specimens that are dry, odorless, durable, and nontoxic. In 2016, The University of Texas Health Science Center at Houston School of Dentistry (UTSD) underwent a significant curriculum reform by replacing cadaveric specimens with plastinated prosections. Objectives: The aim of this study was to investigate our dental students’ and residents’ perceptions of learning anatomy from cadavers or plastinated specimens, and to determine if student performance in anatomy lab exams have changed since this reform. Methods: A survey was administered to dental students and residents who studied anatomy via cadavers and/or plastinated specimens. Lab exam scores from the past six years were compared in these two models of anatomy instruction. Results: More than half of students in all cohorts believed that plastinated prosections can effectively replace the need for dissection. ANOVA analysis revealed that the switch from cadavers to plastinated specimens had a significant improvement of lab exam scores. Conclusions: At UTSD, the shift in learning anatomy from cadavers to plastinated specimens increased student satisfaction with anatomy instruction and improved student performance in the course.

KEY WORDS: anatomy; cadavers; prosections; dissections; plastination

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Introduction
Anatomy is one of the most important and clinically relevant curricular necessities in dental and medical education. Historically, dissection and didactic lectures were its sole pedagogy (Sugand et al., 2010). Over the past few decades, anatomy education has undergone significant changes in order to meet the demands and evolution of curriculum design (Drake 1998; Drake et al., 2009; Pyle 2012). Despite many anatomists who still favor the use of dissection over other teaching tools, there has been on-going debate whether or not cadaveric dissections is still suitable in anatomy education (Patel and Moxham, 2006; Korf et al., 2008; Estai and Bunt, 2016). For example, in place of cadaveric dissections, institutions across North America and Europe have implemented prosected (already-dissected) cadavers along with other teaching modalities (e.g., computer-based learning) in their anatomy curricula. As a result, time required for dissection from both students and faculty has dramatically reduced (Reidenberg and Laitman, 2002; Estai and Bunt, 2016; Rizzolo et al., 2010). In addition, the maintenance of cadavers is associated with high costs such as preservation fluid, ventilation equipment, and lab space (Sugand et al., 2010; Rizzolo et al., 2010; Estai and Bunt, 2016). One particular challenge many dental and medical education programs often face is finding time in their curricula for new content in other courses, while upholding the numerous hours typically allocated to a traditional anatomy course (Rowland and Joy, 2015; Estai and Bunt, 2016). According to the American Dental
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Association (ADA), anatomy instruction in lecture and lab takes up nearly twice the amount of time compared to other disciplines in the biomedical sciences in dental education (Baker et al., 2013).

In 2016, The University of Texas Health Science Center at Houston School of Dentistry (UTSD) underwent a significant reform in their Head and Neck anatomy curriculum by implementing the use of plastinated prosections in place of cadaveric specimens. Plastination is a novel technique for preservation of the human body by replacing water content with polymers. As a result, these specimens are dry, odorless, durable, and nontoxic, which allows for easy storage and handling (Bickley et al., 1981; von Hagens et al., 1987). This reform eliminates the time needed for dissection, including cleanup and maintenance of specimens, and therefore reduces the many hours required for students and faculty to spend in the gross anatomy lab. Previous studies report that students believed plastinated specimens to be very useful during their anatomy coursework (Latorre et al., 2007; Fruhstorfer et al., 2011; Baker et al., 2013). For example, students from Cambridge University felt that the plastinated specimens allowed them to see certain details (i.e., nerves) that were often more difficult to identify in their own dissections (Latorre et al., 2016). Students at Warwick Medical School reported that plastinated prosections were “very useful” and provided opportunities for students to learn anatomy in a short period of time (Fruhstorfer et al., 2011). The New York University College of Dentistry (NYUCD) was the first reported institution in the United States to use plastinated specimens exclusively as an educational model in their anatomy curriculum. Since their switch from cadavers to plastinated prosections in 2005, NYUCD reported improvement in student satisfaction of their anatomy course as well as improvement in board scores (Baker et al., 2013).

Although the use of plastinated specimens has been fairly well received by medical institutions nationally and internationally, currently, there are no reports from other dental schools in the United States as to the measurable outcome of student performance in lab exams for cohorts who studied anatomy via plastinated specimens versus cadavers. The purpose of this study was to investigate dental students’ and residents’ opinions in regards to the change in UTSD’s anatomy curriculum from cadaveric dissections to plastinated prosections, and to determine if student performances in lab practical exams have significantly improved since this change.

**Materials and Methods**

This study took place during the 2017-2018 academic year. A survey was administered to 2nd, 3rd, and 4th year dental students from the UTSD graduating classes of 2018-2020 who took anatomy during their first year of dental school. The dental class of 2018 (4th year students) was the last cohort to have studied anatomy via cadavers, whereas the dental classes of 2019 and 2020 (2nd and 3rd year students) are the first two cohorts to have studied anatomy via plastinated specimens. Dental residents were also surveyed, because they studied anatomy via cadavers at their respective dental schools and plastination during residency at UTSD. The survey contained items asking whether or not students had previous educational experience with cadavers, students’ views on learning anatomy via cadaveric dissection or plastinated specimen, and their general experience in the anatomy course. Dental students and residents filled out the anonymous digital survey administered through Qualtrics. The survey was approved by the University Institutional Review Board (IRB).

Using a Likert scale (with answer choices: agree, neutral and disagree), dental students and residents responded to the following statements:

1. Have you had previous experience with cadaver dissection prior to UTSD?
2. Dissection is an essential part of human anatomy coursework.
3. I prefer the work of uncovering different structures during dissection.
4. I prefer to learn anatomy from cadavers already dissected.
5. I could easily identify important structures on a cadaveric specimen.
6. I could easily identify important structures on a plastinated specimen.
7. I believe plastinated prosections can effectively replace the need for dissection.
8. The amount of time in lab was sufficient for learning the material.

9. I would have preferred to learn head and neck anatomy only through textbooks and computer software.

In the survey, students and residents answered questions that pertained to their cohort. For example, only students who studied anatomy via plastination answered statement #6, whereas only the class of 2018 and residents as well as any students with prior dissection experience answered statement #5.

This study also gathered data from lab exam grades from the past six years. Specifically, lab practical scores from the dental graduating classes of 2016-2021 were assessed in order to compare performances between those who have studied anatomy via cadavers vs. the plastinated specimen. The dental graduating classes of 2016-2018 studied anatomy via cadaveric dissections whereas the classes of 2019-2021 learned anatomy using the plastinated prosections. All statistical analyses were performed using R statistical software (R Core Team 2017).

Results

One hundred and thirty-five dental students (N= 43, 33, and 59 students, respectively, from the graduating classes of 2018-2020) responded to the survey. There were approximately 100 dental students enrolled in each class, giving an overall response rate of 45%. Out of 40 residents in the graduate anatomy course, 10 responded to the survey. At UTSD, the dental class of 2018 learned anatomy from cadaveric dissections, whereas the classes of 2019 and 2020 were the first two cohorts to learn anatomy from the plastinated prosections. Residents enrolled in the Advanced Head and Neck anatomy graduate course learned anatomy via the plastinated prosections.

When asked if students had previous experience with cadaver dissections, only 15% of students in the classes of 2018 and 2020 had human dissection experience prior to attending UTSD. However, for an unknown reason, 40% of students from the class of 2019 had previous human dissection experience. All resident respondents studied anatomy via cadavers prior to residency.

At least half of respondents from all cohorts believed that dissection is an essential part of learning human anatomy (Fig. 1). Cohorts who learned anatomy by cadaver dissection were more likely to agree that dissection is essential to learning anatomy. About 60% of students from the graduating classes of 2018 and 2019, and residents, had this classical view of anatomy education. In the graduating class of 2020, however, 49% of students believed dissection was important to learn anatomy. More students in this cohort who might have viewed dissection as essential had they had dissection experience were swayed to answer neutral because they had education exclusively with plastination. Even though half or more of each cohort viewed dissection as essential to learning human anatomy, approximately a third or less of respondents from each cohort actually preferred doing cadaveric dissection (Fig. 2). Specifically, only 30% of residents and 40% of students from the graduating class of 2018 preferred dissection, whereas less than 20% of dental students from the graduating classes of 2019 and 2020 preferred dissection. The graduating classes of 2019 and 2020 had the most “neutral” responses (about 30%), which may have been due to their lack of experience working with cadavers. If dissected for them, nearly two-thirds of respondents from each cohort were willing to learn anatomy from cadavers (Fig. 3). Interestingly, even through dental residents had experience in dissection and the hand skills of a trained dentist, 70% preferred to learn anatomy from prosected cadavers.

Figure 1. Cohorts who learned anatomy by cadaver dissection were more likely to agree that dissection is essential to learning anatomy.
Respondents were also surveyed on their confidence in identifying important anatomical structures on cadavers (Fig. 4) compared to plastinated specimens (Fig. 5). Because all residents, as well as some respondents from the graduating classes of 2019 and 2020, had human dissection experience prior to UTSD, they were also asked of their confidence in identifying structures on cadavers and the plastinated specimen. Of the three cohorts who had learned from plastinated specimen, at least 96% of respondents believed that they could easily identify structures from plastinated specimens. In contrast, only about one-third of respondents who had dissection experience believed they could easily identify structures on cadavers (23% from the classes of 2018 and 2019, 33% from the class of 2020, and 40% of residents). Lastly, when asked if respondents believed...
plastinated prosections can effectively replace the need for dissection (Fig. 6), 85%, 92%, and 70% of respondents from the classes of 2019, 2020, and residents (respectively) agreed with the statement. Only 51% of students from the class of 2018, who were without plastinated experience, believed dissection can be replaced by plastinated prosections. Dunn-Bonferroni (DB) post hoc analysis revealed 2018 < 2020: DB= -22.28, p<0.032).

When asked if the amount of time in lab was sufficient for learning anatomy (Fig. 7), over 90% of students from the graduating classes of 2019, 2020, and residents, agreed with the statement. In the graduating class of 2018 (the cadaver cohort), about 63% agreed with the statement. This is remarkable, as the cadaver dissection lab was double the duration of plastination labs. This indicates that those who disagree believed that dissections require more time to learn. Dunn-Bonferroni (DB) post hoc analysis revealed 2018< 2019: DB= -44.78, p<0.001 and 2018< 2020, DB= -34.18, p<0.001).

Interestingly, the commonality amongst all the cohorts is that over 96% of all respondents did not prefer to learn head and neck anatomy exclusively through textbooks and computer software. This indicates that anatomical specimens (whether dissection or prosection) is crucial for students to see and understand the structural relationships in anatomy.

Although this report revealed that more than half of all cohorts believed that plastinated prosections can effectively replace the need for dissection, students do recognize the advantages of dissection. For example, our survey also asked if the unique tactile feel of tissues on the specimens were helpful in learning and differentiating structures. There was a clear agreement among respondents from the class of 2018 who agreed (63%) that the unique tactile feel of tissues from the cadaver helped them learn. In contrast, less than 44% of students and dental residents who learned anatomy via the plastinated models agreed with this statement. In fact, the graduating classes of 2019, 2020, and dental residents who learned anatomy from the plastinated models had the highest percentage of responding neutral (34-40%). This may be because touching the plastinated specimens was discouraged in order to preserve their pristine condition. In addition, the tactility of plastinated models is rather homogenous, whereas when learning with cadavers, students can touch and squeeze (for example) nerves vs. arteries. These differences in textures can help students differentiate these structures. Our study also included comments from students on the pros and cons of learning anatomy from cadavers compared to the plastinated models. Here are some comments from the respondents:

- “I am glad I was able to learn anatomy on a cadaver to see variations of normal. But it was often very hard to find structures. I think learning from plastinated models and then transferring that general spatial knowledge to cadavers would be ideal.” - Class of 2018 Respondent
- “Most of the time we destroyed the tissues we were looking for, never got through removing all the fat from the area and left an [indistinguishable] mess..” - Class of 2018 Respondent
- “I prefer to learn anatomy on plastinated specimens. I believe having 2 or 3 days [during the semester] in the cadaver lab would have been beneficial to gain a tactile feel of the different tissues.” - Class of 2019 Respondent
- “The plastinated models also helped take away the stress and time factor that comes with dissecting cadavers and I’m very appreciative of that.” - Class of 2020 Respondent
- “…I believe plasticized models provided a much better and more detailed outline of the structures than what I could do with dissection, but the process of dissecting tissue provides an appreciation for location and layers of tissues that are less clear with the plastinated models.” - Dental Resident Respondent

![Figure 7. Over 90% of the class of 2019, 2020, and residents, believed that there was enough time in lab to learn anatomy from the plastinated specimens, compared to only about a 2/3rd of the class of 2018 (cadaveric cohort) (p<0.001).](image-url)
In addition to assessing students’ opinions and comments of their experiences in learning anatomy via cadavers or plastinated specimens, we compared laboratory exam scores amongst the cohorts to investigate if student performances have significantly improved since this change.

We compared student performances in anatomy lab exams within the past 6 years from the graduating dental classes of 2016 to 2021. The cohorts who studied anatomy via cadavers are from the graduating classes of 2016-2018 and those who studied anatomy via the plastinated specimens are from the graduating classes of 2019-2021. Four anatomy laboratory exams are administered in the Head and Neck Anatomy course. For each cohort, the class average for each anatomy laboratory exam was determined. Then an overall average of the class averages from the four exams was calculated, giving one laboratory exam score average for each cohort. The overall lab exam averages for the cohorts that studied anatomy via cadavers were 83%, 84%, and 83% from the graduating classes of 2016-2018, respectively. For the cohorts that studied anatomy via the plastinated specimens, the class averages were 90%, 88%, and 91% from the graduating classes of 2019-2021, respectively. This indicates vast improvement in lab exam performances since the implementation of the plastinated models in our anatomy curriculum.

Discussion

Following the switch of teaching anatomy from cadaveric dissections to plastinated prosections, our data revealed that student satisfaction and laboratory performance in the Head and Neck Anatomy laboratory curriculum have significantly improved.

At UTSD, Head and Neck Anatomy is a 16-week course offered to first year dental students. One-hour lectures are held twice a week with a 1.5-hour laboratory session following every lecture. Four laboratory exams are administered in the course. Prior to spring 2016, laboratory sessions consisted of cadaveric dissections. There were 20 groups consisting of 5-6 students per group with their assigned cadaver. Students spent approximately 6 hours per week working on their dissections. In spring of 2016, plastinated prosections replaced cadaveric dissections. The plastinated specimens were purchased from the Institute for Plastination in Heidelberg, Germany. Laboratory time was reduced by half in that each 3-hour lab session is divided into two 90 minute sessions with about 50 dental students assigned in each session. Within each session, students are divided into 4 groups consisting of 12-13 students per set of plastinated specimen group along with an anatomy instructor in each group. Students then divide themselves into pairs or groups of threes to discuss and identify structures.

Similar to NYUCD’s anatomy curriculum, frequent, low-stakes quizzing is an integral part of the course. Unlike previous laboratory sessions with cadavers, after each lab session with the plastinated models, students take an online quiz consisting of five questions relating to the anatomical structures discussed in lab that day. The practical exams, however, are similar to those given in the cadaver dissection course; structures are pinned and students must identify the structure by writing out the answer. These low-stakes quizzes not only encouraged attendance in lab, but also motivated students to spend their time in lab wisely learning and discussing the anatomical structures with their colleagues.

The use of plastinated prosections in studying anatomy is advantageous in terms of presenting detailed anatomy in a clear and efficient manner. Previously, students spent an average of 6-8 hours a week in the anatomy lab working on their dissection with some assistance.
from faculty and teaching assistants. In addition, students often attended lab outside of class time in order to finish their dissection or review structures from other cadaveric specimens. Because head and neck anatomy is one of the most complex and difficult areas to dissect, for novice disectors, it is difficult to do a quality dissection and preserve structures of interest. The plastinated prosections allow students to locate muscles, nerves, and vasculature without the added pressure of dissecting during a limited amount of class time. The dissections on the plastinated specimens are flawless and have allowed students to see structures and relationships that are often destroyed in a traditional lab setting where student do the dissections.

Although plastinated specimens are not widely used, there are numerous health professional schools that, similarly, utilize cadavers that are already dissected (prosected) to teach anatomy to students (Ashdown et al., 2013). Interestingly, a study performed by Williams et al. (2019) from the University of Mississippi Medical Center, compared the pedagogical approaches of whether prosection versus dissection was best in learning the human anatomy of the hand and foot. By comparing students' lab exam performances, they found that students who studied anatomy via prosected cadavers performed better than their classmates who studied anatomy via dissections. Nnodim et al. (1996) also investigated students' retention by comparing cohorts who learned anatomy through dissection versus prosected cadavers. Not only did prosected cadavers take up less time in their curriculum, students' anatomical retention 5 years after the course was comparable or slightly better than students who studied anatomy via dissections (Baker et al., 2013). Unlike cadavers, the advantage of the plastinated specimens is that they are odorless, durable, and easy to store. Critically, they save faculty many hours of dissection, as the prosection is done once by the supplier and saved for perpetuity. Therefore, the specimens are available not to only first-year dental students, but also to advanced students preparing for their boards, and residents enrolled in the Advanced Head and Neck anatomy course.

During the course of this study, we encountered several limitations. For example, not all respondents could directly compare cadaveric dissections to plastinated prosections in anatomy education in dental school. The only cohort that was able to do this was the residents. As a result, the dental students who have had exposure to either the cadaveric dissections or plastinated prosections may have answered the survey statements based on their limited to no experiences with other modalities. Ideally, we would like to have had participation from more residents in regards to their attitude about dissection and studying anatomy from plastination. Another limitation was that the overall improvement in anatomy lab grades could be due to fewer specimens for students to study. Previously, students were responsible for recognizing head and neck structures from 20 full-bodied cadavers that were variable in size, shape, anatomical anomalies, and quality of dissection. Our collection of plastinated specimens consists of four sets of 7 hemisected head and neck models, ranging from superficial to deep dissections. Therefore, it could be possible that students had an easier time navigating through the few pristine prosected specimens as opposed to deciphering through cadavers, in which structures are more fragile and are typically torn or missing.

In conclusion, a great majority of dental students and residents believed plastinated prosections can effectively replace instruction with dissection. Of interest to programs continuing with cadaveric instruction, we found that, if taught by cadaveric dissections, students prefer prosected specimens, saving them time and frustration with indiscernible structures. Further, student performance in anatomy laboratory examinations significantly improved since our change to studying anatomy via plastinated models. These facts could possibly ease the decision at schools to transition to teaching anatomy with plastinated specimens.

Acknowledgements

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Preservation of Internal Organs of Goat by an Alternative Method to Plastination

ABSTRACT:
Plastination is a process of long-term preservation of biological tissue. This process is gaining popularity for its benefits as a teaching and research tool in anatomy. The process is based on replacement of water and fat by forced impregnation, after replacing the water by an intermediate solvent, to produce hard, dry and odorless specimens. However, due to the specialized equipment and expensive chemicals, such as polymer, that are needed for plastination, we desired to simplify the process and embed the samples completely in paraffin wax. In this process, the water and fat were replaced by paraffin, yielding specimens that can be touched, that do not smell or decay, and that even retain most properties of the original sample. Various freshly-collected visceral organs of goat were used for preparing specimens. These organs were dissected out to expose different gross anatomical features. The specimens were fixed in 10% formalin, hardened in a deep freeze, dehydrated and dried in freeze dryer, impregnated with melted paraffin, cured, and then stored at room temperature for further use as educational tool. The prepared wax-impregnated specimens were clean, dry, odorless, durable, non-toxic, and can be handled by bare hands and do not require any special storage care. This method will strengthen the appearance, clarity of surface anatomy, and description of other parts, as well as practical demonstrations in undergraduate teaching, and enhance the anatomical museum collection. The anatomical accuracy and durability of these specimens make them powerful tools to accelerate knowledge acquisition, and strengthens diagnostic abilities for veterinary students utilizing a wider variety of learning strategies.

KEY WORDS: goat; internal organs; paraffin; plastination

Introduction
The animal cadaver and its organs are an integral part of learning veterinary anatomy in the DVM program. The specimens used in teaching may be fresh or preserved (Ameko et al., 2012). However, decay of fresh specimens in a short time is a serious problem, so the specimen must be preserved to remain intact for prolonged periods by traditional methods (Mohamed and John, 2018). Even today, the most common practice is that anatomical, pathological, and other biological specimens are preserved and stored in 10% formalin solution or in Keyserling solution for the purpose of display and future study (Fischer, 1905; Siddiqui et al., 1988; Kumar et al., 2005).

These solutions are toxic, allergenic, and possibly carcinogenic. Concentrations of formaldehyde above 0.1 ppm in air can irritate mucous membranes and cause watery eyes. Moreover, inhalation of formaldehyde at the same concentration may cause breathing difficulties, a burning sensation in the throat, headache, and may even lead to asthma. It is troublesome to handle the formalin-fixed animals for teaching and research purposes, and, after a long period of time the quality of the specimens can also deteriorate (de Jong and Henry, 2008). To overcome these problems, Dr. Gunther von Hagens, introduced a new technique, plastination, to the medical world (von Hagens, 1985, 1986).

Plastination is a process for the long-term preservation of biological tissues, with a wide variety of processes and developments. The process is based on the idea of replacing the tissue water by an intermediate solvent that is then replaced by the polymer, by forced impregnation, to produce hard, dry and odorless
specimens (Weiglein, 1997). In recent years, there has been a growing trend toward plastinated products (Jones and Whitaker, 2009). Plastination provides a highly useful method for study that is gaining increased popularity for its utility in anatomy teaching and research (Ravikumar, 2014).

However, due to the specialized equipment and expensive chemicals, such as polymer, that are needed for plastination, we desired to simplify the process and embed the samples completely in paraffin. In this process, the water and fat are replaced by paraffin, yielding specimens that can be touched, do not smell or decay, and even retain most properties of the original sample. The process described here is a promising and economical method for preserving specimens that is a viable alternative to formalin preservation (Dawson et al., 1990).

**Materials and Methods**

Experimental animals were collected from the local market. The animals were euthanized for the prevention of cruelty to animals. The fresh organs were removed from the euthanized goats for further processing.

**Specimen preparation**

For dissecting the animals, a median incision was made from the mandibular space (between the rami of the mandible) to the anus. The body trunks were opened to show the internal organs in situ. Then, the organs of the digestive system, respiratory system, and urogenital tract, as well as the heart, spleen, and brain were collected. The tubular and hollow organs were washed for 3-5 minutes and packed with cotton-gauze to preserve their proper shape.

**Fixation**

Formalin is a commonly-used fixative in embalming fluid to avert decomposition, and deactivate saprophytic bacteria, thus preventing putrefaction. For fixation, collected organs from different systems of the body were preserved in 10% formalin for one (1) week to ensure proper fixation (Fig. 1).

**Hardening**

The fixed samples were washed in running tap water overnight and then placed in a deep freeze until a smoky layer appeared on the surface of the specimens (Fig. 2).

**Dehydration and drying**

All the specimens prepared for paraffin-embedding were placed in the vacuum chamber of a freeze dryer (Fig. 3). The freeze dryer removes all ice and frozen solvents from the specimens through the process of sublimation. It also removes bound water molecules through the process of desorption. In the end, the specimens become light in weight.
Impregnation

Impregnation of the specimens was performed in a chamber containing melted paraffin (Fig. 4). For impregnation, the dehydrated specimens were immersed in melted paraffin in an oven. After two dips in melted paraffin (each dip consisted of 1 minute in 60°C melted paraffin), the specimens were kept at room temperature for hardening. Once the impregnation step was completed, the specimens were placed in a closed container containing silica gel desiccant.

Finishing and storage

The impregnated specimens were trimmed of excess unwanted solid paraffin from the edges of organs using a scalpel. Finally, the samples were stored in a plastic bag at room temperature.

Results

The internal or visceral organs (those of the digestive, respiratory, urinary, genital, cardiovascular, and nervous systems) of goat were impregnated by paraffin for use in practical anatomy demonstrations. After impregnation, the internal organs from the thoracic, abdominal, and pelvic cavities retained their original shape. These impregnated specimens (Figs. 5, 6, and 7) did not lose any aspects of their physical appearance, such as color, following the impregnation process. Their surfaces were dry and were able to be handled using bare hands. The prepared specimens could then be easily stored for a longer period of time without any preservatives.

Discussion

Importance of the plastination technique

The applications and advantages of the plastination technique have been widely reported in the fields of training, research, and education (Chandini, 2014). Its major advantages include the plastinates being dry, free of offensive odor, durable, and safely handled using bare hands (Timothy et al., 1990; Pashaei, 2010; Chaturvedi et al., 2014). These specimens do not appear artificial in any way and do not require any special care or conditions for storage. The importance of the plastination technique has been well described in anatomical education (de la Torre et al., 2004), being reported as a basic method of anatomical investigation. Plastination facilitates contact by anatomy students, and also reduces exposure to irritants, such as formalin, through inhalation during practicals. In anatomy practical classes, the samples used for teaching students are either fresh or preserved. When using fresh samples, it is necessary to buy a new animal each time, while on the other hand, unnecessary storage in formalin can pose health hazards. For a complete academic year, a number of animals are necessary for dissection purposes alongside formalin-preserved samples. Therefore, plastination is an economical alternative to the traditional method of anatomical sample preservation when teaching anatomy. In a study of an undergraduate anatomy course at Cambridge University, plastinated specimens were used alongside wet cadaver dissection in anatomy practical lessons (Latorre et al., 2016). The plastinated specimens occupied less space in the anatomy laboratory than the formalin-preserved ones.
which required containers. Also, the formalin needed to be changed regularly to prevent mold growth. Similarly, the plastination technique has commonly been used not only for anatomical specimens but also for pathological specimens in undergraduate education (Bickley et al., 1987(b); Ravi and Bhat, 2011).

Principles of plastination techniques
The three recognized methods of plastination are silicone plastination, sheet plastination with epoxy, and sheet plastination with polyester (Sargon and Tatar, 2014). Of these three techniques, silicone plastination is the most common, in which fresh or formalin-fixed samples can be plastinated. This method can be used for cadavers, organs, and tissue slices. Epoxy plastination is done only for sliced (2-5 mm thickness) biological specimens. Epoxy and polyester plastination utilize the same basic principles as silicone plastination, with four steps: fixation, dehydration and defatting, forced impregnation, and curing (Bickley et al., 1987(a)). For fixation, formalin solution is used in a concentration between 5% and 20%. Cryosubstitution is the method of choice for dehydration, in a series of -20° C acetone baths. Forced impregnation is performed in a vacuum chamber; the acetone-filled specimens are submerged in a bath of polymer, where the acetone in the specimen is replaced with the polymer of choice using the force of the increasing vacuum. After removal from the polymer bath, the specimens are placed in an airtight container. Initially, polymer oozes out from the surface of the specimens. After a few days, the specimens can be finally stored in a airtight container containing desiccant, after curing by gas or catalyst., The technique described here is a modification of the silicone plastination technique, to facilitate ease of use and economy. Dehydration is performed in a freeze dryer followed by drying. The impregnation step is performed in melted paraffin in an oven. Finally, the samples are stored in polybags with desiccant in a container.

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**Comparative Study of the Outcome of Forced Impregnation of Whole Brains at Cold Temperature, and an Alternative Diffusion/Impregnation Process**

**ABSTRACT:**
Plastination is a modern method of preservation of biological specimens, including human cadavers. This study elucidated how temperature might affect plastination, noting that there is sparse scientific literature on this technique, especially from Africa. It is also relevant to the feasibility of adapting and adopting the technique as a feasible and useful laboratory technique in developing countries, where technological advancement, finance, and socio-cultural factors are suspected to be strong determinants to this effect. The S10 plastination technique is usually done at cold temperature (-25° C), but this study investigated and compared the effects of plastinating at room temperature (~25° C). The four main stages of plastination were carried for the control group while the ‘diffusion’ principle was employed for Group B. The forced impregnation process is typically carried out under vacuum at cold temperature (-25° C) with the use of an additional, relatively costly, refrigerated impregnation chamber. Ten adult (n=10) human brains were randomly assigned to two groups (A and B), comprising 5 brains each. Forced impregnation of the Group A brains was performed at -25° C (cold temperature), and the ‘diffusion’ impregnation procedure was carried out for the Group B brains at 25° C (room temperature). The Group B brains required less time for draining compared to Group A. Both methods yielded brain plastinates with the basic features of plastination outcomes. The weights of the brains (g) were recorded at each stage of the process using the digital Sartorius ENTRIS 4202-1S balance. The volumes were also measured at each stage using Archimedes’ principles of fluid displacement in a calibrated glass jar (cm³). The room temperature specimens yielded better specimens in terms of relative weight loss, relative colour preservation, physical properties, and texture and preservation of surface features and brain surface topographies.

**KEY WORDS:** anatomy; brain; plastination; organ preservation; temperature; S10 technique

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**Introduction**

The word ‘embalming’ is often associated with the preservation and conservation of the human body or remains; however, conservation and preservation include other methods than the conventional process of embalming (Manzoli et al., 2011). Plastination is a modern method of whole body, or body part, preservation, whereby water and lipids in biological tissues are replaced by curable polymers (silicone, epoxy, or polyester), which are subsequently hardened, resulting in dry, odorless and durable specimen (Klaus et al., 2018). Plastination, simply put, is a process used in the study of the structure of bodies, to preserve parts or the whole body, yielding specimens that are durable, odorless, and lifelike. Polymers used in this process, and the class of polymer used determines the optical qualities (transparent or opaque), and mechanical properties (flexible or firm), of the impregnated specimen. The advantage of plastination over other preservation methods lies in the ease with which it is possible for the resins to move between the macroscopic and microscopic levels of the tissues (Sora and Genser-Strobl, 2005). Also, plastinated specimen are very important in cultural knowledge, education, research and other applied medical areas (Jones and Whitaker, 2009).
Plastination is therefore an unusual method of permanently preserving tissue in a life-like state, in which biological specimens are preserved by replacing the fluids of the body (fat and water) with synthetic materials. This method produces ‘plastic-like’ bodies or organs, which remain very lifelike, non-toxic, odorless, dry and durable and may be handled easily for examination (Singh et al., 2013). There are different types of plastination techniques which include the S10, E12, P35, and the P40 techniques (Anant and Madhavi, 2015). There are four basic stages involved in plastination: fixation, dehydration/defatting, forced impregnation, and curing (hardening) (von Hagens, 1979). The S10 plastination technique is not commonly used for the preservation of whole brains, however, it has been much used for whole-body, and body-part specimens, and it has shown positive properties, such as durability, longevity, non-toxicity, and life-like appearance.

It is important to emphasize the importance of plastination to medical education and how it can be used to mitigate the negative effects of resource constraints, especially in developing countries. This is because plastinates can last for many years and can be used by many generations of students. Additionally, they are life-like specimens that offer close-to-real life features, unlike models and drawings. Unfortunately, in Africa for instance, plastination has not really been established as a routine procedure in preservation, learning, and for producing teaching aids (Azu et al., 2013). The poor appreciation and understanding of the techniques, limited financial resources and facilities, and the difficulties in adapting the conditions required for the procedures might have limited its acceptance and applications in Africa. This is a major reason why this investigation is crucial to advancing this technique, and to appreciate how it might be adapted to various conditions and settings. It also enriches the available literature on the technique, thus providing more scientific and empirical literature on the technique. This is absolutely the best means of optimising its use.

The standard temperature for S10 plastination is at cold temperature (-25° C). This research, however, compared the effects of temperature variation on the results of the S10 plastination technique of the brain at cold temperature (-25° C), and a room temperature (25° C) ‘plastination’ technique.

Materials and Methods

The brain specimens: a total of 10 adult human brains \( [n=10] \) were used for this research work. The brains were procured from the Learning Resource Department (museum unit) of the National Postgraduate Medical College of Nigeria and were randomly grouped into two groups of five brains each, designated Group A and Group B.

Chemicals used: 10% formalin, tap water, distilled water, cold acetone, S10 resin (Biodur), S3 (Biodur), S6 (Biodur) and calcium chloride (CaCl2).

Equipment used: acetonometer, deep freezers, stainless steel drum, stainless steel basket, digital thermometer, conveyor pumps, Heidelberg plastination kettle, replacement glass plate, replacement lid sealer, separator for oil and solvent, Bennert manometer, digital manometer, vacuum lifting pad, mixing rod, vacuum adjustment valve, vacuum adjustment unit, vacuum pump, vacuum pump oil, vacuum tubing, gas curing chamber, membrane pump, stainless steel collecting tray, fan, air tubing, glass jar and power cord.

Experimental room housing facility: the laboratory procedures were carried out at the Plastination Laboratory, museum unit of the National Postgraduate Medical College of Nigeria, under standard conditions.

Plastination processes: the four basic processes involved in the plastination technique as prescribed by von Hagens (1979) were observed for Group A brains (Fig. 1).

Figure 1. Equipment, materials and brains being plastinated. Brain specimen at the start of plastination [A]; brains in plastination kettle [B]; bubble formation during plastination process [C]; The Bennert manometer showing pressure measurement [D]; the forced impregnation chamber [E]; brain samples undergoing gas curing [F].
**Fixation:** freshly excised brains were fixed at the time of harvesting, by perfusion and immersion in 10% formalin, for four weeks. To ensure proper fixation before the plastination process commenced, the brains were re-fixed (perfused and immersed) in 5% formalin again for 5 days to prevent autolysis, putrefaction, and to harden the brain tissue.

**Dehydration:** Absolute (100%) pure acetone was used throughout. Three changes of absolute (100%) acetone were used. All brain specimens in both groups were dehydrated by immersion in 100% acetone at -20°C. The ratio of brain specimen weight to volume of dehydration bath was 1:10 or more. All brain specimens were initially immersed in pure acetone for one week, and then transferred to two consecutive pure acetone baths for another two weeks. The total duration of dehydration was thus three weeks. The degree of brain tissue dehydration was monitored with an acetonometer on a daily basis. The dehydration was considered to be completed when the water content was below 1%.

**Degreasing:** Degreasing of brain specimens of both groups was carried out at room temperature in a bath of absolute (100%) acetone for two days.

**Forced impregnation:** Forced impregnation is the central and most important step in plastination.

**Forced impregnation at cold temperature (-25°C) (group A):** the S10 standard technique for forced impregnation was employed for group A, at -25°C. The group A brains were removed from the degreasing tank after two days, and the specimens, designated A1, A2, A3, A4, A5 were placed in the plastination kettle in a deep freeze at -25°C, containing silicone impregnation mixture of S10 and S3 (99:1 by volume) at -25°C. The brain specimens were impregnated under vacuum for three weeks until no further acetone bubbles could be observed, and the absolute pressure reached 5 mmHg.

**Diffusion of S10/S3 mixture at room temperature (25°C) (group B):** the group B brains (B1, B2, B3, B4, B5) were removed from the degreasing tank, and immersed in polymer mixture of S10+S3 (99:1 by volume) at room temperature. No vacuum or external force was employed. The plastination kettle was covered. Impregnation of the S10 + S3 mixture was by diffusion, which took 4 weeks. The process was completed when physical observation of the brains and the chamber were like the standard observations in the forced impregnation procedure - especially, disappearance of bubbles. A digital thermometer was attached to it, and the temperature readings of the room were recorded daily.

**Curing:** finally, after forced impregnation/immersion and diffusion, and the draining of excess silicone, all brain specimens of both group A and B were placed in the gas curing chamber for curing. A crosslinking curing agent, S6, was used to harden the infiltrated polymer on brain tissues. CaCl2 was used as a desiccant to absorb moisture. The curing of the brain specimens was considered complete following absence of excess polymer from the specimens.

**Weighing the specimens:** The brains were weighed at each stage of the process using a digital balance (Sartorius ENTRIS 4202-1S).

**Measurement of brain volume**
Similarly, the volumes of the brains were measured at each stage, using Archimedes’ principle of fluid displacement, in a calibrated glass jar.

**Results**

The following criteria were used to evaluate and compare the outcomes of the two groups of specimens:

1) Change in weight due to plastination processes (Figs. 2.1, 2.2)
2) Specimen shrinkage (Fig. 2.3)
3) Draining time
4) Morphology, general physical appearance and texture quality of impregnated specimens.
Draining time

After impregnation, the excess polymer was drained from the brain specimens and the specimens remained at room temperature until excess polymer was completely drained off (Table 1).

<table>
<thead>
<tr>
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<th>Cold temperature impregnation (Group A)</th>
<th>Room temperature immersion (Group B)</th>
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<tbody>
<tr>
<td>Draining time (hrs)</td>
<td>14.6 hours</td>
<td>4.5 hours</td>
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</table>

Table 1: Average time of draining excess polymer. Draining excess silicone after room temperature immersion took 4.5 hrs on average, which was 3.24 times faster than at cold temperature.

Quality of the brain plastinates:

The quality of brain specimens in each group was examined for color changes and morphological changes such as the prominence of gyri and sulci. Both cold-temperature and room-temperature impregnation techniques yielded brain specimens that were dry, durable, odorless and non-toxic. However, the Group B brains that were processed at room temperature had a better physical appearance by retaining better the original brain colors, better sulci and gyri prominence, and had undergone less shrinkage (Fig. 3).

Changes in Group B Brain Weights at various Stages of Plastination

Figure 2.2 Bar chart showing the changes in weight of the group B brains from the fixation stage to the gas curing stage. The weight of the brains reduced steadily across the stages without any rapid and drastic change in weights. There was only a relatively moderate change between the original fixed brain weight and the final plastinates (p>0.05).

Percentage Changes in Fresh and Plastinated Brain Volumes and Weights

Figure 2.3 Bar chart showing the percentage changes in the volume of the brain after plastination and the percentage changes in the weights of the brains after plastination in an attempt to compare the changes in volume and weights between the two groups. There was a relatively moderate change in the volume of the group B compared to A. Changes in brain weights and volumes were statistically significant (p<0.05).

Figure 3. Images showing morphological features of plastinated brains of group A at cold temperature (-25° C) and group B brains processed at room temperature (25° C). Physical appearance of the Group B brains retained the resemblance of the original brain features better than the Group A specimens; thus, the Group B specimens present a better plastination outcome based on physical appearance and presentation of brain morphological features.
Discussion

General observable changes
The present study investigated and compared the standard S10 cold-temperature technique of plastination with a room-temperature immersion process using human brain samples. Both yielded specimens that were dry, durable, odorless and non-toxic. There were observable variations in the outcomes based on the differences in temperature; it was this effect that was under investigation. There were general changes, such as reductions in the weight and volume, thus resulting in physical shrinkage, irrespective of temperature variation. Also, there were changes in the color of the plastinates. There were, then, observable changes in the outcome of the process, irrespective of temperature, and the final outcome is not an absolutely perfect representation of the original mass, volume and color. The results also provide insights into how this knowledge can help understanding and appreciating the original forms of plastinates. The quantification of proportional changes in morphological attributes might also be used as reliable parameters for evaluating the outcomes of plastination.

Changes attributable to temperature variations and treatments
The processed brain samples appeared to have changed color from the original fixed brain color to a brownish shade of this color as shown in Figure 3. Also, this brownish shade was darker for the brains plastinated at cold temperature, than for the brains processed at room temperature.

Generally, there was a decrease in weight of the brain specimens after each step of both procedures, which is in agreement with Ameko et al. (2013). The observed decrease in weight was most significant in brain specimens plastinated at cold temperature (-25°C) when compared to room temperature (25°C). This decrease in weight is attributable to the shrinkage experienced in each procedural step of plastination. Decrease in weight was most noticeable during impregnation. The difference in weight after impregnation of plastinated specimens at cold temperature compared to room temperature was 376 g to 599.20 g. The texture of the plastinated brains when felt after the plastination procedure has occurred, appeared to have become more turgid. All specimens (both cold-temperature and room-temperature) became turgid, but the brains processed at room temperature showed better surface clarity, with the anatomical surface markings on the brain clearly visible; when compared to the brain samples plastinated at cold temperature, where the surface markings were not very clear. This result is in agreement with Anant and Madhavi (2015).

The brains produced by both processes were odorless, life-like, and durable, which is in agreement with Wadood et al. (2001). According to Sora et al. (2015), silicone impregnation at room temperature is possible using Biodur silicone. Nelson (1990) and de Jong and Henry (2007), report that plastination of nervous tissue at room temperature using silicone might be challenging, especially with respect to degreasing; however, findings from this study have shown that whole brain specimens can be preserved via this novel S10 technique at room temperature, without the process being compromised by the challenge. Many scholars have recommended the use of the following plastination techniques: P35, P40, and P45, in the study of nervous tissue, while the S10 technique (the gold standard for plastination of anatomical specimens) is not considered ideal for nervous tissues like the brain (Tiedmann and von Hagens, 1982). However, we report here a modified S10 plastination technique at room temperature which is suitable for whole brain study.

It is therefore important to state that more experimentation could be done with the various techniques to further improve the outcomes of plastination, especially under different conditions. While this will enrich the wealth of literature on this technique, it might also help to adapt their uses to various conditions and various organs. It is also expected that organ-specific experimentation might help in identifying the best plastination techniques for different body tissues and organs.

Conclusion
It is evident from this study that the room-temperature S10 technique described here can be used for whole brain sample plastination, and can yield high-quality specimens, particular in terms of morphology, relative weights, texture, and color. This might also come with reduced cost implications, and reduced risk hazards due to the use of room temperature. Both processes, irrespective of the variations in temperature (cold or room), still yielded specimens that were life-like, durable, and odorless, but processing at room temperature yielded a better anatomical brain specimen. It is,
therefore, recommended that more research should be done to further the use of plastination as a normal routine for producing teaching aids, and as a means of preservation. Also, processing at room temperature appeared to be a better alternative to plastinating at cold temperature, which requires expensive facilities and power to sustain the required temperature; a factor that might make the procedure less feasible in the developing world.

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Method for Creating Interactive Plastinated Models of the Male and Female Pelvis for Medical Anatomy Education

ABSTRACT:
The purpose of this study was to develop a plastinated model of a male and female pelvis that could be manipulated to allow students to remove organs, blood vessels and nerves from the pelvis. The pelvis of one male (70 years old) and one female (75 years old, para 2), with no known pelvic surgery or disease, were dissected by removing the organs, major arterial trunks and sacral nerves individually. All of the soft tissue was removed from the bony pelvis in each, except for the muscles of the pelvic floor, obturator membrane, sacrotuberous ligaments and sacrospinous ligaments. The erectile tissues were also dissected and removed en bloc. The pelvic components were then plastinated to replace the tissue fluids with silicone. The resulting plastinated pelvic models accurately represent the anatomy of the male and female pelvis, with removable parts. The dissection and plastination technique require a skilled dissector, a plastination lab, and can be repeated as necessary to represent desired pelvic anatomy variability. The plastinated pelvic models also resulted in excellent scanned images that were then used to print 3D models.

KEY WORDS: anatomy; education; model; pelvis; plastination

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Introduction

Understanding the three-dimensional (3D) anatomy of the human body is a critical component of first-year medical education. Many clinical tasks and procedures require a firm understanding of spatial relationships between closely associated structures (Cottam, 1999; Garg et al., 2001). This is especially true for one of the more complex areas of the body, the pelvis. Pelvic issues, in general, make up a significant percentage of patients scheduling visits with their physicians. This is true in both males and females. It is estimated that 25% of women in the United States are affected by urinary incontinence, fecal incontinence and pelvic organ prolapse (Nygaard et al., 2008). In men, prostate cancer is the second most common cause of death (Halpern et al., 2003). It is important for medical students to acquire a very good understanding of pelvic anatomy to effectively treat pelvic conditions in their future patients with minimal disruption to nearby unaffected structures. Understanding the 3D anatomy of the pelvis is also essential for interpreting medical imaging.

Cadaveric dissection is a key teaching component in the anatomy laboratory at the University of Minnesota. This is where students have the opportunity to not only learn anatomy, but understand it through discovery. Dissection has withstood the test of time as an effective teaching tool because it allows students to discover the 3D relationships of the structures of the body through the use of multiple senses (Sugand et al., 2010; DeHoff et al., 2011). Dissection also exposes the wide variety of anatomical variation seen in the general (donor) population. However, when it comes to the pelvis, students are often frustrated with the dissection process because of the layering of structures and organizational complexity in this region. It is notoriously one of the most challenging dissections students face. In order to alleviate some of the pressures during the pelvic dissection laboratory, prosections performed by the anatomy faculty have become important teaching aids that students depend on for understanding this region of the body. However, the time-consuming dissections required to meet the demands of a 175-student class are short-lived, being removed from the laboratory and cremated at the end of each semester.
plastination, in which tissue fluid is replaced with a curable polymer (von Hagens, 1979a; 1979b; 1986), was considered as an option for preserving the carefully dissected pelvic specimens. However, the resulting plastinated model would significantly reduce the ability of students to mobilize structures to inspect surrounding anatomy. This dilemma led to the development of the dissection and plastination method described in this current report. The method described here allows for the creation of plastinated pelvic dissections that allow students to remove organs, blood vessels and nerves individually. Taking advantage of the flexibility of the model described here, it is also possible for students to approach pelvic anatomy through “syncretion,” a term coined by Miller (2000) for anatomical discovery by “putting things back together again.” To our knowledge, this is the first description of the development of a male and female plastinated pelvis model that allows students to “build a pelvis” by inserting organs, blood vessels and nerves into the pelvic cavity with the pelvic floor muscles intact.

Materials and Methods

Pelvic dissections were performed on one male and one female human cadaver. The cadavers were gratefully donated to the Anatomy Bequest Program, at the University of Minnesota. The cadavers were first embalmed with a solution of 70% isopropyl alcohol, 13.25% phenol, 8% sorbitol, 7.5% formaldehyde and 1.25% barquat MB-50 diluted in water (50:50). The female cadaver was 75 years old with a history of two live births. No pelvic surgeries or anomalies were noted. The body was prepared for dissection by isolating the pelvis. A horizontal cut was made through the body at the L3 vertebral level. The lower extremities were then sectioned horizontally through the upper thighs. The pelvic viscera were then dissected, with the urinary bladder, uterus, rectum, pelvic nerves and major arterial trunks removed separately. The erectile tissues of the external genitalia were then dissected and removed en bloc. Finally, the bony pelvis was cleaned of all soft tissues except for the pelvic floor muscles and major ligaments. The pelvic components were then plastinated. The plastination process employed is referred to as “room temperature plastination.” In contrast to the basic cold process, which combines a silicone polymer with a catalyst and chain extender to serve as the impregnation mixture (von Hagens, 1986), the room temperature method combines the silicone polymer with a cross-linker (Glover et al., 1998). This method produces a more stable impregnation-mix at room temperature compared to the cold method. The specific materials and methods used to prepare the plastinated pelvis models in our study are comparable to techniques previously described (Henry, 2007; Raoof, 2007). However, North Carolina products were used based solely on familiarity and availability.

Plastination Process

1. The male and female pelvic components were submerged in a water bath to remove excess preservative chemicals and lipids. The water bath was allowed to overrun with fresh water at a rate of roughly two liters per hour. The specimen was bathed for five days, with gentle agitation once per day to encourage thorough rinsing.

2. The parts were then submerged in a series of cold (~23°C) acetone baths to displace all cellular fluids, beginning with five baths of 98% acetone and ending with one final 100% acetone bath. Cold temperatures decrease tissue shrinkage during dehydration (DeJong and Henry, 2007). The specimen soaked for one week in each bath with gentle agitation every day to encourage fluid displacement. The fourth and fifth acetone baths were allowed to come to room temperature after five days to encourage defatting of the tissues, as adipose tissue does not properly plastinate. Acetone displacement is considered complete when acetone purity measured after one week of tissue soaking is ≥99% (measured by specific gravity acetonometer calibrated for 15°C).
3. The structures were then submerged in a silicone polymer bath (Silicones, Inc. NC-PR12), inside a stainless-steel vacuum chamber, and allowed to settle for 24 hours before placed in vacuum. The vacuum pressure was slowly decreased over five days until a gentle boil of solvent from the tissues was maintained. Rapid boiling of solvent results in poor silicone displacement and incomplete plastination (DeJong and Henry, 2007). Solvent boil continued for two weeks until pressure in the vacuum reached roughly <5 mmHG (measured by standard digital manometer). When silicone displacement was complete, a trickle valve was opened, and atmosphere slowly returned to the vacuum chamber over the course of 24 hours. Forced impregnation took place at room temperature (~23°C).

4. The specimens were then placed over a drip pan and allowed to drain excess silicone polymer for three days with moderate exposure to a heat lamp.

5. Catalyst curing chemical (Silicones, Inc. NC-t32) was applied to the dissections via spray bottle and gently brushed into the tissue surface with a common paint brush. The structures were then moved into a desiccant chamber to cure for one week. Excess silicone polymer was manicured from the specimens daily. Polymer curing occurred at room temperature (~23°C).

6. Cross-linker curing chemical (Silicones, Inc. NC-r22) was applied to the tissues via gas aerosolization inside of the desiccant chamber over a period of eight hours. The specimens were then allowed to settle in the desiccant chamber for three weeks without additional chemical application. Excess silicone polymer was manicured from the structures daily for the first additional week and every three days thereafter. Specimens were dry to the touch after two weeks, but remained in the desiccant chamber for two more weeks to avoid chemical precipitate from forming on the tissues.

Results

The resulting pelvic plastinate models included parts that could be placed within, or removed from, the pelvic cavity.

Eight Parts of Female Pelvic Model:

1. Bony pelvis along with the pelvic diaphragm (levator ani and coccygeus muscles), obturator membrane, sacrotuberous ligaments and sacrospinous ligaments (Fig. 1).

2. Erectile tissues of the external genitalia (Fig. 2).
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3. Urinary bladder, urethra and distal ends of the ureters (Fig. 3a).

4. Uterus, vagina and adnexal structures (Fig. 3b).

5. Rectum and anus (Fig. 3c).

6. Distal aorta, common iliac arteries and main trunks of the internal and external iliac arteries (Fig. 4a).

7&8. Left and right sacral nerves (Fig. 4b).

Figure 5 shows the fully assembled female plastinated pelvis.

Figure 3. Plastinated female pelvic organs, including anterior view of bladder (A), anterior view of uterus (B) and lateral view of rectum (C).

Figure 4. Anterior view of plastinated arterial branches (A) and sacral nerves (B).

Figure 5. Anterior view of assembled female pelvis plastinate.

Seven Parts of Male Pelvic Model:

1. Bony pelvis along with the pelvic diaphragm (levator ani and coccygeus muscles), obturator membrane, sacrotuberous ligaments and sacrospinous ligaments (Fig. 6).

2. Erectile tissues of the penis (Fig. 7).
3. Urinary bladder, ureters (distal ends), prostate gland, seminal vesicles and testes connected by vas deferens (Fig. 8a).

4. Rectum and anus (Fig. 8b).

5. Distal aorta, common iliac arteries and the main trunks of the internal and external iliac arteries (Fig. 9a).

6&7. Left and right sacral nerves (Fig. 9b).

Figure 10 shows the fully assembled male plastinated pelvis.

In order to maintain the natural shape and position of the various pelvic components during plastination, the various pelvic structures were pinned into position or suspended by wires at the start of plastination (Fig. 11) but were removed from the pelvic cavity after impregnation.

Although a formal experience survey was not administered, students have commented that the pelvic plastinate models “really helped” with the understanding of pelvic anatomy, was “a fun way to learn pelvic anatomy,” and provided for “immediate comprehension” of the organization of pelvic contents.
Discussion

To our knowledge, this is the first description of a process by which the male and female pelvis can be dissected and plastinated to allow organs, blood vessels and nerves to be removed individually, or placed into the pelvis to “build a pelvis.” Other types of models can be used to help teach pelvic anatomy. Plastic models have been used in anatomy courses for decades to help students understand the structure of the body. They may be sufficient for an introductory anatomy course, but tend to lack the detail, accuracy and interactive qualities that are desirable for more advanced courses such as medical anatomy. This is especially true for the pelvis. For example, the robustness of the levator ani muscle (the main muscle of the pelvic floor) is overly represented in most plastic models. In reality, the muscle is usually very thin and disrupted with regions of the connective tissue. In addition, plastic models lack the interactive nature desired by students. Many times, several organs are represented in a single mass, limiting a student’s spatial understanding. It is clear that a student’s spatial ability is an important predictor of success in learning anatomy (Garg et al., 2001).

There has also been a rise in the popularity of computer-generated 3D models of the pelvis. Computer models and animations of anatomical features are becoming increasingly attractive as a means to communicate complex spatial relationships effectively (Dev et al., 2002). Virtual models of the pelvis are typically produced from cross-sectional images (Bajka et al., 2004; Holubar et al., 2009; Sergovich et al., 2010; Wu et al., 2010; Sora et al., 2012; Kraima et al., 2013; Sora and Jilavu, 2013). Earlier studies questioned the efficacy of such models with helping students perform better on exams (Garg et al., 2002; Hariri et al., 2004) and suggested that they may actually handicap those students with poor spatial ability (Garg et al., 1999). However, more recent studies have shown that they are beneficial to anatomy students (Qayumi et al., 2004; Nicholson et al., 2006; Brown et al., 2012; Cui et al., 2017), which may be due to the much-improved quality of computer-generated modeling.

These virtual models, however, require a great amount of time and expertise to create. They must have the boundaries of each structure rendered slice by slice by an expert in anatomy and with proficiency using the software. The process, called “segmentation,” is the digital identification and labeling of structures of interest on individual two-dimensional (2D) slices. This process
must be completed in several planes for tortuous structures such as blood vessels. A major problem for segmentation arises from the separation of ligaments and connective tissue from bones and muscles, because structures merge directly into one another (Bajka et al., 2004). The definition of the borders of individual structures is left to the discretion of the software user. The resulting model is an interpretation of 2D sectional anatomy. Secondly, the final 3D model lacks realistic tissue texture. This is because the rough form of the digital model usually undergoes further processing, such as "smoothing" to become more presentable and portable (Sergovich et al., 2010). The smoothing process results in the loss of detail and surface texture.

The process described in our current report does not require expensive, high-tech equipment or software. The plastination process cost approximately $1400 to perform for both pelves. It does, however, require the skill of dissection and plastination capabilities. There is no "guess-work" or "interpretation" involved, but simply revealing the structures in their true form. All of the detail and surface textures of the structures are retained. The technique can be used to preserve unlimited variations of pelvic anatomy with the level of detailed limited only by the person performing the dissections. They can be left natural in color or painted to make structure identification easier. The plastinated models described in this report also work very well for creating 3D printed models, of which the plastination process is a critical step. Once plastinated, the pelvic models’ components hold their shape when being scanned and can be placed directly on the scanning table without special containment or ventilation. Once scanned, the image files are converted to a compatible format for 3D printing. The various components of the models can also be printed in different colors and planes for ease of identification (Fig. 12). If developing colored 3D prints is not feasible, the plastinates can be painted for easier identification.

While the development of innovative learning resources should be actively encouraged, their incorporation into medical education should include quantitative evidence supporting their efficacy at improving students’ knowledge and understanding. We plan on moving forward by determining the utility of our plastinated pelvic models by evaluating student performance in a measurable way.

Conclusions

The pelvis is a challenging region of the human body to conceptualize yet very important for medical students to understand. It is important for interpreting diagnostic imaging as well as for treating the myriad dysfunctions and diseases in the pelvis. The interactive pelvic plastinate models described in this report, with removable organs, blood vessels and nerves, should prove to be of great usefulness in this effort. Interaction with, and manipulation of, the model should improve students’ understanding of the spatial relationships in the male and female pelvis. This approach to producing interactive physical models of the pelvis are also ideal for scanning and 3D printing. The principles of the technique can be applied to virtually any region in the body when physical 3D models are desired.

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References


Are anatomical specimens plastinated using cold-temperature S10 silicone technique microbiologically safe?

ABSTRACT:
S10 silicone technique is the world’s most popular plastination technique. Specimens obtained in S10 plastination retain their shape and color while gaining the hardness and consistency of hard silicone plastic. However, the specimens remain those of tissues and organs, which means that they still constitute biological material susceptible to microbial colonization. Reports of plastinated specimens being infected with various microbial species have been published in the literature. With consideration to the above, this study consisted of swab cultures being collected from surfaces of various organ specimens which had been plastinated using the S10 technique five years earlier. Microbial assays were also performed for the surfaces of anatomical models and dissecting room surfaces frequently touched by the students. As a result, various microfloral species were detected on the dissecting room surfaces, anatomical models, and bone tissue specimens while no bacterial or fungal growth was observed on plastinated samples.

KEY WORDS: plastination; silicone; biosafety

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Introduction
During their Normal Anatomy classes, medical students spend most of their time in dissecting rooms. During these classes, while remaining in closed compartments, students come into contact with multiple microorganisms dwelling on surfaces that may be both man-made (table tops, trays, anatomical models), and biological (anatomical specimens, including plastinated specimens). In every room, particular surfaces provide specific conditions for the growth of specific microorganisms. These conditions depend on two factors, namely: i) the surface coating material; and ii) the source of microfloral growth (Davis et al., 2012). The literature contains numerous reports on the growth of microfloral species on the surfaces of silicone implants widely used in plastic surgery (Eerenstein et al., 1999; Price et al., 2005; Rodger et al., 2010). However, reports of infections on silicone surfaces of S10-plastinated anatomical specimens are very rare (Prinz et al., 1999). BiodurTM S10 plastination is a common plastination technique making use of polyalkyl siloxane (BiodurTM S10 MSDS, Nov. 1998) (Holladay et al., 2001; de Jong and Henry, 2007). At numerous centers, the first steps in plastination are usually made using the silicone technique, as it is relatively simple and associated with low risk of procedural errors (Asadi, 1998; Zhong et al., 2000). The technique was first described by Gunther von Hagens in 1985 (von Hagens, 1985). The main concept consists of the specimen being gradually dehydrated, and subsequently saturated with silicone. At our lab, silicone plastination has been carried out since 2014. Despite their excellent appearance and lack of unpleasant odors, plastinated specimens retain the
character of biological specimens, which may provide favorable conditions for potential microbial growth. Due to the rare reports on microfloral species being detected on specimens plastinated using the S10 technique, we decided to carry out a series of microbial assays to determine whether these plastinates are colonized by microfloral species and what species of microorganisms, if any, are present on their surface.

Materials and Methods
A total of 20 standard swab collection kits was used in the study.

The study team consisted of 4 individuals. Two individuals were responsible for preparation of surfaces for swab collection, the third person was responsible for swab collection while the fourth individual recorded the code and name of the sample.

The study was carried out according to aseptic principles:
- individuals involved in direct contact with the study samples wore sterile, disposable protection garments including caps and surgical masks;
- before study-related tasks, study team members washed their hands according to a surgical hand washing technique and put on sterile gloves. Microbial culture swabs were collected from different surfaces classified into 2 categories:
  1) Surfaces of specimens subjected to cold-temperature S10 silicone plastination technique in 2014;
  2) Surfaces of the practice room and anatomical models.

Swab culture samples were transferred to an analytical lab for culture and identification, using standard techniques. The results were analyzed and compared to data available in the literature.

Results
Microbial assays revealed the presence of Micrococcus species on the surfaces of silicone and plastic anatomical models as well as on the surface of the skull used by the students as a study aid, and Staphylococcus epidermidis on the entrance door handle, as well as Staphylococcus epidermidis and Micrococcus species on the tops of the tables used by the students. No growth was detected for swabs collected from one of the plastic anatomical models, a plastic tray used for handling anatomical preparation, and student chairs. No fungal species were cultured from any of the samples. No microorganisms were cultured from swabs collected from the surfaces of S10-plastinated specimens. The study results are illustrated in Table 1.

Discussion
It is well known that the risk of contamination is particularly high at early specimen preparation stages when the tissues are still fresh and the body fluids are liquid. Contamination may be avoided by means of appropriate prevention measures, careful cleansing and disinfection of working surfaces and instruments, as well as appropriate disposal of tissues remaining after the procedure (Smith and Holladay, 2001). Little information is available on the possibility of plastinated specimens being infected by microbial species after all plastination stages are completed and the specimens are released for educational purposes.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Bacterial microflora</th>
<th>Fungal microflora</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain, cross-section S10</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Placenta S10</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Bone tissue S10</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Lower arm muscles S10</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Myocardium, cross-section S10</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Pericardium S10</td>
<td>No growth</td>
<td>No growth</td>
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</tr>
<tr>
<td>Endocardium S10</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
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<tr>
<td>Small intestine S10</td>
<td>No growth</td>
<td>No growth</td>
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<tr>
<td>Kidney S10</td>
<td>No growth</td>
<td>No growth</td>
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<tr>
<td>Lung, cross-section S10</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Trachea, interior S10</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Plastic model (skull)</td>
<td>Micrococcus species</td>
<td>No growth</td>
<td>2 colonies (100%)</td>
</tr>
<tr>
<td>Plastic model (GIS cross-sections)</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Silicone model (intestinal phantom)</td>
<td>Micrococcus species</td>
<td>No growth</td>
<td>4 colonies (100%)</td>
</tr>
<tr>
<td>Door Handle</td>
<td>Staphylococcus epidermidis</td>
<td>No growth</td>
<td>2 colonies (100%)</td>
</tr>
<tr>
<td>Table tap</td>
<td>Staphylococcus epidermidis</td>
<td>Micrococcus species</td>
<td>2 colonies (40%) 3 colonies (60%)</td>
</tr>
<tr>
<td>Plastic tray</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
<tr>
<td>Dry bone (skull)</td>
<td>Micrococcus species</td>
<td>No growth</td>
<td>16 colonies (100%)</td>
</tr>
<tr>
<td>Chair</td>
<td>No growth</td>
<td>No growth</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Results for swab cultures collected from test surfaces
S10 plastination silicone: structure vs susceptibility to infection

Studies on the chemical activity used in S10 cold-temperature plastination technique suggest that the polyalkyl siloxane within Biodur S10 is likely to be a hydroxyl-terminated polydimethylsiloxane or very similar silicone monomer (Holladay et al., 2001). Polydimethylsiloxanes (PDMS) are macromolecular organosilicon polymers with -Si-O- bonding pattern repeated in the molecular chains. The polysiloxane structure is summarized using the formula -[R2Si-O]- where R is a methyl (alkyl) group; thus, the compounds are classified as alkyl siloxanes (Mojsiewicz-Pieńkowska and Łukasiak, 2003). Silicones, particularly methylsilicone rubbers, are used for production of biomedical materials such as breast implants (Dunn et al., 1992), nasal implants (Deva et al., 1998), ophthalmological implants (Teferra, 2017) and vocal cord implants (Echternach et al., 2008). Polydimethylsiloxanes were also reported as some of the polymer candidates for the low cost, mass production of bio-microelectromechanical system devices (Bio-MEMS) (Mata et al., 2005). Infections of silicone implant materials have been observed and reported in the literature (Wixtrom et al., 2012).

Microbial growth on plastinated specimen surfaces

In our study, no bacterial flora were detected on the surfaces of plastinated specimens. However, other authors have reported cases of fungal microflora growth observed on S10-plastinated specimens. Infections were manifested by the presence of numerous, rapidly growing, white, green, and black spots on the specimen surfaces. Similar features of fungal infections could even be observed on the wooden material of shelves used for specimen storage. Different fungal species were reported for different types of surfaces: Penicillium janthinellum was observed on kidney, cerebellum and brain stem specimens, Penicillium corylophilum was detected on abdominal sagittal section, stomach, and hand specimens; Aspergillus niger was detected on rotator cuff muscle specimens, Aspergillus flavus was detected on heart specimens, and Aspergillus fumigatus was detected on abdominal transverse section specimens. Notably, fungal flora was detected only within the superficial specimen layers. Careful analysis of deeper tissues revealed no presence of microbial cultures (Prinz et al., 1999).

Microfloral cultures on plastinated specimens: causes and prevention

Rapid increase in humidity is reported as the main cause behind plastinated specimens becoming infected with fungal microflora (Prinz et al., 1999). No precise guidelines regarding the humidity and temperature conditions for the storage of such specimens are available in the literature. At our department, plastinated specimens are stored in facilities at constant temperature of 21° C and humidity of 45%; the conditions are subject to continuous monitoring. Since no microbial growth could be observed after 5 years of storage on any of the plastinated specimens, the storage conditions can be considered optimal. In a similar manner, air-conditioned, low-humidity storage conditions have been recommended by other authors as means to prevent fungal contamination of specimens (Prinz et al., 1999). If, however, such a contamination occurs, detailed guidelines describing the procedure of eradicating the infection from the surfaces of plastinated specimens are available in the literature (Prinz et al., 1999).

In our opinion, the instruction to “store in a cool and dry place” is not enough to effectively prevent contamination of plastinates. Temperature and humidity in the storage rooms should be subject to regular monitoring.

Characteristics of microbial species detected on tested surfaces

Micrococcus
The Micrococcus species detected on the anatomical models comprise the natural microflora of skin and mucosal membranes of humans and other mammals (Carr and Kloos, 1977). Together with genera Staphylococcus and Planococcus, the Micrococcus species comprise the family of Micrococcaceae which belongs to a group of 17 Gram-positive cocci (Bergey and Holt, 1994). They are aerobic, non-spore-forming bacteria; some may present with cilia (Herbert et al., 1988). They grow in the temperature range of 25°-37° C. All strains are capable of growing in the presence of 5% NaCl while some are capable of growing even in the presence of 10-15% NaCl (Bergey and Holt, 1994). Micrococcus species may pose a threat to human health only when one’s immunity is impaired. Cases of bacteremia caused by Micrococcus species have been reported as complications of immunodeficiency in some patients (von Eiff et al., 1996).
Staphylococcus

Staphylococcus epidermidis is one of the leading species found in the microbiota of skin and mucosal membranes in humans (Scharschmidt and Fischbach, 2013). They belong to the group of coagulase-negative staphylococci (Becker et al., 2014). S. epidermidis are Gram-positive (Bojar and Holland, 2002). Commensal S. epidermidis are permanent skin residents throughout human life (Grice and Segre, 2011). In order to survive on the skin surface, S. epidermidis have developed a number of mechanisms to detect and defend against, or to bypass, the human immune system (Kocianova et al., 2005).

S. epidermidis actively supports the skin in its barrier function and complements the body’s innate immunity mechanisms. They produce a number of antimicrobial agents active against pathogenic bacteria (Janek et al., 2016). S. epidermidis may, however, also be responsible for hospital-acquired infections. The pathogenesis of these infections is related mainly to the formation of biofilms on the surfaces of biomaterials introduced into the patient’s body (Hidron et al., 2008). S. epidermidis infections develop mainly in immunodeficient patients, patients undergoing immunosuppressive treatment, prematurely born infants, human immunodeficiency virus (HIV)-infected patients, patients undergoing long hospitalization, and critically ill patients (Ghassemi et al., 2015).

The human body is known to provide habitats for different bacterial strains in different body compartments (Costello et al., 2009). When in the dissecting room, students come in contact with many surfaces, potentially leaving behind bacteria typically dwelling on the skin of their hands. When microorganisms are transferred from a human body onto a man-made surface, their presence on that surface is strongly dependent on the contact with humans (Davis et al., 2012). However, atypical strains may also be transferred from man-made surfaces into human systems (Ferier et al., 2010).

Considering the characteristics of the bacteria of Micrococcus species, one may conclude that their presence on the surfaces of training room equipment, bone specimens, and anatomical models is closely correlated with these surfaces coming into contact with human skin. Since the swab collections were taken immediately after completion of classes, and before the rooms were cleaned, the counts of bacteria present on the surfaces were high enough to be detected by the test method. In the case of S. epidermidis, the structure of the bacterial cell wall, consisting of multiple layers of peptidoglycan (murein) ensures high cell stability so that the bacteria are resistant against desiccation, osmotic shock, and mechanical factors (Bojar and Holland, 2002). Thus, they are capable of surviving for significant periods after being transferred from hands onto external surfaces, allowing us to detect their presence on the door handle and the table top. Other authors have reported on a similar mechanism responsible for transmission of various microfloral species to and from man-made surfaces in closed facilities. For example, Meadow et al. (2014) reported that numerous Lactobacillus strains typical for intestines and vagina were detected on chairs in the lecture rooms of the University of Oregon, USA. Streptococcus species typical for human skin and oral cavity, as well as some Streptococci observed in humans with certain pathological conditions were detected on lecture room desks. Bacteria typical for human skin were also detected on the room floor, in addition to other species which are typically present in soil rather than human bodies. Sphingomonas and Alicyclobacillus species were detected on lecture room walls (Meadow et al., 2014).

Other authors who studied the microflora present on the desktops at Connecticut schools, grades 7 to 12, observed an absolute prevalence of bacteria and fungi from the genera Streptococcus (≥37%) and Candida (≥38%), respectively (Kwan et al., 2018).

Microbial analysis of air within the Louvre Museum in Paris, revealed the presence of 103/104 Escherichia coli/Aspergillus fumigatus genome equivalents per m3 (Gaüzere et al., 2014).

Conclusion

As shown by the study results, no bacterial or fungal growth was observed on the surfaces of specimens plastinated using the S10 cold-temperature technique. Avoidance of microbial growth on the surfaces of plastinated specimens requires: i) strict compliance with the plastination protocol as described by von Hagens; and ii) continuous monitoring of temperature and humidity of the plastinate storage rooms. The analysis of microflora within the dissecting practice rooms revealed the presence of benign Micrococcus species and Staphylococcus epidermidis strains.
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References
