

Plastination- A Boon to Medical Teaching & Research

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Abstract: *Plastination is a process of preservation of anatomical specimens by a novel method of forced impregnation with polymers such as silicone, epoxy or polyester resins which on curing yield dry, durable, lightweight and lifelike specimens. These specimens (plastinates) are useful for teaching of anatomy, pathology, radiology and surgery and are also useful for research. First developed by Gunther von Hagens in 1977, this technique is becoming increasingly popular and is a promising method for producing near ideal specimens for teaching and learning processes. This review elaborates the brief history, techniques, types, applications, advantages and disadvantages, and ethical issues of plastination.*

Keywords: Anatomy Specimens, Forced impregnation, Plastination, Plastinates, Polymers

1. Introduction

Fresh and well preserved specimens are a must in anatomy teaching. With the worldwide dearth of cadaver donations, availability of fresh specimens is drastically reducing. The available ones also decay in a few years time. In view of this scarcity of organs and tissues for studies, teaching and research, newer technique preserving the biological tissues for long duration was necessitated.

Different preservation techniques have been used since Egyptian times to preserve the bodies including mummification to cryonics which is preservation by freezing being in experimental stage. Presently bodies are preserved by embalming with formalin and other embalming fluids. Even these bodies decay in a few years.

Plastination has emerged as a ray of hope for near ideal preservation of biological specimens. It is the process of replacing water and lipids in biological tissues by polymers (such as silicone, polyester, epoxy) which harden subsequently to yield dry, durable and light weight specimens (plastinates) [1-3]. It is used in anatomy to preserve bodies or body parts. Professor Gunther Van Hagens, a German born Physician and Anatomist, invented the process in 1977 [1,4,5]. He preserved several human and animal bodies by plastination. After receiving patents from US government, Hagens established Institute for Plastination in 1993 and displayed the first exhibition of plastinated bodies, "Body world" at Japan in 1995 which drew over three million people [2]. Plastinated specimens are dry, durable, odourless, flexible, lifelike and aesthetically pleasing. These properties have made the plastinated specimens very popular. Though difficult and time consuming, it is most promising and stable method to preserve the specimens as an alternative to formalin preservation [2,6]. However, it appears that many anatomists have not yet realized the revolutionary significance of plastination for anatomical research [2].

2. Equipment and Chemicals Required

Apart from adequate space, ventilation, vigilance and manpower, the plastination requires deep freezers, vacuum chamber with pump, gas curing chamber, airtight containers and other materials as PVC pipes, glass rods, glass sheets, clamps etc. [7]. Consumables or chemicals required are curable polymers (such as silicone, polyester, epoxy, polypropylene, cyanoacrylates, araldite), acetone or ethanol (as dehydrating agents), hardeners (such as S3, gas cure S6). Many of these polymers, hardeners and curing agents are patented by Gunther's Biodur® Company and have to be imported. Use of indigenous polymers such as araldite is being experimented and is used successfully at some places. Care needs to be exercised as acetone vapours are highly inflammable and leakage has to be prevented.

3. Standard Plastination Technique

Plastination is the process of permanently preserving tissue in a 'life-like' state by replacing the body fluids (i.e. fat and water) with synthetic materials. The S 10 technique is the standard technique in plastination. It results in opaque, more or less flexible, and natural looking specimens [2]. The standard plastination process consists of four sequential steps viz. Fixation, Dehydration, Forced Impregnation in vacuum and Curing (hardening) [4,8,9]. The preparation of body or tissue for this process involves embalming with Kaiserling-I solution (200 ml formalin + 15 g potassium nitrate + 30 g potassium acetate + 1000 ml deionized water) [10].

a) Fixation is the process by which tissues and organs are preserved by chemicals which prevent autolysis and putrefaction, makes tissue hard and reduce their shrinkage. Commonly used fixative is 10% formalin. Fixation is generally done by immersing the dissected specimen in large volume of fixative (10 times volume of specimen). Special tissues are fixed by infusion or infiltration of fixative. Hollow organs (e.g. heart) are dilated during fixation. Glycerol spoils the specimens and needs to be avoided. One of the advanced

methods of fixation is known as freeze fixation which is done by mixture of acetone (95 parts) and formalin (5 parts) at -25 degree temperature over two weeks period. Fixation could be omitted if Epoxy Resins are used as they have their own fixing properties allowing better colour preservation [2].

b) Dehydration is done by exposure to dehydrating agents such as ethanol or acetone. Fixed specimen is immersed in serial solutions of absolute ethanol or acetone bath. Acetone is preferred over ethanol as the later causes the shrinkage of these tissues [9]. Acetone is ideal for plastination as it acts as a dehydrating, defatting and intermediary solvent, which readily mixes with different resins used for plastination. However, high cost of acetone is the limiting factor for its use. Under freezing conditions, the acetone draws out all the water and replaces it inside the cells. Over a period of 4-5 weeks tissue water is replaced by Acetone. Dehydration is complete when no more water bubbles out (concentration 1% or less). Methylene chloride can be used for degreasing [11]. As described earlier, the freeze fixation method which is done for fixation at freezing temperature, simultaneously serves the purpose of dehydration.

c) Forced impregnation is the most vital step in the plastination procedure and is patented by Hagens. It involves replacement of the intermediary solvent (acetone) occupying tissue spaces by curable polymer, achieved by vacuum. The fixed and dehydrated specimen is kept in the air tight chamber fitted with vacuum pump and containing the liquid polymer such as silicone rubber (S10), PEM 27, polyester or epoxy resin. Vacuum (5mmHg) applied to the chamber creates negative (suction) pressure which causes the acetone to vaporize out of specimen and draws polymer mixture into the specimen. This is indicated by the bubble formation at the top of solution in the tank. Acetone acts as intermediary solvent for polymers and boils readily under vacuum even at low temperature. Acetone can be recycled to overcome its high cost. Forced impregnation is performed at low temperature which prevents polymerization of polymer molecules facilitating reuse of polymer mixture. The speed of impregnation depends on the specimen and the class of polymer used. The larger and denser the specimen, slower impregnation should be done with a low viscosity resin [1,2,4]. Forced Impregnation is carried out at room temperature in case of Epoxy, Polyester, and at -25°C when using Silicone.

d) The plastic must then be cured, either with gas, heat, or UV light, in order to harden it. **Hardening** is the process where polymer molecules join to one another (polymerization) and cross link (curing) to form hardened specimen. The specimen impregnated with the polymer mixture reacts with hardener such as S3 wherein the polymerization (but no curing) occurs. The specimen is now tough but not hard. It is then subjected to curing agent such as gas S6 (acid vapour) which causes cross linking of polymer molecules to yield hardened specimen. This specimen is finally kept in plastic bag to complete the procedure. Curing is complete in several months. A specimen can be anything from a full human body to a small piece of an animal organ, and they are now known as "plastins" or "plastinates" [1,2,4].

Fast cure is the procedure where impregnated specimen is washed off of its excess polymer and directly subjected to curing vapour. It is less time consuming and ideal for neuronal tissue.

4. Modified Plastination Techniques

The basics of plastination techniques remain the same with a few changes and specifications for different specimens.

- **The Polyester P35/P40 procedure:**

This procedure is used to make semi transparent and firm brain slices. Samples are fixed for 4–6 weeks in a formaldehyde mixture. Use of P40 takes less time than P35 and differentiates gray and white matter outstandingly [8,12].

- **The Cor-Tech Room temperature procedure:**

Cor-Tech Products (by Dow Corning Corporation) allow room temperature impregnation with several different polymers, cross linker and catalyst combinations [13].

- **The Epoxy E 12 procedure:**

This technique is used preserving thin, transparent and firm slices of organ and body. Samples are prepared for fixation by deep freezing [1,2,4].

- **The Light-weight plastination:**

Steinke et al. (2008) described light-weight plastination using xylene along with silicone. The resulting plastinates were light-weight, dry and robust. The technique requires less resin making it cost-effective [14].

- **The Quickfix® Procedure:**

Mehra et al. (2003) used a novel method to plastinate cadaveric hearts. A solution comprising equal parts of Quickfix® (Wembley Laboratories) and amylacetate was used for impregnation. They conclude that this procedure is simple to perform, cost effective and is carried out at room temperature (37°C-40°C) [15].

- **Melamylne Procedure:**

Chandel et al. (2013) used Melamylne (polymer) and Xylene (intermediary volatile solvent) for plastination. Formalin fixed, acetone dehydrated specimens were degreased in xylene and finally impregnated with acid curing polymer melamylne with its hardener at room temperature to get dry, durable plastinates [16].

5. Types of Plastination

Depending upon the size, shape and nature of tissue, there are three types of plastination viz. Whole body/organ plastination, Luminal cast plastination and Sheet plastination [1,2,4]

- When **whole organ or a body** of an animal is to be plastinated, Silicon (S10) and polypropylene resins can be used by the same technique described above. Total structure and relationships of an organ/body are preserved.

- **Luminal cast plastination** is done for hollow organs like lungs, stomach, intestine, ventricles of brain, vascular pattern of heart and kidneys. Specimens are dilated/

inflated during fixation, dehydration and curing. Beautiful and precise bronchial pattern can be seen by this technique.

- **Sheet plastination** involves making of thin transparent or thick opaque sections of body or an organ. These sheets are portable and display cross sectional anatomy comparable to CT or MRI scan sections. Sheets can be made in various planes. Thin sections (1-2mm) correlates well with routine histology slides. Polymers such as epoxy (E12), polyester (P35) or polypropylene (araldite) resins can be used for making sheet plastinates.

6. Advantages and Applications of Plastination

Plastination is increasingly finding applications in the varying fields. The plastinated specimens are near ideal and are excellent for teaching gross anatomy, neuroanatomy (where routine specimens are delicate and sparse). Silicon casts of ventricular system of brain and tracheobronchial tree can be utilized for teaching. The anatomical structure and relations are well preserved and appear like fresh specimen [12]. The specimens are dry, durable, odourless, light weight, non-toxic and non-infectious. They are convenient to handle, store and transport. Thin sections of specimen made by sheet plastination preserve the microscopic structure of the tissues [12]. Plastinated specimens can also be used for both light microscopy and ultrastructural studies after deplastination with sodium methoxide [17]. Sheet plastination bridges the gap between histology, radiology and gross anatomy. Surgically removed tissues and pathological specimens can be preserved by plastination for teaching and research. Plastinated animal gastrointestinal tract and tracheobronchial tree can be utilized to teach endoscopic techniques [18]. Exhumed mummies, rare animals or archeological materials can be plastinated for museum display. The technique can preserve tissue sample to be used as medicolegal evidence [19].

7. Disadvantages of Plastination

Plastination procedure needs skills, is time consuming and needs quite a few trial and errors by beginner to attain the desired result. The procedure needs expensive and special equipments unavailable in the conventional laboratories. Majority of the polymers used in the procedure are patented and need to be imported. Acetone used as intermediary solvent is costly and inflammable needing extra precautions. Though the plastinated specimens are of high quality, they lack the feel and texture that is provided by wet cadavers [19].

8. Ethical Issues

Body Art exhibitions raised an ethical debate about display of human specimens. Only educational display is thought to be logical, while hidden aspects (e.g., art, entertainment, showmanship, personal and professional self-actualization reaping financial rewards) of plastination are being questioned [20]. Churches and religious groups protest believing that whole body plastinates are against the laws of nature and disrespect death. Concern over consent of bodies being used in the plastination process has arisen [21].

However, von Hagens have set up dedicated body donation program, however, maintains that "consent is not important for body parts." Anatomists and Forensic experts have to contribute to this debate accepting the educational aid provided by the technique.

9. Conclusion

Plastination has a great future in all fields of teaching and research. Natural appearance of the specimens makes the plastination a boon for anatomy learners. It is a good replacement for formalin as a preservative and there are no health hazards. The future research should target to develop fast and cost effective techniques of plastination.

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