DOI: 10.21088/ija.2320.0022.15226.4

Indian Journal of Anatomy
Volume 15, Number 2, May – August 2026

REVIEW ARTICLE

Bridging the Gap Between Dissection and Surgery: The Role of Soft Embalming in Medical Education

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HOW TO CITE THIS ARTICLE:

Madhavi Keole, Akash, Anita Fating. Bridging the gap between Dissection and Surgery – The role of soft Embalming in Medical Education. Ind Jr Anat. 2026; 15(2): 66-77.

ABSTRACT

Background: Cadavers are fundamental teaching tools that allow students and surgeons to study human structure in detail. The soft-fixation techniques have been developed to overcome the challenges while using formalin models and fresh-frozen cadavers. Soft embalming techniques were gradually developed in order to find a safer and economical alternative.

Aim: The present narrative review aims to explore the key differences between soft embalming techniques. To examine their growing role in anatomical education, and surgical skill development.

Methods: A literature search was performed using electronic databases including PubMed, Google Scholar, Scopus, Embase, Science Direct and Web of Science. Relevant articles published between 2000 and 2025 were identified and reviewed. The advantages, limitations and future prospects of various soft embalming techniques were critically reviewed.

Results: Cadavers preserved with Thiel's method have near normal tissue softness, natural organ colour. They can be used for training of ENT, cardiothoracic, and vascular surgery. Genelyn embalmed cadavers are better suited for laparoscopic and pelvic surgery training. N-vinyl-2-pyrrolidone (NVP) is particularly useful for neurosurgical training because of better preservation of neurological tissue.Soft-embalmed cadavers provide a platform for procedural rehearsals ranging from basic operative skills to microsurgical techniques. Soft-embalmed cadavers have emerged as versatile resources that support research and lifelong learning across modern medical sciences. Post-graduate students consistently report greater confidence and satisfaction when training on soft-embalmed models compared to other alternatives.

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➢ **Received:** 22-06-2026 ➢ **Accepted:** 20-07-2026

Limitations: Financial and infrastructure limitations narrow down widespread implementation. Prolonged preparation periods and the need of well trained staff should also be considered. There is need of standardized preservation protocols.

Conclusion: Soft embalming has transformed the study of anatomy by preserving structure with a life like feel to it. These techniques have not only benefitted undergraduate anatomy teaching but also postgraduate surgical training. Unlike formalin embalming, soft-embalmed cadavers allow students to learn anatomy in a clinically oriented pattern. Reforms in medical education, may lead to increasingly important role of soft embalmed cadavers for training. In future it may be possible to create increasingly sophisticated training environment to closely resemble real clinical practice. Increasing progress in embalming techniques ensures that these cadavers will remain indispensable tools for education in the years to come.

KEYWORDS

• Soft Embalming • Thiel Embalming • Cadaver Preservation • Anatomy Education • Surgical Simulation • Competency-Based Medical Education • Genelyn • Saturated Salt Solution Embalming • Soft-Fixed Cadavers • Surgical Training

INTRODUCTION

Anatomy and the Cadaver: An Enduring Partnership

Cadavers are fundamental teaching tools that allow medical students, anatomists, and surgeons to study human structure in detail.[1-4] Embalming has been used since ancient Egyptian times to preserve human remains.[5] Embalming prolongs the decay and facilitates the learning of three-dimensional and relative anatomy and structural variations.[3] The current working-time restrictions have negatively affected the hours surgical trainees spend in the operating theater.[6,7] As such, Simulation-Based medical education using cadavers for surgical skills practice has become essential for patient safety.[8]

The Formalin Era

Formalin has been used for over 150 years as a standard preservative. Formalin preserves tissue by cross-linking proteins to prevent decay.[2-4,7,9] However, there are some limitations of embalming with formalin. Formalin induces tissue rigidity and the loss of natural colour and elasticity.[7,10-12] This often makes it difficult to apply theoretical anatomical knowledge to realistic surgical practice.[1,4] The effects of formalin on health depend heavily on the method and level of exposure.[11,13-15] Acute exposure results in respiratory and dermal irritation.[14,16,17] Formaldehyde can bind directly with DNA. Chronic exposure is highly toxic and likely to cause leukemia and naso-pharyngeal cancers.[13] It is also a significant environmental pollutant.[18]

The fresh-frozen cadavers provide high haptic realism. For surgical training & dissection, cadavers can be preserved from some months up to 1 year.[19,20] Provided, the temperature is maintained between -10 and -20 degrees. Fresh frozen cadavers maintain realistic tissue flexibility and color for about 6 to 12 months. Once thawed, these specimens are typically used only once.[21] Repeated freeze-thaw cycles damage cellular structures and degrade tissue quality. That is why the use of fresh frozen cadavers faces challenges in Indian climate as temperatures reach even beyond 45 degrees in some parts of India.[22] In contrast, synthetic models are not anatomically realistic and accurate. The details are often missing due to which surgical trainees are not happy.[23]

Consequently, the anatomists have increasingly searched for newer safe and sustainable preservation methods. With a goal to maintain the structural integrity of tissues without the toxic hazards associated with traditional formalin-fixed cadavers.[7,24] The soft-fixation techniques have been developed to overcome the challenges while using stiff formalin models and decaying fresh-frozen tissue. Different soft embalming methods like Thiel's method, saturated salt solution embalming, soft embalming using Genelyn and the Modified Larssen solution,are currently being used.[3]

AIMS AND OBJECTIVES

Aims

The present narrative review aims to explore the key differences between soft embalming techniques. To find how the limitations of one

technique gave rise to newer and better soft embalming methods. And to examine their growing role in anatomical education, surgical training, and clinical skill development. We aim to understand whether soft embalmed cadavers serve to bridge the gap between the basic anatomy knowldege and surgical practice.

Objectives

1. To compare various soft embalming methods with formalin based preservation.
2. To analyse the role of soft-embalmed cadavers in undergraduate and postgraduate teaching.
3. To study the role of soft-embalmed cadavers in simulation based learning. Its usefulness to comply with competency based medical education. To find out which embalming method suits the training purpose of which surgical speciality.
4. To discuss whether soft-embalmed cadavers serve as a bridge between learning foundational anatomy and mastering surgical practice.
5. To examine challenges and future directions in cadaver preservation.

METHODOLOGY

This is a narrative review of the utility of various soft embalming techniques in medical education. A literature search was performed using electronic databases. Articles related to soft embalming were searched from PubMed, Google Scholar, Scopus, Embase, Science direct, Web of Science. Relevant articles published during the last 20 years were identified between 2000 to 2025. Keywords such as "soft embalming", "Thiel embalming", "cadaver preservation","surgical simulation", "anatomy education", "Genelyn", "saturated salt solution embalming", "Larssen solution", and "soft-fixed cadavers" were utilised.

Inclusion Criteria:

Articles were included if they were published in English. Articles were screened for relevance based on their title, abstract, and full-text. During the search, studies describing the characteristics of soft embalming techniques; anatomical and surgical uses of soft-embalmed cadavers were selected. Original research articles, review articles, and studies involving human cadavers were considered for inclusion. Especially, literature that evaluated the use of soft embalming in anatomy teaching, procedural skills training, and surgical simulation were selected.

Exclusion Criteria:

Animal studies, non-English publications, conference abstracts without full-text availability, and studies lacking relevance to the objectives of the review were excluded.

The retrieved literature was reviewed with an aim to evaluate how different soft embalming methods have evolved to meet the present needs of simulation based medical education. And whether these methods fulfill the idea of utilising cadavers for skill based learning as per competency based medical education. Which method suits which purpose ranging from foundational anatomical education up to post graduate surgical training. The advantages, limitations, and future prospects of various soft embalming techniques were critically reviewed. This narrative review will be helpful for educational institutions while selecting the optimum preservation method to suit their educational and curricular purpose.

Principles of Soft Embalming Techniques

The evolution of soft embalming represents a significant breakthrough in anatomical preservation.[3,23,25-28] Soft embalming techniques were gradually developed in order to find a safer alternative to formalin preservation. Scientists tried to develop better embalming solutions to increase the durability of the cadavers.[4] Various soft embalming methods utilise the different chemicals in varying concentration.[3] A fixative causes controlled protein cross-linking to prevent autolysis and decomposition.[3] Plasticizers maintain moisture & pliability of the tissue. Buffers and salts are used for color retention and pH balance. A solvent prevents the polymerization of formaldehyde. Surfactants reduce the surface tension of water. As a result, the embalming solution easily penetrates into the deeper tissues of cadaver. When these agents work together in an embalming fluid, cadavers closely resembling living tissues are obtained.[4]

Thiel's Method

Developed in 1992, the Thiel's method of embalming consists of multiple steps. After intravascular injection of embalming fluid, the cadaver is immersed in an embalming tank for

months. The solution consists of a combination of salts, glycols, and low concentrations of formaldehyde. The unique, life like texture of a Thiel's treated cadaver is the direct result of how these chemicals interact with human tissue.[3,29]

Glycols act as humectants, retaining moisture and maintaining tissue softness and pliability. Boric acid reduces cellular adhesion, helping preserve the flexibility of muscles and fascial planes. Ammonium and potassium nitrates limit post-mortem muscle stiffening and contribute to the maintenance of near-natural elasticity. Sulphites reduce oxidation of blood pigments, thereby helping tissues retain a more natural colour. Finally, low concentrations of formaldehyde inhibit autolysis and microbial degradation while avoiding the excessive tissue rigidity associated with conventional formalin fixation.[3]

Advantages

Cadavers preserved with Thiel's method have near normal tissue softness, natural organ colour. They can be dissected, retracted and sutured in a manner similar to living tissues. One of the most critical features is that they last on average from three to five years.[26]

Limitations

The Thiel embalming method does not accurately simulate conditions like heart attacks, brain edema and active fluid perfusion. It causes significant neurological tissue softening. Other drawbacks of this method are high costs and lengthy preparation times.[30]

MODIFIED LARSSEN SOLUTION

In the Modified Larssen Solution consists of glycerol, chloral hydrate, sodium chloride & sodium bicarbonate.The Modified Larssen Solution reduces formalin fumes toxicity while maintaining tissue integrity. This solution is more cost-effective as compared to the standard Thiel method.[3]

Genelyn Embalming

Because Genelyn is a commercial, proprietary brand, its exact chemical formula and full composition are not publicly revealed by the manufacturer. Genelyn cadavers exhibit tissue colour, texture and handling characteristics that are very similar to living tissues during laparoscopic and pelvic surgery training.[3] Establishment of pneumoperitoneum can be done successfully. Electrosurgical devices produce tissue reactions similar to live surgery.[31]

The primary advantage of Genelyn lies in its practicality. Genelyn is cheaper, quicker to prepare, easier to implement. But still has better surgical simulation capabilities than Thiel embalming. Genelyn-fixed specimens last for lesser limited duration as compared to those treated with the Thiel method.[32]

Saturated Salt Solution (SSS) Embalming

The embalming of a saturated salt solution (SSS) has recently emerged as a cheap low-toxic embalming agent. The method employs concentrated salt solutions that inhibit microbial growth through plasmolysis.[33]

Cadavers that have been preserved using the SSS method are moderately flexible with movable joints. Additionally, their use reduces the level of formaldehyde in the lab and improves the quality of air in the laboratory setting. The method is very easy to conduct, inexpensive, and can be implemented in almost all settings.[3]

However, limitations exist. The high concentration of saline poses certain practical difficulties. It may lead to faster tissue dehydration and discoloration over time.[33] Also salt tends to errode the equipments. SSS, which is superior to standard formalin fixation, usually offers less colour retention than Thiel or Genelyn.[3]

N-vinyl-2-pyrrolidone (NVP)

N-vinyl-2-pyrrolidone (NVP) is useful for plastination of neurological tissue. It maintains tissue flexibility and enhance neurovascular visualization. It may be beneficial for training of endoscopic skull-base surgery.[34,35]

Applications in Undergraduate Education

The Competency based medical education emphasizes on achieving necessary clinical skills for an Indian medical graduate.[36] Soft embalmed tissues possess superior tissue texture.[2] This allows undergraduate students to develop a more accurate tactile understanding of human anatomy. The opportunity to handle fascia and muscles which are of life like consistency, brings theory from the atlas alive on the dissection table.[26] The improved color retention enhances the

identification of structures during teaching and simulation. This realistic tactile and visual feedback is invaluable for undergraduate students who are establishing foundational anatomical knowledge.[37]

Soft embalming preserves better range of motion of joints. This improves the understanding of musculoskeletal anatomy and basics of joint movements.[38] It also facilitates vertical integration of anatomy with orthopedics, leading to early clinical exposure.[2] Also, it makes surgical positioning, minor orthopedic procedures, and dental techniques possible during learning. Undergraduate students can gain practical experience in anatomical relationships that would be impossible with rigid specimens.[39] The ability to demonstrate three-dimensional spatial relationships significantly enhances the depth of anatomical understanding. Also, these cadavers can be used to teach minor surgical skills and life saving basics.[26]

Postgraduate Anatomy Applications

Postgraduate anatomy training demands superior tissue preservation for advanced research and specialist training applications.[40] Soft embalming eliminates over-hardening, allowing trainees to trace delicate neuro-vascular branches and study subtle neurological variations.[24] Detailed dissection of joint cavities becomes possible.[37] Arterial and venous paths can be injected with colored silicone or latex for precise micro-anatomy. Identification of anatomical variations and study of neurological tissue becomes possible.[41]

Bridging the gap between theoretical Anatomy and Surgical practice.

The adoption of competency-based medical education has emphasized the importance of simulation-based learning.[36] Modern curricula require graduates to demonstrate procedural competence rather than just theoretical knowledge. Soft-embalmed cadavers not only provide a platform for practice but also make assessment of possible.[23] Soft embalmed cadavers function as an intermediate step between the anatomy laboratory and the operating theatre. Technical skills can be acquired step wise from anatomy to surgery before performing procedures on living patients.[37]

Furthermore, soft-embalmed cadavers promote interdisciplinary learning by bringing together anatomists, surgeons, radiologists.[42] Cadaveric workshops frequently combine anatomical dissection with procedural training. This reinforces the clinical relevance of anatomy and encourages collaboration across specialties. Such integration strengthens the connection between foundational sciences and clinical practice.[43]

Applications of Soft Embalming in Surgical Training

Surgical skill acquisition remains the foundation of post graduate training in various surgical specialities.[6,40] Soft-embalmed cadavers provide a platform for procedural rehearsals. Their use ranges from basic operative skills to advanced minimally invasive and microsurgical techniques.[6,8]

1. General Surgery Training

Training on soft-embalmed cadavers improves confidence in advanced suturing techniques.[2] It facilitates practice of complex abdominal and pelvic procedures like foregut and bariatric surgery.[44] Mastering emergency techniques such as artery ligation enhances patient safety.[23] Surgical oncology training evaluation using soft embalmed cadavers have improved the precision of trainee dissections.[45]

2. Laparoscopic and Robotic Surgery

Reliable pneumoperitoneum creation is the prerequisite for minimally invasive surgery training.[40] Thiel cadavers are widely used for procedures such as sleeve gastrectomy. Thiel's Soft embalmed cadavers are useful for practicing basics of bariatric surgery, pelvic and kidney surgery.[4] Genelyn-preserved cadavers are useful for advanced laparoscopic and robotic training.[31]

3. Neurosurgical Training

Methods such as N-vinyl-2-pyrrolidone (NVP) improve visualization of delicate neurovascular structures. These models enable skull-base dissection, micro-drilling, and neurovascular procedures while overcoming limitations of virtual simulators.[34,35,47]

4. Orthopedic Surgical Training

Soft-embalmed cadavers are suitable for arthroscopic training of the knee and shoulder.[39] Practice of procedures such as

meniscectomy, ligament repair, arthrocentesis; And ultrasound-guided interventions improves trainee competence. Orthopedic surgical procedures such as various types of fixations, amputations can be performed.[48]

5. Plastic and Reconstructive Surgery

Preservation of natural tissue planes and vascular structures makes soft-embalmed cadavers excellent models for flap dissection and microsurgical training. Various flaps can be harvested. Intact vessels permit microvascular anastomosis and patency testing.[32]

6. ENT and Head–Neck Surgery

Thiel soft-embalmed cadavers are excellent for endoscopic sinus, airway, and head–neck procedures.[49] They enable training in cricothyrotomy, thyroid surgery, and temporal bone dissection. There is improvement of spatial orientation and technical skills.

7. Cardiothoracic and Vascular Surgery

Soft-embalmed cadavers serve as anatomically accurate models for cardiothoracic and vascular procedures.[50] They facilitate training in esophagectomy, vascular dissection, arteriotomy, vascular anastomosis, and endovascular procedures.[6,8,26,51] Preserved vessel patency also supports ultrasound-guided vascular access training.[52] The Thiel cadaveric aortic perfusion model provides creates optimum conditions to conduct a realistic simulation of TEVAR and EVAR procedures.[50]

Student Perceptions

Outcome based medical education is the basis of formulation of postgraduate curriculum. Evidence demonstrates that soft-embalmed cadavers significantly improve postgraduate student perceptions and learning outcomes. For example, residents assessing a Thiel-embalmed neonatal cadaver rated its educational usefulness significantly greater than a standard high-fidelity pediatric manikin (4.37 vs 3.43 out of 5). Better skill acquisition can be achieved using soft embalmed cadavers thus ensuring patient safety.[53]

The success of surgical skill training needs better muscle memory, tissue discrimination and force regulation. With a cadaver lasting upto one year, post graduate students can practice their skills for prolonged hours. A simulation of risky operative procedures allows young surgeons to achieve proficiency in complex maneuvers,before transitioning to real patients.[54,55]

Postgraduate students consistently report greater confidence and satisfaction when training on soft-embalmed models compared to traditional alternatives. The realistic tissue handling, contribute to improved learning experiences and better preparation for clinical practice.[24,56]

Dissection-based learning is found to be superior to digital alternatives, as it leads to better engagement of students in learning anatomy.[57] Soft-embalmed specimens maintain the superior educational benefits of cadaveric dissection over conventional preservation methods.[56,58]

Soft embalmed cadavers allow learners to observe anatomical relationships in a surgically relevant context.[23] Thus facilitating the transition from dissection-room learning to operative practice. Such exposure helps reduce the traditional gap between preclinical anatomy education and clinical surgical training.[55]

Applications Beyond Surgical Training

The realistic tissue properties of soft-embalmed cadavers make them valuable for research, medical device development, and continuing professional training.[50]Advanced anatomical and radiological research on soft embalmed cadavers facilitates the study of anatomical variations, validation of imaging techniques.[8] Development of novel procedural approaches that would be impractical or unethical in living subjects can be tested on these cadavers.[36,59]

Soft-embalmed cadavers further serve as platforms for testing surgical instruments, endovascular devices and other medical technologies before clinical application.[26,40] Soft embalmed cadaveric workshops and simulation boot camps facilitate continuing medical education programs.[8,40] As they are long lasting, a single specimen can be used for multiple training sessions thus improving cost-effectiveness and educational value.[6] Consequently, soft-embalmed cadavers have emerged as versatile resources that support innovation, research, and lifelong learning across modern medical sciences.[8,9,26,40]

Comparative Evaluation of Soft Embalming Techniques

The development of soft embalming

techniques has transformed cadaver-based education by providing alternatives to traditional formalin fixation.[6,9,23] Considerable differences are seen among preservation methods with respect to tissue quality, cost, infrastructure needs, and suitability for surgical training.[28] While conventional formalin embalming remains the most widely used technique because of its simplicity and affordability, its limitations are well recognized.[25] Formalin-fixed cadavers are poorly suited for advanced surgical and minimally invasive training. Although the cost of conventional embalming is relatively low soft embalmed cadavers are preferred whenever specialised training is required.[60]

Among contemporary soft-embalming methods, Thiel embalming is widely regarded as the benchmark for tissue preservation. Numerous studies have reported that Thiel cadavers retain near-natural colour, flexibility and elasticity closely resembling the living tissues.[29,61,62] These properties permit realistic simulation of complex surgical procedures. Laparoscopic and endoscopic techniques and micro-surgical dissections can be easily performed on Thiel's embalmed cadavers. However, these advantages are accompanied by substantial practical challenges.[23,26,40] Thiel's embalming requires prolonged immersion period. There should be dedicated stainless-steel storage facilities. The demand and supply of the constituents and their storage should be ensured beforehand. Thus Thiel's embalming becomes 8–14 times expensive as compared to formalin based embalming. Consequently, the implementation of Theil's embalming becomes difficult in limited financial settings.[26]

The Genelyn brand was developed first by an Australia based company. They created a proprietory solution that contains replacement of formalin with safer alternatives. Genelyn method has served as an alternative to formalin based embalming and fresh frozen cadavers. Genelyn is injected in the arterial system of a fresh unfrozen cadaver. Unlike the Thiel method, it does not require prolonged immersion, so the preparation time is reduced.[27] Genely fluids keep the cadaver hydrated as compared to formalin which dehydrates the tissue. So, Genelyn-preserved cadavers respond very well to electrosurgical devices used for cutting and coagulation. As there is good electrical conduction through this embalmed tissues just like live human tissue, simulation based surgical training is facilitated. Thus, Genelyn embalmed cadavers become highly suitable for open, laparoscopic and robotic surgical training. Genelyn keeps the tissue layers soft and easy to separate and does not turn it into one thick solid block. This facilitates electrical instruments to separate the tissue along the correct anatomical borders as expected in live human. Fresh frozen cadavers need electricity backup system and large walk-in freezers. There should be meticulous temperature monitoring of the freezers by dedicated staff. The thawing of fresh frozen cadavers need 24 to 48 hours under closely monitored conditions. Thus the use of fresh frozen cadavers increase financial burden and need of manpower. Genelyn treated bodies can be stored in standard bodybags at 4 degree celsius in ordinary cold rooms. They do not need thawing and are ready to use anytime. Thus use of Genelyn fluid becomes cheaper as compared to freezing. thawing and maintaining fresh frozen cadavers, Unlike Thiels method, Genelyn does not utilise large amounts of alcohol thus reducing the fire hazard during training. It also does not require massive submersion tanks needed for Thiel's embalming. Thus Genelyn method is cheaper at the same time superior for post graduate surgical training.[31]

Saturated Salt Solution preservation causes plasmolysis of human cells due to high salt concentration. This produces moderately flexible tissues at lower costs as compared to other soft-embalming techniques. The use of salt solution is safe and easy to implement. However, studies suggest that microanatomical detail may get altered with repeated immersion in saturated salt solution. As a result, SSS cadavers may be more appropriate for routine anatomy teaching than for specialized surgical simulation.[33]

Overall, soft embalming techniques should be chosen as per the desired purpose. Thiel embalming provides near life anatomical details. Genelyn offers a balance between realism and affordability. SSS represents is a cost-effective, safety and accessible. Selection of the preservation method should therefore be based on institutional objectives, available resources and the desired educational outcomes.[7,27,63] The following table summarises the difference between embalming methods (Table 1).

Table 1: Difference beween embalming methods

Method	Tissue Realism	Cost	Duration	Surgical Training
Thiel	Excellent	High	3–5 years	Excellent
Genelyn	Very Good	Moderate	Moderate	Very Good
SSS	Good	Low	Moderate	Moderate
Formalin	Poor	Low	Long	Poor

Limitations and Challenges

Several limitations restrict the wide-spread use of cadavers treated with soft embalming methods for educational purpose. The biggest challenge is the high cost needed for production and maintenance.[64] Some methods require special chemicals, dedicated storage facilities. There might be a need of strict protocols and continuous monitoring.[26] Methods needing prolonged immersion use large stainless-steel tanks and are space consuming.[9,26,28] The institutes with a limited budget and infrastructure find it difficult to meet the above requirements.

Prolonged preparation process and specially trained staff are some more challenges. Formalin based embalming is relatively easy to carry out and does not need too much time. Soft-embalming may need weeks to months before the cadaver is ready for use. The staff should be well trained in intravascular perfusion techniques for soft embalming methods. The staff should be able to achieve even fixation. Inadequate perfusion may result in localized degradation or vascular rupture. So to maintain the quality of cadavers, trained personnel are required.[2,23,26,28]

As some chemicals constituents may be poisonous or inflammable; there may be legal restrictions to possess them. The embalming team should check the regional and local rules regarding sourcing and possession of these chemicals. Sometimes, license, legal paperwork and permit might be needed. Such chemicals need safe storage and adherence to rules of fire department. Some compounds such as ammonium nitrate may be misused. This makes it difficult to obtain, transport and store these chemicals. There should be a steady flow of necessary chemicals. The institute should therefore have a thorough discussion before deciding to use specific embalming method.[65]

Safety of the personnel, students and teachers should be considered on priority basis. Storage conditions should be optimum for soft embalmed cadavers otherwise quality may not be preserved. Institutions must therefore maintain strict protocols for specimen handling and storage. In low-resource settings, maintaining these standards may be difficult.[2,10,15,28]

Thus, successful implementation of soft embalming methods depends on economy, government rules and feasibility.[28]

CONCLUSION

Soft embalming has transformed the study of anatomy by preserving structure with a life like feel to it. These soft embalming techniques have not only benefitted undergraduate anatomy teaching but also post graduate surgical training. These techniques bring the knowledge of anatomical dissection a step closer to application for surgical training. The simulation of operative surgery on cadavers boosts the confidence of young surgeons and improves patient outcomee. Continuing medical education in the form of cadaveric workshops that are arranged for established surgeons help them to get hands on experience of newer surgical techniques. Unlike formalin embalming, soft-embalmed cadavers allow students to learn anatomy in a clinically oriented pattern. The integration of anatomical knowledge with surgical skills is better achieved with the use of soft embalmed cadavers. This increases the preparedness for clinical and surgical practice.

The increasing popularity of soft-embalmed cadavers reflects the changing scenario of medical education. Competency-based curriculum is being widely adopted all over the Indian subcontinent. It emphasizes on experiential learning, simulation and patient safety. With soft embalming, it becomes possible to recreate realistic tissue handling experience on cadavers. Thus, the use of cadavers have evolved from merely for anatomical education to research and technology testing. Today, they are widely utilized in bio-medical device evaluation like prosthesis that help to improve quality of life. With the use of artificial intelligence, soft embalmed cadavers may be used to produce smart and accurate prosthesis. The possibility to use cadavers for human research have contributed significantly to technical proficiency without compromising on ethics.

Several challenges should also be considered. Financial and infrastructure

limitations narrow down widespread implementation. Prolonged preparation periods, and need of well trained staff should also be considered. Different methods have variable tissue preservation. There is need of standardized preservation protocols. This will make direct comparison between different soft-embalming techniques easier. Continued research is therefore required to overcome the above challenges.

Future advances in chemistry and imaging technology is likely to further enrich the science of soft-embalming. It might be possible to create increasingly sophisticated training environment to closely resemble real clinical practice. Reforms in medical education, might lead to increasingly important role of soft embalmed cadavers for training. Increasing progress in embalming techniques ensures that these cadavers will remain indispensable tools for education in the years to come. As anatomists we should focus on developing affordable, low-toxicity preservation methods with increased fidelity but sustainable approach.

Despite their advantages, several challenges remain. Financial constraints, and infrastructure requirements limit widespread implementation in resource limited settings. Prolonged preparation periods, need of trained staff and variability in tissue preservation should also be considered. Furthermore, the lack of standardized preservation protocols makes direct comparison between different soft-embalming techniques difficult. Continued research is therefore required to optimize preservation methods, reduce costs.

Looking ahead, advances in chemistry, imaging technologies, artificial perfusion systems, are likely to further enhance the value of soft-embalmed cadavers. Further research in these methods may create increasingly sophisticated training environments that closely resemble real clinical practice. With ongoing reforms in medical education, soft embalmed cadavers are likely to assume an increasingly important role in the future. Their unique ability to unite anatomical understanding with practical skill development ensures that they will remain indispensable tools for education in the years to come. Future innovations should focus on developing affordable, low-toxicity preservation methods that combine anatomical fidelity with long-term sustainability.

REFERENCES

1. Suyashi, Sharma RS, Sharma S, Ramteke M. Beyond The Traditional: Discovering The Benefits Of Thiel-Embalmed Cadavers In Learning Human Anatomy. African Journal OF Biomedical Research. 2024 Sep 29;27:5561–8.
2. Eisma R, Wilkinson T. From "Silent Teachers" to Models. PLoS Biology. 2014 Oct 21;12(10):e1001971.
3. Ariyanachi Kaliappan, Motwani R, Gupta T, Mrudula Chandrupatla. Innovative Cadaver Preservation Techniques: a Systematic Review. PubMed [Internet]. 2023 Mar 1 [cited 2026 Jun 18];18(1):127–35. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10231151/
4. Pezzino S, Angelico G, Luca T, Crescimanno C, Castorina M, Puleo S, et al. Revitalizing the Silent Teacher: Cutting-Edge Techniques for High-Fidelity Cadaveric Anatomy. Applied Sciences [Internet]. 2026 Jun 18 [cited 2026 Apr 24];16(4):1782. Available from: https://www.mdpi.com/2076-3417/16/4/1782?utm_source=chatgpt.com
5. Shaffer K. Teaching Anatomy in the Digital World. New England Journal of Medicine. 2004 Sep 23;351(13):1279–81.
6. Theeuwes H. A New Model for Training on Human Specimens in Surgical-Anatomical Skills Labs. Anatomy Physiology & Biochemistry International Journal. 2017 Jul 18;3(1).
7. Balta JY, Cronin M, Cryan JF, O'Mahony SM. Human preservation techniques in anatomy: A 21st century medical education perspective. Clinical Anatomy. 2015 Jun 28;28(6):725–34.
8. Badash I, Burtt K, Solorzano CA, Carey JN. Innovations in surgery simulation: a review of past, current and future techniques. Annals of Translational Medicine [Internet]. 2016 Dec [cited 2026 Jun 18];4(23):453–3. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5220028/#r7
9. Varner C, Dixon L, Simons MC. The Past, Present, and Future: A Discussion of Cadaver Use in Medical and Veterinary Education. Frontiers in Veterinary Science. 2021 Nov 10;8(8).
10. Donczo B, Guttman A. Biomedical analysis of formalin-fixed, paraffin-embedded tissue samples: The Holy Grail for molecular diagnostics. Journal of Pharmaceutical and Biomedical Analysis. 2018 Jun;155:125–34.

11. Sparey K. Effectiveness, Adaptation, and Health Risks of Embalming Fluids: Just what is the Solution? The FASEB Journal. 2012 Apr;26(S1).

12. Toy S, Secgin Y. Cadaver embalming and fixing solutions from past to present. Journal of Clinical Medicine of Kazakhstan. 2022 Oct 27;19(5):9–11.

13. Charlier B, Coglianese A, De Rosa F, De Caro F, Piazza O, Motta O, et al. Chemical Risk in Hospital Settings: Overview on Monitoring Strategies and International Regulatory Aspects. Journal of Public Health Research [Internet]. 2021 Jan 14 [cited 2022 Sep 11];10(1):jphr.2021.1993. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8018262/

14. Kundu S, De A, Mitra S. Formaldehyde: Fact sheet reflecting uses, exposure hazards, health effects and toxicological profile- A broad overview for medical professionals and embalmers. Journal of Clinical & Experimental Research. 2015;3(2):183.

15. Alnagar FA, Shmela ME, M Alrtib A, M Benashour F, Buker AO, Abdalmula AM. Health adverse effects of formaldehyde exposure to students and staff in gross anatomy. International Journal of Scientific Research and Management. 2018 Feb 9;6(02).

16. Arora DL. Exposure of Medical fraternity to formaldehyde in Anatomy and search for better alternatives to formalin. IOSR Journal of Dental and Medical Sciences. 2014;13(10):56–7.

17. Ganesh Handady, Dsouza A, Nayak V, Abraham J. Formaldehyde Levels and the Indoor Air Quality of an Anatomy Dissection Hall with Different Ventilation Setups. Environmental Health Insights [Internet]. 2024 Jan 1 [cited 2025 Feb 28];18. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC11603455/

18. Checkoway H, Boffetta P, Mundt DJ, Mundt KA. Critical review and synthesis of the epidemiologic evidence on formaldehyde exposure and risk of leukemia and other lymphohematopoietic malignancies. Cancer Causes & Control. 2012 Sep 15;23(11):1747–66.

19. Song YK, Jo DH. Current and potential use of fresh frozen cadaver in surgical training and anatomical education. Anatomical Sciences Education. 2022 Jan 20;

20. Jansen MM, Hazenberg CEVB, de Ruiter QMB, van Hamersvelt RW, Bleys RLAW, van Herwaarden JA. Feasibility of fresh frozen human cadavers as a research and training model for endovascular image guided interventions. PLoS ONE [Internet]. 2020 Nov 30;15(11):e0242596. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7704126/

21. McGarvey CR, Drees SM, Lawrence A, Miller ND, Kapur S, De Silva V, et al. Establishing a best practice for the freeze-thaw cycle of cryopreservation to approximate living muscle, joint, and associated soft tissue properties in cadaveric upper limbs. JPRAS Open [Internet]. 2025 Aug 22;46:500–9. Available from: https://www.sciencedirect.com/science/article/pii/S2352587825001470

22. De Bakshi S, Priya P, Gandhi J. Cadaver Models: The Future of Surgical Training or the Need of the Hour? A Narrative Review. Annals of Minimal Access Surgery & Allied Science. 2025 Sep;1(3):114–8.

23. Yiasemidou M, Roberts D, Glassman D, Tomlinson J, Biyani S, Miskovic D. A Multispecialty Evaluation of Thiel Cadavers for Surgical Training. World Journal of Surgery [Internet]. 2017 [cited 2021 Apr 14];41(5):1201–7. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5394144/

24. G A, Ray S, Mohapatra S, G A, Ray S, Jr SM. Preparation of Soft Embalmed Cadavers by the Modified Thiel Embalming Technique for Surgical Skill Training and Development of a Universal Quantitative Scoring System to Assess the Suitability of Soft Embalmed Cadavers for Such Training Purposes. Cureus [Internet]. 2023 Aug 23;15(8). Available from: https://www.cureus.com/articles/178007-preparation-of-soft-embalmed-cadavers-by-the-modified-thiel-embalming-technique-for-surgical-skill-training-and-development-of-a-universal-quantitative-scoring-system-to-assess-the-suitability-of-soft-embalmed-cadavers-for-such-training-purposes#

25. Amanda Teixeira Prata, Baptista S. The proposition of a new method to convert formalin cadavers to academic and museology purposes. Research, Society and Development. 2021 Jan 8;10(1):e21510111575-e21510111575.

26. Rakuša M, Kocbek Šaherl L. Thiel embalming method used for anatomy dissection as an educational tool in teaching human anatomy, in research, and in training in comparison of different methods for long term preservation. Folia Morphologica. 2022 Jun 10;

27. Hammer N, Löffler S, Bechmann I, Steinke H, Hädrich C, Feja C. Comparison of modified thiel embalming and ethanol-glycerin fixation in an anatomy environment: Potentials and limitations of two complementary techniques. Anatomical Sciences Education. 2014 Apr 4;8(1):74–85.

28. Ottone NE, Vargas CA, Fuentes R, del Sol M. Walter Thiel's Embalming Method: Review of Solutions and Applications in Different Fields of Biomedical Research. International Journal of Morphology [Internet]. 2016 Dec [cited 2020 Oct 22];34(4):1442–54. Available from: https://scielo.conicyt.cl/pdf/ijmorphol/v34n4/art44.pdf

29. Liao PY, Wang ZG Thiel-embalming technique: investigation of possible modification in embalming tissue as evaluation model for radiofrequency ablation J Biomed Res 2019 Apr 8;33(4):280–8 doi: 107555/JBR3220160148 Epub ahead of print PMID: 30956232; PMCID: PMC6813523.

30. Miyake S, Suenaga J, Miyazaki R, Sasame J, Akimoto T, Tanaka T, et al. Thiel's embalming method with additional intra-cerebral ventricular formalin injection (TEIF) for cadaver training of head and brain surgery. Anatomical Science International. 2020 Apr 27;95(4):564–70.

31. Kalayarasan R, Rajasekhar SSSN, Kumar Vd, Raveendranath V, Gnanasekaran S, Pottakkat B, et al. Advanced training in laparoscopic gastrointestinal surgical procedures using Genelyn®-embalmed human cadavers: A novel model. Journal of Minimal Access Surgery. 2021;17(4):495.

32. Manikumari B, Jaggavarapu SR, Subha K, Kalpana T, Muni RKN, Kishve P, et al. Simulation of Reconstructive Microsurgery in Soft Embalmed Cadavers: A Teaching Module for Plastic Surgery Residents. Indian Journal of Plastic Surgery. 2022 Jun;55(03):262–7.

33. Hayashi S, Homma H, Naito M, Oda J, Nishiyama T, Kawamoto A, et al. Saturated salt solution method: a useful cadaver embalming for surgical skills training. Medicine. 2014 Dec;93(27):e196.

34. Nagase M, Kimoto Y, Eiji Sunami, Matsumura G. A new human cadaver model for laparoscopic training using N-vinyl-2-pyrrolidone: a feasibility study. Anatomical Science International. 2019 Jul 26;95(1):156–64.

35. Maruyama K, Yokoi H, Nagaase M, Yoshida H, Noguchi A, Matsumura G, et al. Usefulness of N-vinyl-2-pyrrolidone Embalming for Endoscopic Transnasal Skull Base Approach in Cadaver Dissection. Neurologia medico-chirurgica. 2019;59(10):379–83.

36. Akaike M, Fukutomi M, Nagamune M, Fujimoto A, Tsuji A, Ishida K, et al. Simulation-based medical education in clinical skills laboratory. The Journal of Medical Investigation. 2012;59(1,2):28–35.

37. Reddy R, Iyer S, Pillay M, Thankappan K, Ramu J. Soft embalming of cadavers for training purposes: Optimising for long-term use in tropical weather. Indian Journal of Plastic Surgery. 2017 Jan;50(01):029–34.

38. Sthapak E, Pasricha N, Bhatnagar R, Siddiqui M, Jaiswal S. Soft-fixed embalming: Our experiences. National Journal of Clinical Anatomy. 2020;9(2):43.

39. Arce JE, Contreras ES, Vaghani P, Goyal K, Balta JY. Using Soft-Preserved Body Donors to Improve the Anatomy Learning Experience for Orthopedic Residents. Journal of Surgical Education [Internet]. 2024 Nov 21;82(1):103321. Available from: https://www.sciencedirect.com/science/article/pii/S1931720424004690?pes=vor&utm_source=scopus&getft_integrator=scopus#sec0020.

40. Ackermann J, Wedel T, Hagedorn H, Maass N, Mettler L, Heinze T, et al. Establishment and evaluation of a training course in advanced laparoscopic surgery based on human body donors embalmed by ethanol-glycerol-lysoformin fixation. Surgical Endoscopy. 2020 May 22;35(3):1385–94.

41. Abraham JK, Souza AD, Bhat AK, Thomas J, Pereira CB, Iyer S, et al. Enhancing Cadaveric Soft-Tissue Dissection Training for Plastic Surgery Residents. Annals of Plastic Surgery. 2025 Sep 1;95(3S):S42–8.

42. Kawashima T, Sakai M, Hiramatsu K, Sato F. Integrated anatomical practice combining cadaver dissection and matched cadaver CT data processing and analysis. Surgical and Radiologic Anatomy. 2022 Jan 25;44(3):335–43.

43. Tripathy P, Gaikwad M, Mishra P. Role of Cadaveric workshop in refining the Surgical Skills: an experience and way ahead in an institute of National importance. Indian Journal of Anatomy and Surgery of Head, Neck and Brain. 2017 Feb 5;3(1):6–8.

44. Schlottmann F, Herbella FAM, Patti MG. Simulation for Foregut and Bariatric Surgery: Current Status and Future Directions. Journal of Laparoendoscopic & Advanced Surgical Techniques. 2021 May 1;31(5):546–50.

45. Desmond P.J. Barton, Davies L, Mahadevan V, Dennis L, Adib T, Satvinder Mudan, et al. Dissection of soft-preserved cadavers in the training of gynaecological oncologists: Report of the first UK workshop. Gynecologic Oncology. 2009 Jun 1;113(3):352–6.

46. Mantica G, Pini G, De Marchi D, Paraboschi I, Esperto F, Van der Merwe A, et al. Intensive simulation training on urological mini-invasive procedures using Thiel-embalmed cadavers: The IAMSurgery experience. Archivio Italiano di Urologia e Andrologia. 2020 Jun 23;92(2).

47. Gehlot D, Srivastava S. Unlocking the Advantages Of N-Vinyl-2-Pyrrolidone as A Superior Alternative to Formalin in Cadaver Preservation: A Comprehensive Review. Journal of Biomedicine and Biochemistry. 2023 Dec 1;

48. Stirling ER, Lewis TL, Ferran NA. Surgical skills simulation in trauma and orthopaedic training. Journal of Orthopaedic Surgery and Research. 2014 Dec;9(1).

49. Grullo PER, Hernando HCT, Carrillo RJDC, Villacorta PRF, Hernandez JG, Lopa RAB, et al. Surgical Simulation of Endoscopic Sinus Surgery using Thiel Soft-Embalmed Human Cadaver. Acta Medica Philippina. 2017 Mar 31;51(1).

50. Saw A. A New Approach to Body Donation for Medical Education: The Silent Mentor Programme. Malaysian Orthopaedic Journal [Internet]. 2018 Jul 1 [cited 2021 Dec 8];12(2):68–72. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6092528/?tool=pmcentrez&report=abstract

51. Nesbitt CI, Birdi N, Mafeld S, Stansby G. The role of simulation in the development of endovascular surgical skills. Perspectives on Medical Education. 2016 Jan 21;5(1):8–14.

52. McLeod H, Cox BF, Robertson J, Duncan R, Matthew S, Bhat R, et al. Human Thiel-Embalmed Cadaveric Aortic Model with Perfusion for Endovascular Intervention Training and Medical Device Evaluation. CardioVascular and Interventional Radiology. 2017 Apr 27;40(9):1454–60.

53. Sanchez-Ferrer F, Grima-Murcia MD, Sánchez-del-Campo F, Sánchez-Ferrer ML, Fernández-Jover E. Thiel embalming in neonates: methodology and benefits in medical training. Anatomical Science International. 2022 Feb 8;97(3):290–6.

54. Ajileye AB, Esan EO, Adeyemi OA. Human Embalming Techniques: A Review. American Journal of Biomedical Sciences [Internet]. 2018 Apr;10(2):82–95. Available from: http://www.nwpii.com/ajbms/papers/AJ20180203.pdf

55. Eisma R, Lamb C, Soames RW. From formalin to thiel embalming: What changes? One anatomy department's experiences. Clinical Anatomy. 2013 Feb 13;26(5):564–71.

56. Kennel L, Martin DMA, Shaw H, Wilkinson T. Learning anatomy through Thiel- vs. formalin-embalmed cadavers: Student perceptions of embalming methods and effect on functional anatomy knowledge. Anatomical Sciences Education. 2017 Jul 18;11(2):166–74.

57. Ghosh SK. Human cadaveric dissection: a historical account from ancient Greece to the modern era. Anatomy & Cell Biology. 2015 Sep 22;48(3):153.

58. Niels H. Thirty years of Thiel embalming—A systematic review on its utility in medical research. Clinical Anatomy. 2022 Aug 18;35(7):987–97.

59. Giger U, Frésard I, Häfliger A, Bergmann M, Krähenbühl L. Laparoscopic training on Thiel human cadavers: A model to teach advanced laparoscopic procedures. Surgical Endoscopy. 2007 Aug 18;22(4):901–6.

60. Jaung R, Cook P, Blyth P. A comparison of embalming fluids for use in surgical workshops. Clinical Anatomy. 2011 Jan 12;24(2):155–61.

61. Dea Aaldijk, Reusser A, Eppler E, Yao E, Djonov V, Halm S. Morphological changes in striated muscle fibers caused by components of the Thiel embalming method. Folia Morphologica. 2023 Feb 22;83(1):83–91.

62. Munirama S, Eisma R, Columb M, Corner GA, McLeod GA. Physical properties and functional alignment of soft-embalmed Thiel human cadaver when used as a simulator for ultrasound-guided regional anaesthesia. British Journal of Anaesthesia. 2016 May;116(5):699–707.

63. Balta JY, Twomey M, Moloney F, Duggan O, Murphy KP, O'Connor OJ, et al. A comparison of embalming fluids on the structures and properties of tissue in human cadavers. Anatomia, Histologia, Embryologia. 2018 Nov 18;48(1):64–73.

64. Brenner E. Human body preservation - old and new techniques. Journal of Anatomy [Internet]. 2014 Jan 18 [cited 2019 Oct 14];224(3):316–44. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3931544/#!po=3.76344

65. Leake M, Ejaz A, Patel R, Balta JY. The utility of soft-preservation in Medical Education: Current trends & future directions. European Journal of Anatomy. 2024 May;28(3):389–98.