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Original Research Article

Preservation of Thoracic Cage Following Cadaveric Dissection: An Innovative Cost-Effective Approach for Anatomical Education

Baneswar Baro[1], Jyotsna Bhuyan[2], Akheruz Zaman Ahmed[3], Gunamani Rabha[4], Ritu Saloi[5]

[1]Professor, Department of Anatomy, Bongaigaon Medical College & Hospital, Bongaigaon, Assam, India
[2]Assistant Professor, Department of Anatomy, Assam Medical College & Hospital, Dibrugarh, Assam, India
[3]Assistant Professor, Department of Anatomy, Bongaigaon Medical College & Hospital, Bongaigaon, Assam, India
[4]Associate Professor, Department of Anatomy, Diphu Medical College & Hospital, Diphu, Assam, India
[5]Professor, Department of Anatomy, Diphu Medical College & Hospital, Diphu, Assam, India

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Corresponding author: Dr. Baneswar Baro
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Abstract

Objective: This study aimed to develop and evaluate a simple, cost-effective technique for the preservation of the human thoracic cage obtained from cadaveric specimens following dissection.

Methods: The articulated thoracic cage was collected from cadaveric specimens was subjected to a systematic preservation technique involving fixation of joints, manual maceration, aerosol coating and with subsequent dry preservation. The prepared thoracic cage was evaluated for the retention of its anatomical features, structural integrity, and suitability for educational use.

Results: This cost-effective preservation technique produced satisfactory results, with the thoracic cage maintaining its crucial anatomical features and structural configuration. The prepared thoracic cage was lightweight, effortlessly handled, and suitable for teaching resource, while requiring minimal maintenance after completion of the preservation process.

Conclusion: This study had shown a simple, cost-effective manual method for the preservation of human skeletal specimens from post cadaveric dissection. Henceforth, this study may fulfil the shortage of skeletal specimens in medical colleges and provide an accessible resource for anatomical teaching and learning.

Keywords: Thoracic cage, Anatomy, Osteology, Dry Preservation, Dissection.

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Introduction

Human anatomy is one of the fundamental cornerstones of medical education, dates back to the 2nd and 3rd centuries BCE, when early Greek and Egyptian scholars made significant discoveries about the structures of the human body 1. With the modernization of undergraduate medical education, anatomy teaching has undergone significant transformation. However, cadaveric dissection continues to be regarded as a key of anatomy education, offering students a comprehensive three-dimensional perspective that is fundamental to the acquisition of clinical knowledge and skills [1,2]. Teaching anatomy has become increasingly challenging in many places due to lack of cadaver, though it is a keystone of medical education [3]. In anatomy, the study of bones is an integral component of the medical education, providing students with invaluable deep insights into the knowledge of osteology and skeletal anatomy [1]. The study of bones facilitates a comprehensive understanding of soft tissue attachments and the pathways of neurovascular structures. Effective learning of bone anatomy is typically achieved through the integrated use of dried bones, textbooks, anatomical atlases, and hands-on cadaveric dissection in anatomy laboratory settings. A part from education, bone maceration plays a crucial role in forensic investigations of human remains in medico-legal cases and archaeological studies by facilitating the retrieval, cleaning, and preservation of skeletal remains for analysis and research purpose [4]. Good maceration is essential for producing clean, well-preserved bones suitable for anatomical education, forensic reconstruction, and long-term preservation in anatomy museum. Preparation of human skeleton requires a series of

systematic process, including the removal of soft tissues, bleaching, articulation, and accurate labelling to ensure their educational and scientific value [5]. Inappropriately performed maceration techniques can produce brittle, cracked, or discoloured specimens, diminishing their educational and scientific value [5]. The duration of these preparation processes may vary depending on the size of the specimen, environmental conditions, and the preparation method employed [6]. The commonly used methods of skeletal preparation include insect-assisted cleaning, cold- or warm-water maceration, and chemical treatments, with processing times varying according to environmental conditions and microbial activity. For instance, preparing dried human skulls from fresh or frozen cadavers generally requires about eight weeks, encompassing enzyme-assisted maceration followed by defatting, washing, and bleaching [5].

Numerous chemical agents, including ammonium hydroxide, antiformin, and sodium hydroxide, are employed in bone preparation for their ability to facilitate the removal of soft tissues [5]. Enzymatic agents, including papain and organic washing powders, further improve the efficiency of the cleaning process. Combined with other preparation techniques, these methods yield high-quality anatomical bones suitable for anatomical education and research [5].

Osteology is the branch of anatomy concerned with the study of bone structure, classification, articulations, growth and ossification, neurovascular supply, and characteristic anatomical features such as bone markings and muscle attachment sites. These features contribute to a better understanding of functional and clinical anatomy and plays important role for medical and physiotherapy students [7]. However, the detailed study of the specific features of individual bones cannot be achieved through textbooks. Direct observation and handling of human bones are essential for effective learning and retention of osteological and clinical knowledge.

Due to strict regulations governing the procurement and use of human remains, current teaching practices often depend on alternatives such as plaster or resin models, which may lack the detailed anatomical features and landmarks present in real bone [7]**.** However, a substantial number of unclaimed bodies are received in forensic departments throughout the year, but not all are suitable for dissection or medical education. Body received after prolonged death intervals often exhibit decomposition, and not suitable for dissection and henceforth necessitating burial is done. Highlighting the shortage of skeletal specimens in medical colleges, these partially decompose cadavers may serve as a valuable source of bones for undergraduate medical education following appropriate skeletal preparation. This shortage emphasizes the importance of developing effective bone retrieval and preparation methods, particularly using post-dissection cadavers, to support the increasing requirements of medical and allied health education. This study demonstrates a novel low-cost technique for preserving the human thoracic cage from cadaveric specimens. This approach may help address the shortage of skeletal specimens in medical colleges and support anatomical education in the future

Materials and Methods

Procurement of Cadaver: The study was carried out from an unclaimed male cadaver received in the Department of Anatomy, Diphu Medical College and Hospital (DMCH), Diphu, Karbi Anglong, Assam, India.

Ethics Committee Approval: This study was approved by the institutional ethics committee of DMCH, Diphu with reference no DMCH/EC/2022/105/772 dated 09.07.2024 and has, therefore, been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and all subsequent revisions.

Study Protocol: The cadaver was initially embalmed with a 10% formalin solution and utilized for medical student dissection. The thoracic cage was isolated following the completion of dissection. After dissection, fixation of all the joints of thoracic cage were done by a transparent adhesive (ethyl cyanoacrylate) as follows: costochondral junction between ribs and costal cartilage, sternocostal joint between ribs and sternum, xiphisternal joint between the inferior margin of the body of the sternum and the superior margin of the xiphoid process , sternoclavicular joint between the clavicle and the sternum, acromioclavicular joint between lateral end of the clavicle and acromion process of scapula, intervertebral joint between adjacent vertebrae in the spine and costovertebral joint between ribs and vertebrae. After fixation of all the joints, maceration of ribs and thoracic cage was done by manually with the help of scalpel. Maceration was also performed with iron brush fitted with machine. After that, the thoracic cage was dried in sunlight. Following drying again maceration was done by sand paper. After drying, ethyl cyanoacrylate was added again for strong fixation. At last, aerosol coating was applied to the thoracic cage for beautification and then images were taken. The images of all the instruments used in this study was shown in figure 1.

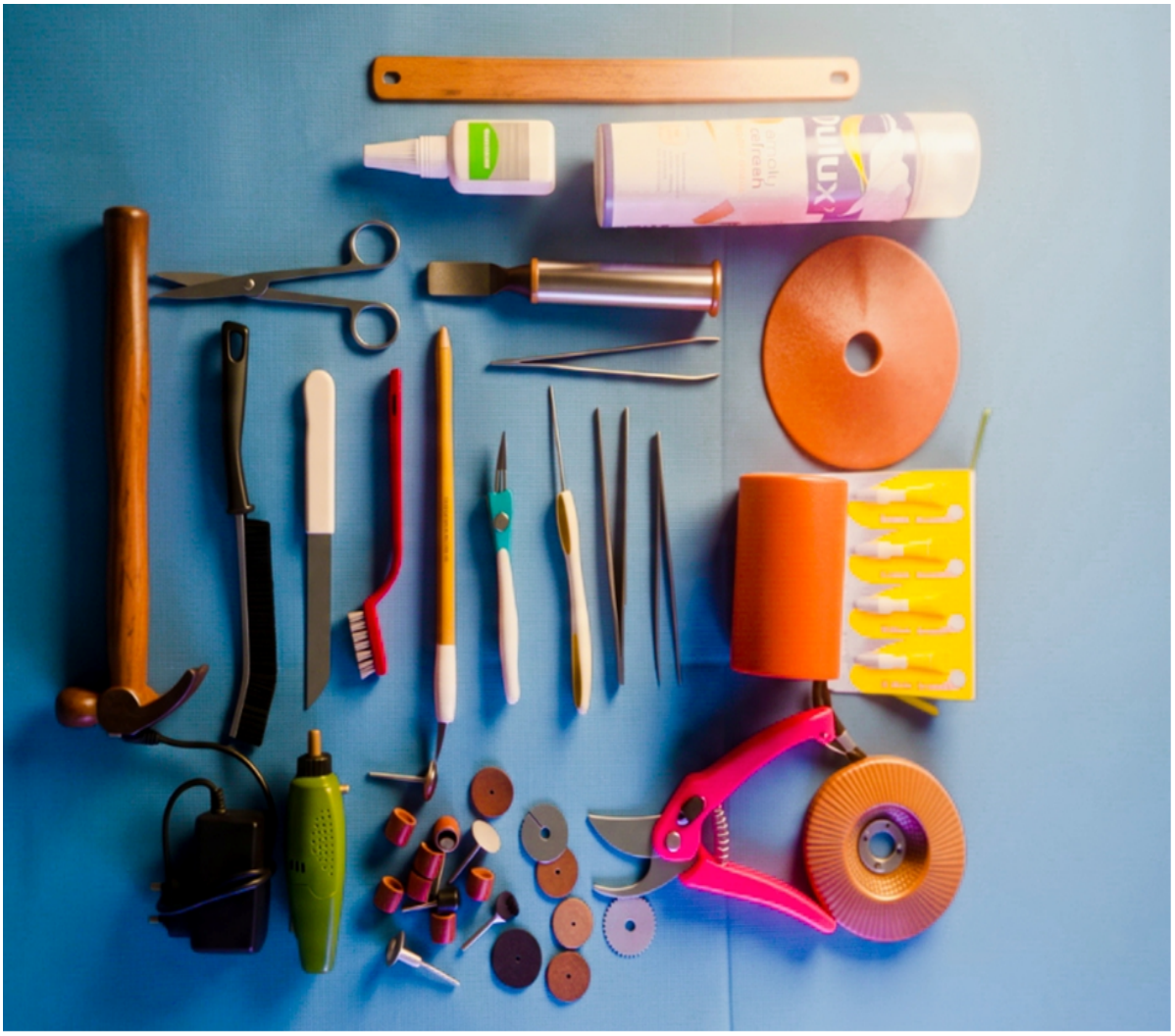

Figure 1: Images of all the instruments used in this study

Results

After preserving the thoracic cage images were captured using a digital camera. The following figure 2 & 3 depict thoracic cage with smooth surfaces which are now ready to be used in various academic teaching programmes. The bones are enlisted in the Figure 2 & 3. After air-drying, the specimen was firm and structurally sound. The most critical finding was the successful maintenance of all the joints in the thoracic cage i.e., costochondral junction between ribs & costal cartilage, sternocostal joint between costal cartilage & sternum and costovertebral joint between ribs & vertebrae. This was possible because of the use of transparent adhesive which gave the specimen a durable, non-tacky finish that sealed the bone surfaces and provided a perceptible increase in structural rigidity, particularly at the joints.

The final preserved specimen was lightweight, easy to handle, and showed no signs of flaking or decay. In qualitative assessment studies the key morphological features can be used for sex and age determination remained clear and unimpaired by the preservation process.

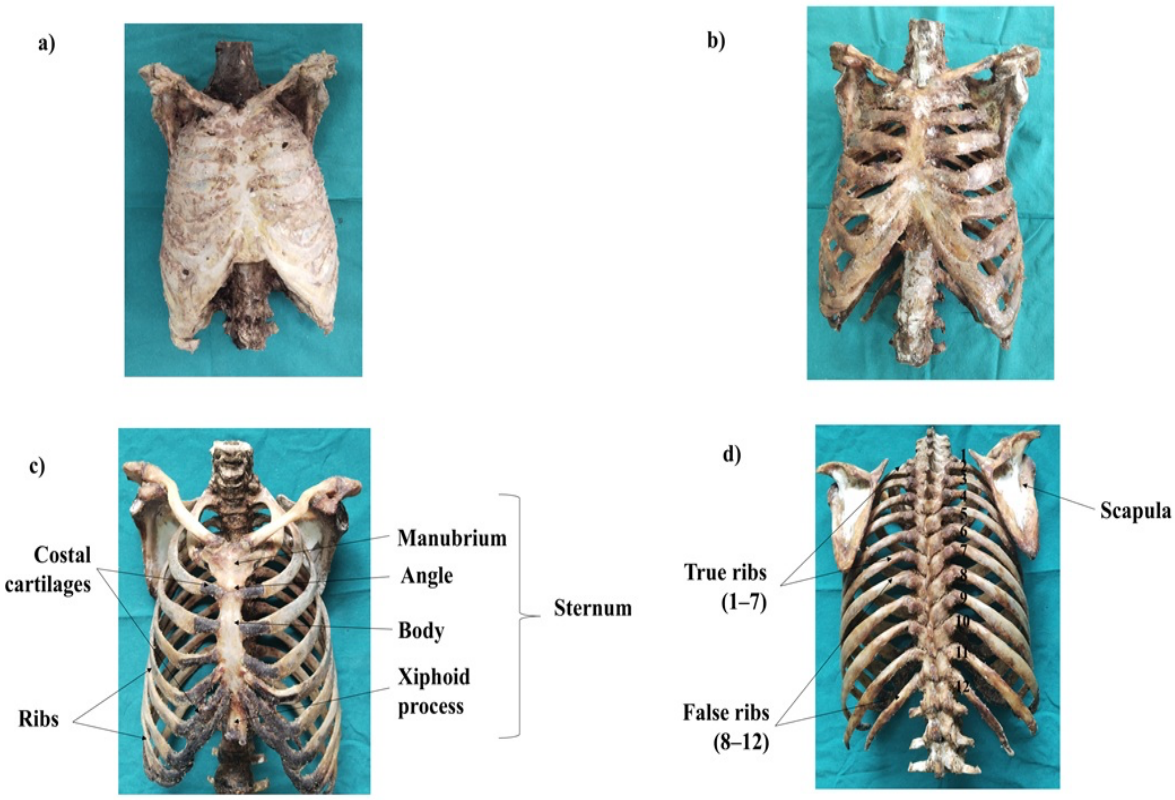

Figure 2: (a) Anterior view of thorax after removing skin and pectoralis muscle, (b) Anterior view of bony framework of thorax after removing intercostal muscles, (c) Anterior view of bony framework of thorax after completion of maceration, (d) Posterior view of bony framework of thorax after completion of maceration.

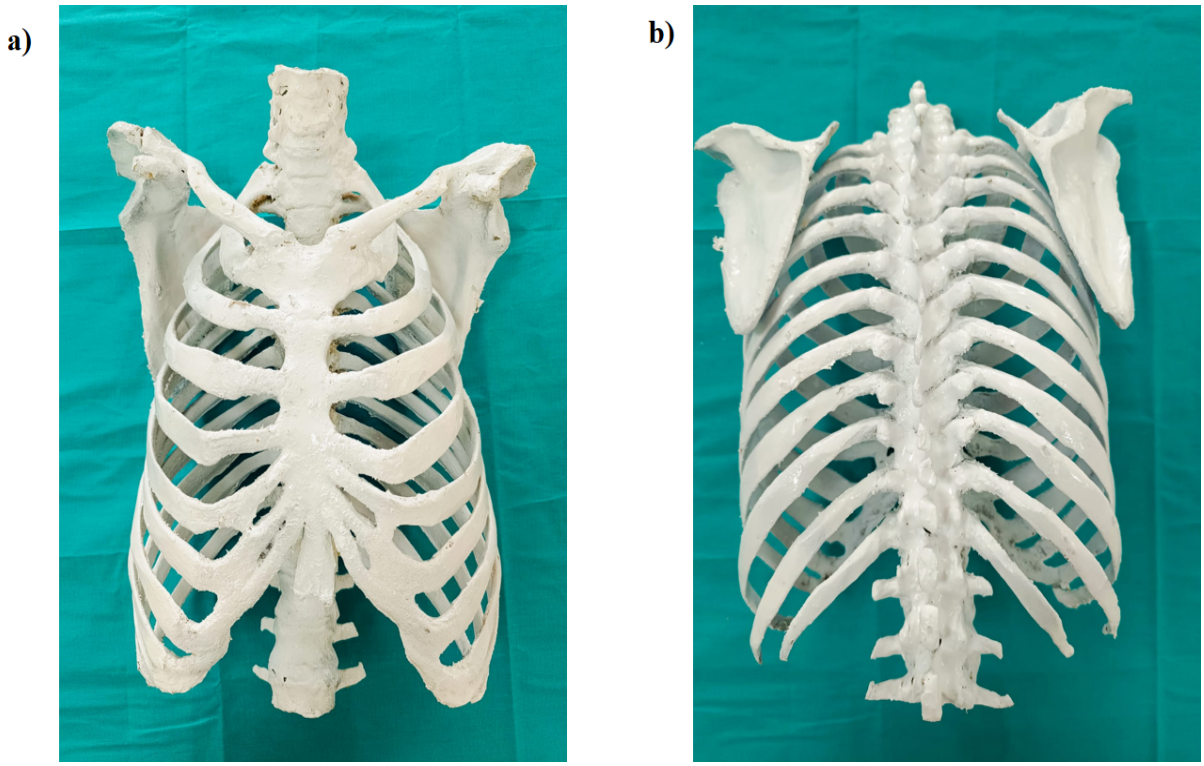

Figure 3: (a) Anterior view of bony framework of thorax after aerosol coating (b) Posterior view of bony framework of thorax after aerosol coating.

Discussion

The preservation of bones and cartilages provides a valuable source of biological information that can facilitate a comprehensive understanding of anatomical structures, their biomechanical properties, and the pathological conditions associated with them [8]. In view of the current challenges associated with cadaver procurement, including the substantial financial costs and the practical difficulties involved in long-term preservation due to limited manpower, as well as ethical and social considerations, there is an increasing need for simple, cost-effective, and sustainable methods of specimen preservation [9].

In Government medical college, most of the bone specimens were obtained from embalmed human cadavers and dissected anatomical specimens routinely utilized for teaching and educational purposes in the department of anatomy. At the end each academic year, the cadavers and prosected anatomical specimens underwent a controlled maceration process to facilitate the removal of soft tissues and subsequent isolation of the skeletal elements [5]. In this present study an unclaimed male cadaver was used and given for dissection to the undergraduate students. At the end of the dissection thoracic cage was preserved for this study. This study had shown an innovative cost-effective technique for preservation of thoracic cage with intact all joints. This will help the students to understand the orientation of all the joints in thoracic cage. A part of teaching this technique can be used for preservation of specimen in the museum, forensic investigations and archaeological studies.

The most difficult part of bone specimen preparation is the maceration technique. There are both physical and chemical maceration techniques are available. The physical maceration technique is a simple, low-cost method for preparing bone specimens while preserving their essential anatomical features and landmarks. In this study, we used a physical maceration technique involving the systematic removal of soft tissues using basic dissection instruments, including scalpels, scissors, forceps, brushes, sand papers, and scouring pads. The remaining soft-tissue residues were precisely removed with the help of anatomical forceps. A part of physical maceration, several chemical maceration techniques are available for skeletal specimen preparation. These methods use agents such as detergents and hydrogen peroxide (H2O2) to facilitate the removal of residual soft tissues [5]. These chemical maceration techniques may cause tissue shrinkage and alter the physical and structural integrity of the specimens through the action of chemical or preservative agents. Such alterations may significantly induce confounding effects and compromise the accuracy and reliability of subsequent anatomical observations and analyses [9,10]. However, some skeleton preservation techniques require specialized equipment and technically trained personnel, which may not be readily available in many anatomy laboratory settings. Additionally, bone preparation techniques such as freeze-drying require sophisticated infrastructure, including vacuum chambers and lyophilization systems, thereby imposing substantial financial and logistical constraints. Henceforth, the routine implementation of such procedures may be impractical, particularly in resource-limited laboratories [11]. Some bone preparation techniques use formalin, which are potentially hazardous to human health. Due to its carcinogenic properties, the use of formalin is limited in many laboratory settings. Moreover, these chemical maceration techniques may alter or compromise important anatomical features and landmarks, potentially leading to misinterpretation during anatomical teaching and learning. These alterations may also interfere in the accurate examination and interpretation of human remains in forensic and medico-legal investigations, as well as in anthropological and archaeological research. Henceforth, it is important to find the best possible way to preserve the specimens in an easy, cost-effective way which is safer for the handlers and should be able to mitigate environmental concerns as well [12,13]. In this context, the present study demonstrates a simple, cost-effective method of bone preservation based on manual maceration rather than chemical maceration. As illustrated in Figure 2 & 3, the preserved specimen retained the major anatomical features and landmarks of the bones, thereby facilitating students' understanding of muscle attachments, neurovascular relationships, and other clinically relevant anatomical structures. Such well-preserved specimens can serve as valuable teaching resources and enhance the effectiveness of anatomical education. Henceforth, physical maceration may be considered a practical and cost-effective approach for the preservation of bone specimens, particularly in resource-limited educational settings.

Additionally, this study highlights the use of a transparent, waterproof adhesive glue to maintain the articulations of the thoracic cage. In the absence of an adhesive glue, the joints tend to disarticulate as the bones undergo drying, resulting in the loss of the anatomical configuration of the thoracic cage. Thus, the application of a suitable adhesive glue provides an effective means of preserving the natural articulation and structural integrity of the specimen. Various adhesive materials are available, including ethyl cyanoacrylate-based adhesives and epoxy resins, have been described in previous studies for the stabilization and preservation of skeletal specimen [14]. In this present study, ethyl cyanoacrylate was used as a transparent adhesive

glue for the fixing of all the joints of the thoracic cage. As it forms strong adhesive bonds across the surfaces of the skeletal elements and effectively seals small gaps and surface irregularities. It forms a protective barrier which limits the penetration of moisture, oxygen, and other reactive substances, thereby reducing exposure to environmental factors that may contribute to specimen deterioration and degradation [9]. Additionally, this transparent adhesive glue can create strong bonds with the surfaces of bones and cartilaginous structures through interactions between their reactive functional groups and the organic components of the skeletal matrix, including collagen in bone and proteoglycans in cartilage. This adhesive stabilization helps in maintaining the anatomical integrity and structural relationships of the specimens, making them valuable resources for teaching and demonstration in anatomy classrooms. Their lightweight nature, ease of handling, and relatively low toxicity further enhance their practical utility. Moreover, the preserved specimens can be easily carried by the students for individual study, thereby facilitating convenient access to anatomical material beyond the conventional classroom setting.

Furthermore, this study was used as dry preservation technique to make the specimen light. In one of the similar studies, the same dry preservation technique was used and excellent findings were observed as the present study [15]. The combination of dry preservation with a transparent adhesive glue shown promising results for the preservation of wet bone and cartilaginous specimens [15]. Our study offers several advantages over conventional preservation techniques, including effortlessness of transportation, minimal toxicity, and reduced risk during handling. Furthermore, wet-preserved specimens generally require regular maintenance and monitoring, whereas the dry preservation method described in the present study requires minimal maintenance once the preservation process has been completed. Additionally, specimens maintained in preservative-filled containers require periodic replacement of the preservation solution, along with regular monitoring for changes in colour, concentration, or other signs of deterioration. In contrast, the adhesive-based dry preservation technique requires moderately minimal supervision and maintenance, thereby reducing both recurring costs and the logistical burden associated with long-term specimen storage.

Further enhancement and standardization of this preservation protocol may be explored through interdisciplinary collaboration. Advances in emerging fields such as tissue engineering, three-dimensional printing (3D), biomaterials science, and microfluidics may provide opportunities to develop improved, sustainable, and more sophisticated approaches for the long-term preservation of anatomical specimens

Conclusions

Anatomy is the cornerstones of medical education, with osteology constituting a fundamental component of the medical curriculum. However, limited access to adequate skeletal specimens remains a challenge in many Government medical colleges in India, potentially restricting students' opportunities for comprehensive anatomical learning. This present study had shown a simple, cost-effective, and manual technique for preserving bone specimens obtained from post cadaveric dissection, with satisfactory preservation of their precise anatomical features and structural integrity. This proposed technique may serve as a valuable adjunct to conventional anatomical teaching by providing durable, easily handled, and readily accessible skeletal specimens. Beyond medical education, this method may have potential applications in forensic and medico-legal investigations, skeletal analysis, anatomical museums, and research. Although the present study was limited to preservation of the thoracic cage, the findings provide a basis for further investigation into the applicability of this technique to other skeletal regions. Future studies may therefore explore the feasibility of extending the protocol to the preservation of complete human skeletons and evaluate its long-term durability and broader applications.

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Authors Contributions: All the authors had contributed equally in this present study.

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