Original Article

A Novel Museum Technique for Embedding Human Cadaveric Specimens Using Epoxy and Polyester Resin: A Comparative Study

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Abstract

Background: Plastination has become an alternative method of preservation that yields dry, non-toxic, non-odorous, and durable anatomical specimens that are highly effective compared with traditional formalin processing. Plastinated specimens can be embedded in clear resin, which increases their durability, handling, and educational value. Comparative studies evaluating different types of epoxy and polyester resins for embedding human cadaveric material remain limited. **Material and Methods:** A simple epoxy embedding method for human cadaveric specimens was successfully developed using two casting resins—epoxy and polyester—and the two resins were compared with respect to colour change, transparency, gross anatomical preservation, and feasibility for museum display. This experimental study was carried out on 40 formalin-fixed human cadaveric specimens obtained from embalmed cadavers. Twenty specimens were prepared using epoxy resin, and 20 specimens were prepared using isophthalic polyester resin. Each group included 12 whole-organ specimens and 8 sectional specimens. The plastination procedure comprised fixation, cold acetone dehydration, intermittent vacuum impregnation, and curing, followed by embedding in silicone moulds. **Results:** Pre- and post-impregnation measurements were taken to assess tissue shrinkage. The embedded specimens were evaluated for colour, transparency, anatomical details, air bubbles, and museum quality. **Conclusion:** Epoxy resin and polyester resin produced good results in terms of preservation of gross anatomical features; the specimens were dry, odourless, and durable. Tissue shrinkage remained low (approximately 4–5%) in both groups. Epoxy resin showed slightly lower shrinkage, better colour stability, and higher transparency, resulting in better visualization of anatomical structures than polyester resin. Polyester resin also yielded good museum specimens and was an inexpensive option. Both resins produced good results, but epoxy resin was more transparent and retained colour better, making it the preferred resin for anatomical museum display. The modified protocol described in this study is easy, inexpensive, and practical for routine use in an anatomy laboratory.

Keywords: Plastination, Embedding of cadaveric specimens, Epoxy resin, Polyester resin.

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Introduction

Neither the preservation of human cadaveric specimens nor anatomy instruction, research, or museum education can be carried out without adequate specimen preservation. The traditional method of preserving an anatomical specimen involves placing it in a container filled with formalin, which can be used repeatedly for the demonstration of normal and pathological anatomy. Formalin fixation prevents tissue decay, but it has many disadvantages, such as a strong smell, colour changes in the tissues, toxicity, maintenance difficulties, and loss of tissue quality over time. With recent advances in anatomical preservation, better, more effective, and more aesthetic alternatives are being sought. In 1977, Gunther von Hagens first developed a process called plastination, which involved replacing tissue water and lipids with curable polymers to produce specimens that are dry, odour-free, non-toxic, and durable. Among the most popular polymers are epoxy resins and polyester resins, which retain anatomical characteristics with minimal changes or shrinkage and can be easily maintained. Although the benefits of plastinated specimens are many, repeated handling during classroom or museum presentations can cause damage. Embedding plastinated specimens within transparent resin provides additional mechanical protection while improving durability, visualization, and ease of handling. Resin embedding also eliminates the need for preservative fluids and glass jars, thereby reducing maintenance costs and minimizing formalin exposure. Although resin embedding has been described for selected anatomical sections, comparative studies evaluating epoxy and polyester resins for embedding a wide variety of human cadaveric specimens remain limited. Establishing a simple, reproducible, and cost-effective protocol would benefit anatomy museums, particularly in resource-limited institutions. Therefore, the present study aimed to

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develop a novel museum technique for embedding plastinated human cadaveric specimens using epoxy and polyester resins and to compare both materials with respect to specimen shrinkage, colour retention, preservation of gross anatomical details, transparency, and overall suitability for long-term museum display.

Materials and Methods

This experimental study was conducted in the Department of Anatomy, Government Theni Medical College, Tamil Nadu, India. The study included 40 formalin-fixed human cadaveric specimens obtained from embalmed cadavers used for routine undergraduate dissection after obtaining institutional ethical approval.

The equipment used included a steel vacuum chamber with an electrically operated compressor motor, a negative-pressure gauge, a deep freezer, a hot-air oven, an acetonometer, an appropriately sized glass container with an airtight glass lid, a sleeved lid, a brain knife, a measuring jar, silicone moulds, and a steel tray.

The chemicals used were acetone, epoxy resin and its hardener, polyester resin and its hardener, and mould-release agents.

The specimens were randomly divided into two equal groups. Twenty specimens underwent plastination using epoxy resin, while the remaining 20 were plastinated using isophthalic polyester resin. Each group consisted of 12 whole-organ specimens (Group A) and 8 sectional specimens (Group B), representing various anatomical regions.

Plastination Procedure

Plastination was carried out in four sequential stages:

Fixation: Formalin-fixed specimens were washed thoroughly under running water to remove excess formalin and cleaned with dilute hydrogen peroxide to remove blood clots and residual soft tissue debris.

Cold dehydration: Specimens were dehydrated in graded acetone baths at −20°C to −25°C. Acetone concentration was monitored periodically using an acetonometer until it stabilized at 98–99%, indicating complete dehydration. The duration of dehydration depended on the size and thickness of the specimens.

Forced impregnation: Dehydrated specimens were immersed in resin-hardener mixtures (epoxy resin:hardener, 100:40; polyester resin:hardener, 100:3) and subjected to intermittent vacuum impregnation at room temperature using a vacuum chamber. Vacuum pressure was gradually increased until air bubbles ceased, indicating complete polymer impregnation.

Curing: Following impregnation, specimens were cured initially in a hot-air oven at 45–55°C for 12–24 hours and subsequently exposed to sunlight for 2–4 days to achieve complete polymerization.

Resin Embedding Technique: After plastination, specimens were embedded using appropriately sized silicone moulds. Resin and hardener were mixed according to the manufacturer's recommended proportions and poured in layers. A base layer was first allowed to partially polymerize before carefully positioning the plastinated specimen. Additional resin was then poured to ensure complete embedding while minimizing air bubble formation. After complete curing, the embedded specimens were removed from the moulds using mould-release agents to obtain transparent, durable museum models.

Figure 1: Stomach embedded in epoxy resin (a) and polyester resin (b)

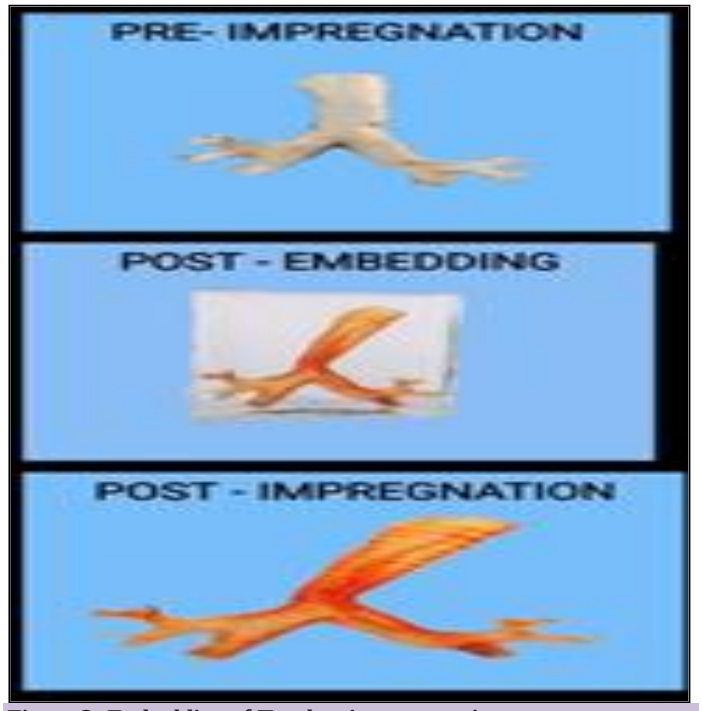

Figure 2: Embedding of Trachea in epoxy resin

Outcome Measures: Measurements of specimen dimensions were recorded before and after plastination using a Vernier caliper. Percentage shrinkage was calculated for each specimen. The embedded specimens were evaluated using the following parameters:

- Percentage of shrinkage
- Colour retention
- Preservation of gross anatomical details
- Transparency of the embedding medium
- Presence or absence of air bubbles
- Overall suitability for museum display

Statistical Analysis: The observations obtained from epoxy- and polyester-treated specimens were tabulated and compared descriptively. The performance of the two resins was assessed

based on shrinkage, colour preservation, anatomical clarity, transparency, and overall quality of the embedded specimens.

MEASUREMENT OF SPECIMENS PRE AND POST IMPREGNATION WITH RESINS - GROUP A

NAME OF THE SPECIMENS- GROUP A	Type of resin	BEFORE IMPREGNATION				AFTER IMPREGNATION				Difference	Shrinkage %
		L (cm)	B (cm)	T (cm)	Total (cu. cm)	L (cm)	B (cm)	T (cm)	Total (cu. cm)		
1.Kidney	epoxy	7.82	5.61	3.1	135.998	7.8	5.56	3.01	130.538	5.45994	4.01473
	polyester	7.98	5.59	3.06	136.501	7.92	5.49	3.01	130.877	5.62388	4.12003
2.Spleen	epoxy	6.93	5.45	4.25	160.516	6.82	5.43	4.15	153.685	6.83084	4.25554
	polyester	7.73	6.37	5.18	255.064	7.62	6.3	5.08	243.87	11.1932	4.38841
3.Pancreas	epoxy	14.68	4.32	2.11	133.811	14.63	4.28	2.05	128.364	5.44752	4.07105
	polyester	12.98	6.92	4.86	436.533	12.89	6.75	4.81	418.506	18.0269	4.12956
4.Heart	epoxy	10.96	9.56	4.63	485.12	10.76	9.46	4.55	463.143	21.9776	4.53034
	polyester	12.1	10.06	5.92	720.618	12.05	9.99	5.71	687.367	33.251	4.61423
5.Trachea	epoxy	12.56	3.54	2.1	93.371	12.46	3.49	2.06	89.5799	3.79112	4.06027
	polyester	11.49	3.25	2.08	77.6724	11.24	3.2	2.07	74.4538	3.21864	4.14387
6.Medial surface of brain	epoxy	12.67	7.58	2.1	201.681	12.56	7.57	2.03	193.011	8.67028	4.29901
	polyester	11.98	6.72	1.8	144.91	11.95	6.59	1.76	138.601	6.3092	4.35387
7.Submandibular gland	epoxy	4.26	3.21	2.12	28.9902	4.25	3.1	2.11	27.7993	1.1909	4.10795
	polyester	5.12	4.78	3.08	75.3787	5.07	4.72	3.02	72.2698	3.10888	4.12435
8.Testis	epoxy	4.21	3.52	2.51	37.1962	4.2	3.51	2.42	35.6756	1.52055	4.08792
	polyester	4.81	3.68	2.81	49.7392	4.77	3.62	2.76	47.658	2.08122	4.18427
9.Hyoid bone	epoxy	4.51	4.4	1.8	35.7192	4.48	4.37	1.75	34.2608	1.4584	4.08296
	polyester	3.55	2.98	1.2	12.6948	3.53	2.9	1.19	12.182	0.51277	4.03921
10.Cricoid cartilage	epoxy	2.8	3.56	2.86	28.5085	2.79	3.48	2.82	27.3799	1.12854	3.9586
	polyester	2.58	3.18	2.42	19.8546	2.56	3.11	2.39	19.0282	0.82642	4.16237
11.Thyroid gland	epoxy	4.5	3.36	1.1	16.632	4.48	3.35	1.06	15.9085	0.72352	4.35017
	polyester	5.96	4.63	1.78	49.1187	5.91	4.49	1.77	46.9685	2.1502	4.37756
12.Thyroid cartilage	epoxy	5.53	4.49	1.25	31.0371	5.46	4.47	1.22	29.7756	1.26156	4.06468
	polyester	5.88	4.67	1.68	46.1321	5.79	4.63	1.65	44.2327	1.89942	4.11735

MEASUREMENT OF SPECIMENS PRE AND POST IMPREGNATION WITH RESINS - GROUP B

NAME OF THE SPECIMENS IN GROUP B	Type of resin	BEFORE IMPREGNATION				AFTER IMPREGNATION				DIFFERENCE	Shrinkage %
		AD (cm)	TD (cm)	V.Ht (cm)	Total (cu. Cm	AD (cm)	TD (cm)	V.Ht (cm)	Total (cu. Cm)		
1. Stomach-interior	Epoxy	13.56	7.81	5.89	623.7722	13.35	7.77	5.8	601.6311	22.141104	3.54955
	Polyester	12.45	7.65	5.88	560.0259	12.42	7.64	5.71	541.815048	18.210852	3.251787
2.C.S of brain showing lateral ventricle	Epoxy	7.32	8.41	6.12	376.75454	7.25	8.37	6.01	364.701825	12.052719	3.199091
	Polyester	8.89	9.32	7.81	647.09599	8.86	9.23	7.69	628.871282	18.224706	2.816384
3.Section of cerebellum	Epoxy	4.31	3.52	2	30.3424	4.29	3.51	1.96	29.513484	0.828916	2.731874
	Polyester	4.56	3.61	2.21	36.380136	4.55	3.59	2.17	35.445865	0.934271	2.56808
4.Section through penis	Epoxy	2.92	3.65	2.18	23.23444	2.89	3.61	2.16	22.535064	0.699376	3.010083
	Polyester	2.89	3.57	2.08	21.459984	2.86	3.56	2.05	20.87228	0.587704	2.738604
5.Section through kidney	Epoxy	12.58	5.98	3.24	243.74002	12.54	5.88	3.21	236.689992	7.050024	2.892436
	Polyester	11.93	5.64	3.12	209.92982	11.89	5.59	3.08	204.712508	5.217316	2.485267
6. Inter-ventricular septum	Epoxy	3.25	5.36	2.56	44.5952	3.21	5.32	2.53	43.205316	1.389884	3.116667
	Polyester	3.36	4.67	2.08	32.637696	3.31	4.65	2.06	31.70649	0.931206	2.853161
7.Section through pons	Epoxy	2.43	2.53	1.8	11.06622	2.39	2.52	1.79	10.780812	0.285408	2.579092
	Polyester	2.39	2.18	1.69	8.805238	2.36	2.17	1.68	8.603616	0.201622	2.289796
8.T.S of brain showing lateral ventricle	Epoxy	12.42	11.82	1.2	176.16528	12.41	11.56	1.19	170.716924	5.448356	3.09
	Polyester	11.98	6.72	1.8	144.91008	11.96	6.62	1.78	140.931856	3.978224	2.745305

RESULTS

The plastination and embedding procedures were completed successfully in all specimens without specimen loss. Both techniques produced dry, odourless, durable museum specimens suitable for long-term display.

Shrinkage of plastinated specimens: Dimensional measurements obtained before and after plastination demonstrated only minimal shrinkage in both groups. The percentage of shrinkage ranged from approximately 4% and 5%, irrespective of the type of resin used. Epoxy resin showed marginally lower shrinkage than polyester resin; however, the difference was not substantial.

Whole-organ specimens exhibited slightly greater shrinkage than sectional specimens because of their larger size and tissue thickness.

Colour retention: The colour-preserving effect of the epoxy resin was fairly good and was comparable to that of the polyester resin. Epoxy resin showed relatively good colour retention, especially in highly vascular organs such as the heart, spleen, and kidney. Colour preservation was also satisfactory with polyester resin, although slight yellowing was observed in some specimens following complete curing.

Preservation of anatomical structures was satisfactory.

Gross anatomical features were found to be well preserved in both groups.

Anatomical structures and fine anatomical details, tissue planes, vascular markings, and sectional anatomy were clearly visible after embedding. Post-embedding preservation was excellent, with brain sections, renal sections, and cardiac specimens showing excellent structural clarity.

Transparency of embedded materials: The embedded specimens filled with epoxy resin were very transparent and deeper anatomical structures could be seen clearly.

Transparent specimens were also obtained from polyester resin although these sometimes were slightly less transparent during the polymerization process.

Air bubble formation: Occasional small air bubbles were observed during embedding with both resins. They could be successfully reduced by slow mixing of the resin, pouring in layers, and careful handling before complete curing.

Overall museum quality

Both embedding techniques produced durable museum models that were:

- Dry
- Odourless
- Easy to handle
- Resistant to physical damage
- Suitable for long-term room-temperature storage
- Free from formalin exposure during teaching

Epoxy resin produced superior aesthetic quality owing to better transparency, improved colour retention, and enhanced visualization of anatomical structures. Polyester resin remained a satisfactory and comparatively economical alternative for museum specimen preparation.

Table 1: Characteristics of specimens included in the study

Specimen type	Epoxy (n)	Polyester (n)
Whole organs	12	12
Sectional specimens	8	8
Total	20	20

Table 2: Comparison of epoxy and polyester resin

Parameter	Epoxy resin	Polyester resin
Shrinkage	Slightly lower	Slightly higher
Colour retention	Excellent	Good
Transparency	Excellent	Good
Anatomical detail	Excellent	Excellent
Air bubbles	Minimal	Minimal
Museum appearance	Excellent	Very good

Table 3: Advantages of the proposed embedding technique

Parameter	Observation
Formalin exposure	Eliminated during handling

Odour	None
Storage	Room temperature
Durability	Excellent
Maintenance	Minimal
Educational value	High

Discussion

Since its introduction by Gunther von Hagens, plastination has been one of the greatest developments in the preservation of anatomical specimens. Plastinated specimens have the advantage of being dry, odourless, durable, and non-toxic and can be easily handled with minimal maintenance compared with conventional formalin-preserved specimens. Such properties have increased the value of plastination for anatomy education, museum display, and surgical education. The technique of plastination and resin embedding in the present study produced 40 successful human cadaveric specimens, with plastination carried out using a modified protocol. The results showed that the plastination and embedding technique was successful, as all specimens retained their structural integrity and gross anatomical details. A main finding of this study was that tissue shrinkage after plastination was low, at around 4–5%. Shrinkage is an important factor in specimen quality and should be assessed for each specimen; excessive shrinkage can compromise anatomical relationships and reduce educational value. The use of cold acetone dehydration at −20°C to −25°C, combined with gradual intermittent vacuum impregnation, likely contributed to minimizing tissue shrinkage. The results are in line with those of previous plastination studies, which have reported less tissue distortion with low-temperature dehydration. In the present study, epoxy resin also resulted in somewhat lower shrinkage than polyester resin. The difference was not significant, but epoxy-treated samples consistently showed surface morphology and dimensional stability comparable to those of the original samples. This agrees with earlier reports of better dimensional stability of epoxy polymers due to their excellent penetration into biological tissues and lower polymer shrinkage during polymerization. Another significant factor in specimen quality is the ability to preserve colour, especially for museum exhibitions, where the appearance of anatomical parts is important for specimen recognition. Both resins preserved tissue colour well in the present study. The appearance of natural organs, however, was better preserved with epoxy resin than with polyester resin, which showed mild yellow discoloration after curing in some specimens. Previous studies have also shown that epoxy-based plastination provides better optical properties and colour stability. Both gross anatomical preservation and gross anatomical details remained excellent. Fine anatomical structures, tissue planes, vascular impressions, and sectional anatomy were well defined after embedding, particularly in brain sections.

The preservation of the renal sections and cardiac specimens was outstanding. The results further confirm the educational potential of plastinated material for undergraduate education, postgraduate training, and museum use as an educational demonstration. A significant advantage of the present investigation is the embedding of plastinated specimens in transparent blocks of resin. While plastination can create very durable specimens, some structures may be more fragile than others and could become damaged or broken during teaching if handled repeatedly. Embedding offers additional mechanical protection without sacrificing visibility. Transparent resin can also be used to examine deep structures from several angles without directly touching the specimen. Of the two embedding materials tested, epoxy resin provided greater transparency, allowing the anatomical structures to be better visualized than with polyester resin.

In museum specimens, the better optical clarity of epoxy resin increases their educational value and allows complex anatomical relationships to be demonstrated. For institutions with limited finances, however, polyester resin remains an economical choice. Another important advantage was the absence of formalin-related problems at the end of the plastination and embedding process. The embedded specimens were dry, did not require preservative solution, and had no odour. This significantly reduces the occupational risks associated with formaldehyde, a chemical known to irritate the mucous membranes and potentially cause long-term adverse health effects. The method thus provides a safer learning environment for students, teachers, and museum staff. The modified protocol employed in this study is also practically significant. Intermittent vacuum impregnation was successfully performed at room temperature using ordinary equipment rather than the sophisticated, temperature-controlled vacuum system of the original von Hagens technique. This modification substantially decreases the cost of plastination without sacrificing specimen quality and is feasible for many hospitals and medical colleges in developing countries.

Conclusion

The present study demonstrates that these plastinated specimens, after resin embedding, can be used to produce durable, dry, and anatomically accurate museum specimens. Both epoxy and polyester resins were found to produce acceptable transparency, but epoxy resin produced superior colour retention and specimen quality. This modified technique is simple, economical, and easily adaptable for routine use in anatomy departments. The use of this protocol could facilitate better museum preservation while minimizing formalin exposure and maintenance requirements.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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