Plastination- Advanced Technique to Preserve Specimens in Medical and Dental Colleges

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ABSTRACT

In addition to its educational significance, this chapter highlights the practical advantages of plastinated specimens in medical and dental colleges. Plastination offers a cost-effective and safe alternative to traditional preservation methods, reducing the need for toxic fixatives and frequent maintenance. With their long-lasting properties, plastinated specimens provide a valuable resource for long-term research and histologic examination. Furthermore, the chapter discusses the limitations and challenges associated with plastination, including the technique's complexity and the need for specialized equipment and dedicated staff. Despite these challenges, plastination remains a transformative technique that continues to shape the future of anatomical teaching and research in medical and dental education.

Keywords – plastination; specimen preservation; transformative technique; teaching; research

I. INTRODUCTION

The study of gross specimens plays a vital role in learning anatomy and pathology as they provide valuable visual aids for understanding normal and diseased conditions. However, the natural process of decay poses challenges for morphological studies, teaching, and research. Biological specimens tend to shrink significantly when exposed to normal atmospheric conditions, making it essential to find effective preservation techniques.

The most common method of preservation involves using formalin-based fixatives, but this approach has drawbacks. Open wet preparations emit unpleasant odors and formalin vapors that can cause skin and eye irritation, discouraging students from handling them. Specimens preserved in glass jars or Perspex containers offer some benefits, but they are bulky, fragile, and require regular maintenance to prevent fluid clouding and loss of details. Moreover, the color preservation is poor, and spatial separation from the container surface causes parallax errors, making it difficult to identify features. Additionally, the health hazards associated with formalin limit the usefulness of these preservation methods.

In pursuit of a "real" or "ideal" specimen that is dry, odorless, durable, and safe to handle without protective equipment, researchers have explored various techniques. Whole specimen paraffinization and infiltration with high-molecular-weight polyethylene glycols have been attempted in the past, but they proved unsatisfactory due to specimen shrinkage, poor color preservation, and improper glycol impregnation.

Fortunately, plastination emerges as the most acceptable method of specimen preservation, meeting many desired criteria for an "ideal" specimen. Plastination yields specimens that are dry, odorless, and durable, and they do not pose health risks like formalin-preserved specimens. Plastinated specimens can be used in classrooms and laboratories without the need for protective equipment like gloves, making them more accessible for educational purposes.

Plastination presents a revolutionary advancement in specimen preservation, offering numerous advantages over traditional methods. With plastination, anatomists, pathologists, and students can access high-quality, durable, and safe specimens that enhance the learning experience and contribute to better understanding in the fields of anatomy and pathology. Plastinated specimens are individually superior to their counterparts, both aesthetically and in their demonstration of specific features. They are easier to interpret than conventional "pots," generating more interest among students to examine and study them. Plastinated specimens can be easily transported to classrooms and passed among students for better appreciation of features. Additionally, they serve as valuable spotters in undergraduate practical examinations.

Beyond educational use, plastinated specimens find applications in research. Whole organ plastination allows the study of anatomical variations, while luminal plastination aids in investigating the segmentation and luminal patterns of hollow organs and placenta. Sheet plastination provides researchers with cross-sectional images, offering detailed insights into anatomical structures.

Moreover, plastinated specimens have diverse uses and advantages. They are nontoxic, noninfectious, and do not emit fumes or fluids, ensuring safety during handling and storage. Plastination facilitates the preparation of unusual or historically important material for museum display, preserving specimens for future generations. It also extends to surgical replacements, where facial organs like the nose and ear can be plastinated for use as prosthetic replacements. In forensic applications, plastination can preserve tissue samples as evidence for criminal investigations.

Despite its benefits, plastination does have limitations and disadvantages. The process is technique-sensitive and time-consuming, requiring a dedicated staff for optimal results. Beginners may face challenges during the process, leading to specimen wastage. Plastination can be slightly more expensive and necessitates additional equipment compared to conventional laboratory methods. Furthermore, post-curing work such as trimming, polishing, coloring, and mounting is essential to obtain high-quality display specimens.

While plastination offers unparalleled advantages, it is important to acknowledge its limitations. Learning anatomy solely through plastinated specimens may compromise the tactile and emotional experience that wet cadavers provide. In oral pathology, the technique may be more suitable for larger specimens, limiting its scope in certain areas.

Plastination has revolutionized the field of anatomical preservation, becoming an invaluable tool for teaching, research, and other applications. Its remarkable properties, such as dryness, durability, and safety, have opened new avenues for anatomical studies. By addressing its limitations and maximizing its potential, plastination continues to enhance anatomical understanding and contribute to advancements in medical science.

II. PRINCIPLES OF PLASTINATION

The process of plastination involves a series of steps (**Figure 1**) designed to preserve biological specimens in a durable and lifelike state for anatomical and pathological studies. The central principle of plastination revolves around the replacement of water and lipids in the tissues with a plastic (curable polymer), resulting in specimens that maintain their original anatomical structures and properties.

A. Removal of Water and Lipids

The first step in plastination is the removal of water and lipids from the biological tissues. This process is crucial as it prevents decay and putrefaction, which could lead to the deterioration of the specimen over time. The removal of water and lipids is achieved through a series of dehydration and defatting techniques.

B. Polymer Impregnation

Once the tissues are dehydrated and defatted, they are ready for polymer impregnation. The selected polymer, which can be epoxy, silicone rubber, or polyester, is used to fill the voids left by the removed water and lipids. The polymer should have a low viscosity in its uncured state, making it easy to handle and ensuring thorough impregnation of the tissues.

C. Curing of the Polymer

After the tissues are impregnated with the polymer, the next step is the curing or hardening of the polymer. The curing process can vary depending on the type of polymer used. For example, epoxy specimens are cured by heat treatment at a specific temperature, while silicone rubber specimens may require the addition of an accelerator to speed up the curing process.

D. Finishing and Storage

Once the polymer is fully cured, the plastinated specimen is ready for finishing touches. Trimming, polishing, and coloring may be applied to enhance the specimen's visual appeal and highlight specific anatomical structures. Plastinated specimens can be stored for long periods without significant deterioration, allowing them to be used for educational and research purposes over time.

The choice of polymer is critical to the success of the plastination process. The selected polymer must possess specific desirable properties to ensure optimal results. These properties include:

A. Low Viscosity

The polymer should have the lowest possible viscosity in its uncured state. This characteristic allows for easy handling and penetration of the tissues during impregnation.

B. Refractive Index

The refractive index of the polymer should differ from that of the tissue, except when a transparent specimen is desired. This difference in refractive index ensures proper visualization of the anatomical structures.

C. Long Working Time

The resin activator mixture (base and catalyst) should have a long working time. This extended working time allows for thorough impregnation of the tissues before the polymer starts to harden.

D. No Inhibition of Curing

The presence of tissue should not inhibit the curing process of the polymer. Proper curing ensures the stability and durability of the plastinated specimen.

E. Appropriate Mechanical Properties

Once cured, the polymer should exhibit mechanical properties that resemble the natural state of the tissue. The polymer can be rubber-like or firm, depending on the desired simulation of the anatomical structure.

F. Affordability

Cost-effectiveness is a crucial factor in selecting the polymer for plastination. Affordable polymers make the plastination process more accessible and economically feasible.

By meeting these criteria, the chosen polymer can effectively facilitate the plastination process, resulting in high-quality, preserved specimens with accurate representations of the original anatomical structures. Plastination has revolutionized anatomical teaching and research, providing durable and informative specimens for educational purposes and advancing the understanding of human anatomy and pathology.

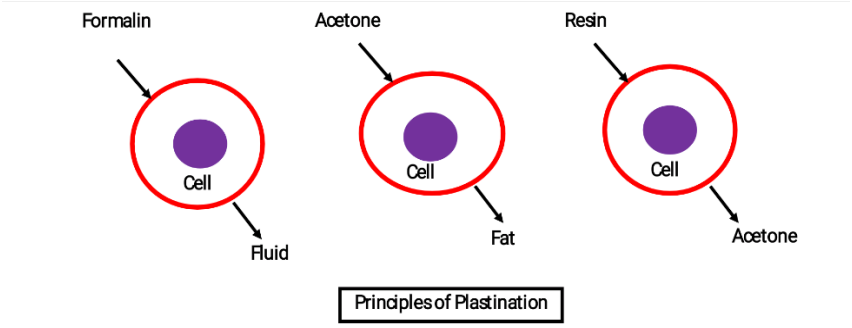

Figure 1: Principles of plastination

III. PROCESSING IN PLASTINATION

Plastination is a highly sophisticated technique used in anatomical and pathological studies to preserve biological specimens in a dry, durable, and odorless state. The process involves a series of well-defined steps, each crucial to ensuring the successful preservation of the specimens (**Figure 2**). Here is a detailed explanation of the four fundamental steps involved in the plastination process:

A. Fixation

Fixation is the initial and essential step in plastination. It involves treating the biological material with a fixative to prevent decay and enzymatic activity. Formalin-based solutions are commonly used as fixatives, with concentrations ranging from 5% to 20%. The choice of fixative depends on the size and nature of the specimen. For improved color preservation, a cold Kaiserling solution containing 5% formalin at 4°C is recommended.

During fixation, the specimen is immersed in the fixative solution for a specific period, typically taking 24 to 48 hours. However, larger specimens or those with higher lipid content may require longer fixation periods. Additionally, older museum specimens that have been stored in formalin for an extended period, up to 10 years, can still undergo plastination, provided that any interference from glycerol is eliminated through thorough rinsing.

B. Dehydration

After fixation, the next step in plastination is dehydration. Dehydration removes the water from the tissues, preventing decay and enabling them to be impregnated with the polymer. Cryosubstitution is the preferred method for dehydration, as it minimizes coloration and shrinkage compared to using an ethanol series.

In cryosubstitution, the fixed specimen is placed in acetone at 25°C, causing it to rapidly freeze while retaining its shape. Over time, the acetone replaces the water crystals within the tissues. It is essential to ensure that the volume of acetone used is at least ten times that of the specimen to ensure proper dehydration. The duration of this step varies depending on the size of the specimen. Usually, three changes of acetone are used, and the concentration of water should not exceed 1%.

In some cases where ethanol dehydration is used, an additional step is required. The final saturation of absolute alcohol is replaced with a suitable intermediary solvent, such as acetone or methylene chloride, to enhance dehydration. Acetone is preferred for its ability to enhance dehydration, while methylene chloride is immiscible with water and helps improve transparency in specimens intended for epoxy plastination.

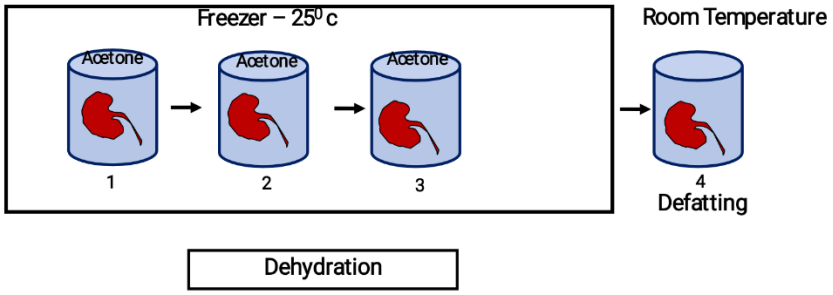

Figure 2: Steps involved in plastination

C. Defatting

Lipid-rich specimens require defatting to remove lipids from the tissues. Transfer to acetone at room temperature for a few hours achieves this, and additional defatting in methylene chloride is necessary for specimens intended for epoxy plastination to improve transparency.

D. Forced Impregnation

Forced impregnation is a critical step in plastination, where the dehydrated specimen is impregnated with the curable polymer. This process is performed in a vacuum chamber (**Figure 3**) to ensure thorough penetration of the polymer into the tissues down to their microscopic level. The removal of acetone, achieved through the vacuum, creates a vacuum inside the specimens, facilitating the penetration of the polymer.

During forced impregnation, the acetone-saturated specimen is submerged in a bath of liquid polymer. As the vacuum pressure is slowly decreased using a vacuum pump, the acetone changes from its liquid phase to a vapor phase and is aspirated by the pump. This extraction of acetone creates the vacuum within the specimen, enabling the polymer to infiltrate the tissue fully.

It is crucial to control the vacuum with a regulator and regularly monitor the process visually. Proper control ensures that the acetone is not removed too quickly, preventing premature collapse of the specimen before the more viscous polymer can fully infiltrate the tissue. The correct vacuum setting is indicated by continuous bubbles arising from the specimen surface

Once impregnation is complete, the specimen is removed from the polymer bath and allowed to drain.

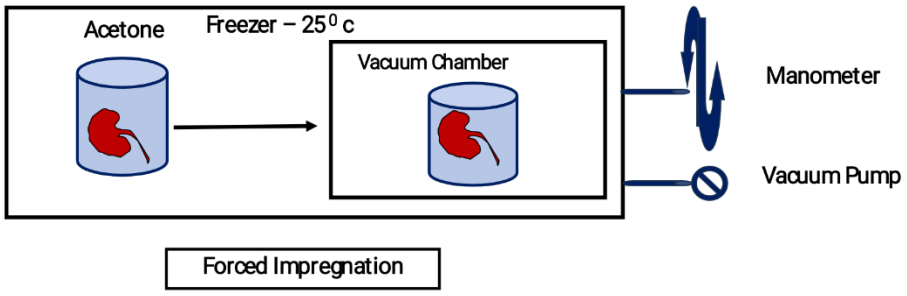

Figure 3: Vacuum pump mechanism during impregnation step

E. Curing

The final step in the plastination process is curing, where the polymer is hardened to its final state. The curing technique depends on the type of polymer used in the process.

For silicone specimens, the polymer and hardener mixture used in impregnation will eventually harden over a period of days to weeks. To speed up the curing process, an accelerator in the form of vapor or gas is used to promote cross-linking between the polymer chains (**Figures 4 and 5**). The specimen is placed in an airtight container above the volatile accelerator, with a desiccant present to remove any moisture that could cause whitish discoloration on the specimen surface. During curing, the polymer may initially expand and ooze out from the surface, requiring wiping until the surface hardens. After a few days, the specimen can be removed to a closed container with only desiccant to allow the accelerator already in the tissue to diffuse evenly and complete the curing process.

In the case of epoxy resin-impregnated specimens, curing is achieved through heat treatment at 45°C. This final curing in an oven takes a few days to complete. Specimens impregnated with polyester are cured through exposure to UV light for 45 minutes, followed by further curing in an oven at 45°C for a few days.

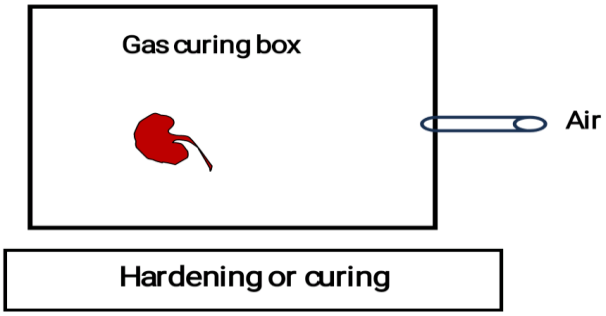

Figure 4: Hardening or curing

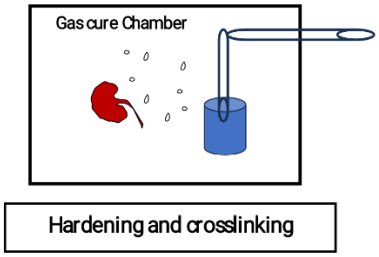

Figure 5: Hardening and crosslinking in gas cure chamber

IV. FINISHING AND STORAGE OF PLASTINATED SPECIMENS

After the plastination process is complete, the specimens undergo finishing steps to enhance their appearance and ensure longevity. These finishing procedures play a crucial role in transforming the plastinated tissues into visually appealing and informative specimens. Additionally, proper storage is essential to maintain the integrity and quality of the plastinated specimens. Below are the details of finishing and storage processes:

A. Finishing

1. Trimming

Plastinated specimens may have excess polymer or unwanted areas that need to be removed to achieve a clean and polished appearance. Trimming is performed using a scalpel or other appropriate cutting tools to shape the specimen to the desired form.

2. Cleaning

To maintain the clarity of the plastinated specimen's surface, cleaning is carried out using a dilute detergent or lubricant. This process helps remove any residual debris or impurities, ensuring a clear view of the anatomical structures.

3. Buffing

Buffing is a critical step in achieving a smooth and polished surface on the plastinated specimen. This process involves gently rubbing the surface with suitable materials to eliminate any imperfections and enhance its overall appearance.

4. Mounting

Plastinated specimens can be mounted on Perspex stands or other suitable display platforms. Mounting not only enhances the specimen's visibility but also provides a stable and secure way to showcase the anatomical structures.

B. Storage

1. Plastic Bags

Plastinated specimens can be conveniently stored in plastic bags at room temperature. The use of plastic bags provides a protective barrier against dust and moisture, helping to maintain the integrity of the specimen over time.

2. Controlled Environment

Storing plastinated specimens in a controlled environment is essential to ensure their longevity. It is best to keep them in a dry, cool place away from direct sunlight and extreme temperature fluctuations.

3. Documentation

Properly labeled and documented storage is vital for easy retrieval and reference in educational and research settings. Each specimen should be carefully labeled with relevant information, such as the anatomical structures represented, date of plastination, and any specific details that aid in identification.

4. Archival Storage

For rare or valuable plastinated specimens, archival storage may be considered. Archival storage involves special containers and preservation techniques that offer maximum protection and stability for long-term storage.

The plastination technique's finishing and storage processes ensure that the specimens remain visually appealing, durable, and informative for educational and scientific purposes. Plastinated specimens have revolutionized anatomical teaching and research by providing an advanced preservation method that allows for better understanding and appreciation of anatomical structures. With their remarkable qualities of being dry, durable, and visually captivating, plastinated specimens continue to be a valuable resource in the field of anatomy and beyond. Plastinated organs from different body systems are shown in **Figures 6, 7 and 8**.

V. PLASTINATED SPECIMENS AS RESEARCH MATERIALS

Beyond their value as teaching aids, plastinated specimens also offer significant benefits for research purposes in various fields. Here are some ways in which plastinated specimens serve as valuable research materials:

A. Study of Anatomical Variations

Plastinated whole organ specimens allow researchers to study anatomical variations in detail, providing a comprehensive understanding of structural diversity within the human body.

B. Research on Luminal Patterns

Luminal plastination enables researchers to investigate the segmentation of organs and the patterns of hollow organ lumens, shedding light on the intricacies of internal structures.

C. Cross-Sectional Studies

Sheet plastination is particularly useful for cross-sectional studies, providing researchers with detailed insights into the internal morphology of various tissues and organs.

D. Investigation of Pathological Conditions

Plastinated pathological specimens offer researchers a closer examination of diseased tissues, aiding in the study of specific pathological conditions and disease processes.

E. Detailed Visualization

Plastinated specimens provide researchers with precise and accurate visual representations of anatomical structures, allowing for detailed observation and analysis.

F. Incorporation into Research Studies

Plastinated specimens can be seamlessly integrated into research studies, offering researchers a tangible and accessible resource for conducting experiments and investigations.

G. Long-Term Storage

Plastination ensures the long-term preservation of specimens, making them available for research purposes even after many years, providing a valuable resource for longitudinal studies.

H. Comparative Studies

Plastinated specimens can be used in comparative studies, allowing researchers to examine anatomical differences and similarities between various species or individuals.

I. Advanced Imaging Techniques

Plastinated specimens can be used in conjunction with advanced imaging techniques, such as CT scans and MRI, to gain a comprehensive understanding of internal structures.

J. Contribution to Medical Advancements

The use of plastinated specimens in research contributes to medical advancements, facilitating discoveries and innovations in various medical disciplines.

Overall, plastinated specimens play a crucial role in advancing scientific research, providing researchers with valuable resources for investigation and contributing to the overall body of knowledge in anatomy, pathology, and related fields.

VI. OTHER USES/ADVANTAGES OF PLASTINATION

A. Non-Toxic and Non-Infectious

Plastinated specimens are non-toxic, non-infectious, and do not emit fumes or fluids, ensuring a safe and healthy environment in educational and research settings.

B. Teaching Aid

The hands-on aspect is very important for the learning process, especially for complex structures where an understanding of the three-dimensional organization is required and plastinated specimens are highly appreciated by students and faculty.

C. Museum Displays

Plastination allows the preparation of unusual or historically important materials for museum displays, preserving specimens for public education and appreciation.

D. Prosthetic Replacement

Tissue samples from surgically removed facial organs, such as the nose and ear, can be plastinated and used as their own prosthetic replacements, offering a unique application of the technique in medical practice.

E. Legal and Forensic Applications

Plastinated specimens can serve as evidence in legal and forensic investigations, providing tangible and reliable material for scientific analysis.

F. Ease of Storage

Plastinated specimens require minimal storage space and maintenance, allowing for efficient use of resources and more focus on expanding specimen collections.

VII. LIMITATIONS OF PLASTINATION

Despite the numerous advantages of plastination, it is essential to acknowledge some limitations and disadvantages associated with the technique:

A. Technique Sensitivity

Plastination is a technique-sensitive process, requiring precision and expertise. Beginners may experience a learning curve, leading to trial and error, and potential consumption or wastage of specimens.

B. Time-Consuming

Plastination is a time-consuming process, necessitating dedicated staff and careful planning to ensure successful preservation of specimens.

C. Cost and Equipment

Plastination can be slightly more expensive than conventional preservation methods and may require additional specialized equipment, making it less accessible in some settings.

D. Post-Curing Work

Plastinated specimens require post-curing work, such as trimming, polishing, coloring, and mounting, to achieve optimal display quality.

E. Limited Tactile and Emotional Experience

Plastination, while providing exceptional visual representations, may not fully replace the tactile and emotional experience provided by wet cadavers in anatomical learning.

F. Limited Application in Oral Pathology

Plastination may have limited application in oral pathology, as the technique is more suitable for larger specimens and may not be ideal for intricate oral structures.

VIII. CONCLUSION

Over all plastination is a cutting-edge technique that has revolutionized the preservation and utilization of biological specimens in anatomical teaching, research, and beyond. Its ability to create dry, durable, and visually appealing specimens offers numerous advantages, enhancing the learning experience for students and providing valuable resources for scientific investigation. However, it is essential to consider both the benefits and limitations of plastination in its application to various fields of study.

Figure 6: Lumina cast method of respiratory system

Figure 7: Sheet plastination of nervous system

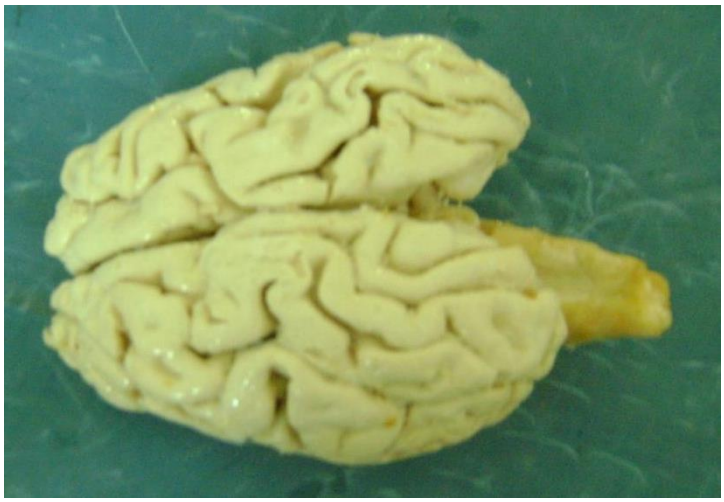

Figure 8: Whole organ plastination method of brain

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