Original Article

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Anatomy Section

Evaluating Bone Cleaning Methods for Educational Use by Using Student Satisfaction Index: A Cross-sectional Study

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ABSTRACT

Introduction: Bones play a crucial role in anatomy education programs, impacting the study of human body structure. Medical schools providing bones for self-study improve students' understanding of osteology. The integration of student feedback and satisfaction scores has emerged as a valuable tool for evaluating bone cleaning methods. Students, particularly those in educational settings, are often directly involved in the cleaning and preparation of skeletal materials for research and study purposes.

Aim: To assess student perceptions of various bone cleaning methods.

Materials and Methods: A cross-sectional study was conducted in the Department of Anatomy, Government Medical College, Kota, Rajasthan, India, from February 2023 to February 2025. Bones retrieved after seven years of burial and underwent various cleaning techniques using bleaching powder (method A), sodium hypochlorite solution (method B), detergent boiling (method D), and sun drying (method E). Students evaluated the bones using a prevalidated questionnaire on colour, odour, texture, cleanliness and clarity of structures and their perception was compared using a Chi-square test using Statistical Package for Social Sciences (SPSS) software version 17.0.

Results: Data analysis revealed patterns in their perceptions of bone quality, with mean scores of 3.55, 3.35, 3.42, and 3.26 for methods A, B, D, and E, respectively. These scores were comparable to the 4.15, the mean perception of commercially available bones considered the gold standard.

Conclusion: Simple, low-cost indigenous techniques, particularly bleaching powder, can produce bones of acceptable quality for osteology teaching, making them practical alternatives to commercially available specimens in medical education settings.

Keywords: Evaluation, Likert scale, Osteology, Perception, Preparation, Tools

INTRODUCTION

Bones play a crucial role in the anatomy education program [1]. Bones assist in determining the locations where soft-tissues are attached and the paths of neurovascular structures found in a specific area [2]. Providing bones to students for self-study in medical colleges could greatly improve the fundamental knowledge of osteology [2]. Medical schools have two options for obtaining human bones: buying them ready-made or preparing them in-house from cadavers at the school. Obtaining a complete human skeleton comes with a high price tag, sometimes going up to INR 6,50,000 for one fully assembled skeleton [2]. The high cost of buying human skeletons for medical colleges makes them an expensive investment [3].

In the realm of biological anthropology, archaeology, and forensic science, the meticulous cleaning and preparation of skeletal remains are imperative for accurate analysis and interpretation. Bone cleaning methods vary widely, ranging from chemical treatments to mechanical processes, each with its advantages and limitations [3]. Maceration, either with hot or cold water, is one of the simplest and most economical techniques, allowing natural breakdown of soft-tissues, but it is time-consuming and may weaken or deform delicate bones if temperatures are too high or soaking is prolonged [4]. Chemical methods, such as detergents, enzymes, sodium carbonate, or hydrogen peroxide, accelerate tissue removal and provide effective degreasing and whitening; however, improper concentration or overexposure can make bones brittle or alter surface characteristics [4]. Biological methods, particularly the use of dermestid beetles, are highly precise and preserve fine anatomical details without chemical damage, but these methods are slow, expensive, and require careful maintenance to prevent infestation [4]. Mechanical methods, including scraping, brushing, or pressure washing, offer immediate results and are useful for large bones with minimal soft-tissue, though they are labour-intensive and carry a high risk of scratching or damaging the bone surface [4]. Many Institutions therefore, use combination methods that integrate mechanical, maceration, and chemical steps to balance efficiency and preservation quality, although improper sequencing can still result in cumulative damage if not closely monitored [4].

The selection of an appropriate method depends on several factors, including the preservation goals, the nature of the bone material, and the desired outcomes [3]. As bone cleaning methods play a pivotal role in the integrity and usability of skeletal specimens, it is crucial to assess their efficacy and user satisfaction comprehensively. In recent years, the integration of student feedback and satisfaction scores has emerged as a valuable tool for evaluating bone cleaning methods. Students, particularly those in educational settings, are often directly involved in the cleaning and preparation of skeletal materials for research and study purposes. Their first-hand experiences and perceptions provide invaluable insights into the practicality, ease of use, and overall satisfaction with different cleaning techniques [5]. Hence, the study aimed to evaluate student perceptions of different bone cleaning methods used in anthropological and forensic contexts and to provide insights for educators and researchers on optimising bone cleaning methods based on student preferences and satisfaction.

MATERIALS AND METHODS

The cross-sectional study was performed in the Department of Anatomy, Government Medical College Kota, Rajasthan, India, from February 2023 to February 2025 after receiving ethical clearance from the Institutional Ethical Committee (ethical clearance no.F3/Acad/Ethical Clearance/2023/38 dated 14.06.2023.) The study material comprised bones that were retrieved from the graveyard of the anatomy department after seven years of burial, ensuring legal and ethical compliance. Study duration was then split into two phases, in which the first half was about the procurement and various procedures of bone cleaning, and the second phase was to study the students' perception of treated and procured bones, which was carried out through a pre-validated questionnaire that estimates the quality of various methods of bone cleaning. A convenient sampling method was employed for the study.

Inclusion criteria for bones:

1. All bones retrieved from the burial ground after seven years;
2. All bones that were damaged during the chemical treatment were also included as samples.

Exclusion criteria:

1. All broken and damaged bones were procured from the burial ground.

Study Procedure

Methodology for bone treatment [5]: Soft-tissue removal: Soft-tissue from the bones was removed using appropriate tools such as brushes, scrapers, or tweezers, cautiously, to preserve the integrity of the bone structure during this process.

Maceration: The bones were submerged in a 4% hydrogen peroxide (H2O2) solution diluted with water at a ratio of 1:7 [5]. Bones were allowed to soak in this solution for a duration of seven days.

Bleaching: The bones that were still not cleared from soft-tissue were treated in four different ways and were then labelled as set A, B, D and E.

Set C comprised commercially available bones and was used as a control group.

Description of the methods utilised for the bleaching of bones is as follows [Table/Fig-1]:

[Table/Fig-1]: Showing bones retrieved from various methods- Set D detergent boiling process, Set A bleaching powder treated bones, Set C commercially procured, Set B sodium hypochlorite treated and Set E sundried, followed by Set D detergent boil result.

Method for set A: Bleaching powder treatment [6]: A solution of bleaching powder (calcium hypochlorite) and water was prepared. The bones were then submerged in this solution and allowed to soak for a period of seven days. Cleaning: After the seven-day soaking period, the bones were removed from the bleaching powder solution and rinsed thoroughly with water to remove any residue. Drying: Once cleaned, the bones were allowed to air dry completely in a well-ventilated area.

Method for set B-Sodium hypochlorite treatment [7]: The bones were submerged in a solution of 5% sodium hypochlorite (NaOCl mol wt 74.4) for duration of 15 to 20 minutes. This short immersion helped to disinfect the bones and prevent microbial growth without causing erosion or significant damage to the bone structure.

Method for set C: Commercially procured bones that served as the gold standard.

Method for set D Boiling with detergent [8]: The bones were boiled in a solution of 250 gm washing detergent and 15 litres of water. The bones were boiled continuously for seven days, ensuring that the water level was maintained and replenished as needed to prevent drying out. Boil the bones for two consecutive days, with each day consisting of six hours of boiling. This prolonged boiling process helps to further remove residual tissue, grease, and other contaminants from the bones.

Method for set E: Initial cleaning (sundrying) [9]: Bones were allowed to dry for seven days continuously, and the soft-tissue remaining was scraped off later. This step aided in the removal of organic matter and disinfection of the bones by sunlight.

Methodical description of student perception: Inclusion criterion for participants: All the 1st year MBBS students of batch 2023-24 who filled the consent form and had >80 % of attendance were included in the study.

Exclusion criterion: Students having <80% attendance and who were chronically absent were excluded from the study.

Participant recruitment: Out of the total 250 1st year MBBS students, 210 students consented and were subsequently enrolled for the study and the rest were excluded from the study due to their irregular attendance. Students recruited were taught about the four bone cleaning methods in detail but were blinded about the allocated sets A, B, C, D and E to minimise the bias. Only the investigator was aware of the allocated sets. Participation was voluntary, and students were informed about the purpose and procedures of the study.

Data collection instrument: A Google form survey was designed to collect student perceptions of bone cleaning methods. The survey included questions assessing various aspects of bone quality, including aesthetic appearance, odour, handling, presence of soft-tissue (texture), and clarity of structures. Responses were recorded on a 5-point Likert scale ranging from 1 (poor) to 5 (excellent). A Cronbach's alpha of 0.914 indicates a high level of internal consistency reliability for the items analysed in the questionnaire, suggesting that the items are highly correlated with each other, indicating that they are measuring the same underlying construct reliably.

Evaluation procedure: Students were divided into small groups, each consisting of 10 students. They were instructed to visually inspect each set of bones and provide ratings based on their perceptions of the specified aspects. Students were given adequate time to examine each set of bones before recording their responses on the Google Form survey through their mobile phones.

Student Satisfaction Index (SSI) [10]:

The SSI was calculated to quantify students' overall satisfaction with each bone-cleaning method. Students rated each parameter using

a 5-point Likert scale (1= poor to 5= excellent). For each method, the mean of all item scores was converted to a percentage index using the formula:

SSI= (mean likert score-1/total likert score)×100

SSI (%) ⟶ Interpretation
0-20% ⟶ Very low satisfaction
21-40% ⟶ Low satisfaction
41-60% ⟶ Moderate satisfaction
61-80% ⟶ High satisfaction
81-100% ⟶ Very high satisfaction

STATISTICAL ANALYSIS

Responses from the Google form survey were collated and analysed using statistical software, such as SPSS version 17.0. Descriptive statistics, including means, standard deviations, and frequency distributions, were calculated for each aspect assessed. Differences in ratings across various aspects were examined and subjected to Chi-square test to determine which methods were perceived more favourably by students. A p-value<0.001 was considered to be significant.

RESULTS

It appears that respondents perceived the bleaching powder method as having lower perceptions in terms of colour and texture, while odour, clarity of structures, and cleanliness are perceived more positively, as their mean scores were greater than the average score of 3.55 [Table/Fig-2].

Respondents appear to view the method B (sodium hypochlorite) method as having lower perceptions of colour and odour, however clarity of structures, texture, and cleanliness are perceived more positively, as their mean scores were higher than the average score of 3.35 [Table/Fig-3].

It reveals that respondents viewed commercially accessible bones as having poorer perceptions in terms of odour and cleanliness, whereas clarity, colour, and texture are perceived more positively, as their mean scores were greater than the average score of 4.1458 [Table/Fig-4].

It reveals that respondents regarded detergent boiled bones as having poorer perceptions in terms of colour, odour, and texture, clarity and cleanliness were perceived more positively, as their mean scores were higher than the average of 3.42 [Table/Fig-5].

It reveals that respondents regarded sun dried bones as having poorer perceptions in terms of colour and odour, however, clarity, texture and cleanliness were perceived more positively, as their mean scores were higher than the average of 3.26 [Table/Fig-6].

Commercially processed bones demonstrated the highest satisfaction score at 75.8%. There is no significant difference in the distribution of colour among the groups, A and B with the p-value of 0.32 and 0.127, respectively. While there is significant difference in the distribution of among group D and E with the p-value of 0.00 and 0.05, respectively (p-value<0.05) when compared with Set C. There significant difference in the distribution of cleanliness among the all groups, A, B, D and E with the p-value of 0.000, 0.000, 0.000 and 0.002, respectively (p-value<0.05) [Table/Fig-7].

Method A	Item analysis	Percent of students with score 5	Percent of student with score 4	Percent of student with score 3	Percent of student with score 2	Percent of student with score 1	Scores (Mean±SD)	Perception
Bleaching powder	Colour	27 (12.9%)	59 (28.1%)	89 (42.4%)	28 (13.3%)	7 (3.3%)	3.338±.98	Low perception
	Odour	45 (21.4%)	72 (34.3%)	52 (24.8%)	36 (17.1%)	5 (2.4%)	3.552±1.08	High perception
	Clarity of structures	60 (28.6%)	56 (26.7%)	61 (29.0%)	26 (12.4%)	7 (3.3%)	3.648±1.12	High perception
	Texture	41 (19.5%)	67 (31.9%)	61 (29.0%)	31 (14.8%)	10 (4.8%)	3.467±1.11	Low perception
	Cleanliness	61 (29.0%)	77 (36.7%)	40 (19.0%)	27 (12.9%)	5 (2.4%)	3.771±1.08	High perception
	Average score						3.5552	

[Table/Fig-2]: Scores of perception of students for set A.
Scores 1= poor; 2= Bad; 3= Fair; 4= Good, 5= Excellent

Method -B	Item analysis	Percent of student with score-5	Percent of student with score-4	Percent of student with score-3	Percent of student with score-2	Percent of student with score-1	Scores (Mean±SD)	Perception
Sodium hypochlorite	Colour	26 (12.4%)	53 (25.2%)	67 (31.9%)	45 (21.4%)	19 (9.0%)	3.105±1.14	Low perception
	Odour	30 (14.3%)	75 (35.7%)	52 (24.8%)	41 (19.5%)	12 (5.7%)	3.333±1.16	Low perception
	Clarity of structures	40 (19.0%)	66 (31.4%)	65 (31.0%)	30 (14.3%)	9 (4.3%)	3.467±1.08	High perception
	Texture	34 (16.2%)	62 (29.5%)	71 (33.8%)	32 (15.2%)	11 (5.2%)	3.362±1.08	High perception
	Cleanliness	40 (19.0%)	77 (36.7%)	56 (26.7%)	26 (12.4%)	11 (5.2%)	3.519±1.09	High perception
	Average score						3.3572	

[Table/Fig-3]: Scores of perceptions of students for set B.
Scores 1= poor; 2= Bad; 3= Fair; 4= Good; 5= Excellent

Control group C	Item analysis	Percent of student with score-5	Percent of student with score-4	Percent of student with score-3	Percent of student with score-2	Percent of student with score-1	Scores (Mean±SD)	Perception
Commercially procured	Colour	100 (47.6%)	57 (27.1%)	39 (18.6%)	12 (5.7%)	2 (1.0%)	4.148±0.97	High perception
	Odour	87 (41.4%)	66 (31.4%)	36 (17.1%)	17 (8.1%)	4 (1.9%)	4.024±1.04	Low perception
	Clarity of structures	106 (50.5%)	67 (31.9%)	33 (15.7%)	1 (0.5%)	3 (1.4%)	4.295±0.85	High Perception
	Texture	94 (44.8%)	71 (33.8%)	33 (15.7%)	10 (4.8%)	2 (1.0%)	4.167±0.92	High Perception
	Cleanliness	94 (44.8%)	69 (32.9%)	31 (14.8%)	5 (2.4%)	11 (5.2%)	4.095±1.07	Low perception
	Total score						4.1458	

[Table/Fig-4]: Scores of perceptions of students for set C.
Scores 1= poor; 2= Bad; 3= Fair; 4= Good; 5= Excellent

Method D	Item analysis	Percent of student with score-5	Percent of student with score-4	Percent of student with score-3	Percent of student with score-2	Percent of student with score-1	Scores (Mean±SD)	Perception
Detergent boil	Colour	22 (10.5%)	62 (29.5%)	76 (36.2%)	41 (19.5%)	9 (4.3%)	3.224±1.01	Low perception
	Odour	31 (14.8%)	71 (33.8%)	65 (31.0%)	35 16.7%)	8 (3.8%)	3.390±1.04	Low perception
	Clarity of stuctures	42 (20.0%)	66 (31.4%)	71 (33.8%)	22 (10.5%)	9 (4.3%)	3.524±1.05	High perception
	Texture	30 (14.3%)	74 (35.2%)	66 (31.4%)	30 (14.3%)	10 (4.8%)	3.400±1.04	Low perception
	Cleanliness	43 (20.5%)	77 (36.7%)	57 (27.1%)	21 (10.0%)	12 (5.7%)	3.562±1.09	High perception
	Average score						3.42	

[Table/Fig-5]: Scores of perceptions of students for set D.
Scores 1= poor; 2= Bad; 3= Fair; 4= Good; 5= Excellent

Method E	Item analysis	Percent of student with score-5	Percent of student with score-4	Percent of student with score-3	Percent of student with score-2	Percent of student with score-1	Scores (Mean±SD)	Perception
Sun drying	Colour	25 (11.9%)	56 (26.7%)	55 (26.2%)	43 (20.5%)	31 (14.8%)	3.005±1.24	Low perception
	Odour	29 (13.8%)	64 (30.5%)	59 (28.1%)	43 (20.5%)	15 (7.1%)	3.233±1.13	Low perception
	Clarity of stuctures	40 (19.0%)	58 (27.6%)	50 (23.8%)	45 (21.4%)	17 (8.1%)	3.281±1.22	High perception
	Texture	38 (18.1%)	64 (30.5%)	58 (27.6%)	36 (17.1%)	14 (6.7%)	3.362±1.15	High perception
	Cleanliness	46 (21.9%)	71 (33.8%)	46 (21.9%)	29 (13.8%)	18 (8.6%)	3.467±1.21	High perception
	Average score						3.2698	

[Table/Fig-6]: Scores of perceptions of students for Set E.
Scores 1= poor; 2= Bad; 3= Fair; 4= Good; 5= Excellent

	Methods				
Variables	A	B	C	D	E
	Bleaching powder	Sodium hypochlorite (6%)	Commercially procured which served as gold standard	Detergent boil (25 gm in 10lt)	Sun drying
Colour	3.338 p=0.323 Chi-sq.=4.67	3.105 p=0.127 Chi-sq.=7.178	4.148	3.224 p= 0.000 Chi-sq.=21.830	3.005 p=005 Chi-sq.=15.01
Odour	3.552 p=0.738 Chi-sq.=1.987	3.333 p=0.000 Chi-sq=22.542	4.024	3.390 p=0.000 Chi-sq.=28.624	3.233 p=0.362 Chi-sq=4.337
Clarity	3.648 p=0.723 Chi-sq.=2.067	3.467 p=0.711 Chi-sq.=2.135	4.295	3.524 p=0.119 Chi-sq.=7.346	3.281 p=0.257 Chi-sq.=5.310
Handling (greasy)	3.467 p=0.393 Chi-sq.=4.097	3.362 p=0.586 Chi-sq.=2.832	4.167	3.400 p=0.080 Chi-sq.=8.322	3.467 p=0.660 Chi-sq.=2.413
Cleanliness	3.771 p=0.000 Chi-sq.=57.743	3.519 p=0.000 Chi-sq.=22.327	4.095	3.562 p=0.000 Chi-sq.=27.674	3.467 p=0.002 Chi-sq.=16.666
Mean score	3.55	3.3572	4.1458	3.42	3.2698
Student satisfaction index	71.8%	70.1%	75.8%	70.76%	69.4%

[Table/Fig-7]: Scores of perceptions of student and student satisfaction index.
p = A p-value<0.001 wa s considered to be significant.

DISCUSSION

Bone cleaning and procuring methods have been subjects of extensive research and innovation over the past decade, driven by a variety of disciplines such as archaeology, forensic science, museum conservation, and biological sciences [2].

Bleaching powder, also known as calcium hypochlorite, has been utilised for bone cleaning in archaeological and forensic contexts. It effectively removes organic matter and reduces bacterial contamination [6]. However, prolonged exposure to bleaching powder may lead to degradation of bone collagen and alterations in bone mineral. In the current study, the bleaching powder method may result in bones with a good odour, clear structures, and high cleanliness, there are concerns regarding colour perception and handling properties.

Sodium hypochlorite is widely used for bone cleaning due to its disinfectant properties. It effectively eliminates microbial contaminants from bones [11]. Nevertheless, exposure to hypochlorite solutions should be controlled to prevent damage to bone structure and potential interference with subsequent analyses [5]. In the present study, the scores suggested that though the sodium hypochlorite method may result in relatively clean bones with clear structures and good handling properties, there are concerns regarding colour and odour.

Yadav P et al., in 2022 instigated a comparison of laundry detergent and antiformin solution methods to retrieve clean bones from embalmed cadavers [8]. Detergents, particularly enzymatic detergents, are commonly used in bone cleaning processes to break down fats and proteins. Studies have shown that enzymatic detergents can effectively remove soft-tissue residues from bones [12]. However, caution should be exercised as some detergents may leave residues on bones, affecting subsequent analyses [1].

Studies suggest that hydrogen peroxide is effective in removing organic matter from bones due to its oxidising properties [13]. Research indicates that soaking bones in a solution of hydrogen peroxide and water helps in whitening and disinfecting bones without causing significant damage to the bone structure [14].

Comparison of the outcomes of studies published in the literature [Table/Fig-8] [6-8,15-18].

Authors	Year	Place	Study
Kumar S et al., [7]	2023	Uttrakhand, India	Developed an economical technique with a 10:1 ratio of hypochlorite to water.
Yadav P et al., [8]	2022	India	Compared laundry detergent and antiformin solution for the bone retrieval and indicated no single bone preparation technique was superior; instead, the choice of method should be tailored to the type of bone, as different techniques offer distinct qualitative advantages
Soni A et al., [15]	2021	India	Compared maceration techniques for bone retrieval, finding 30% H_2O_2 as the best method and a new paste of baking soda and H_2O_2 for smaller specimens.

Sharma DK and Chaudhary N [16]	2019	Chhattisgarh, India	Compared use of water, 50% H_2O_2, NaOH and lime water for cleaning the bones and found the method of limewater method superior to H2O2 method
Sarma DA et al., [6]	2017	Rajasthan, India	Graded bleaching powder solutions enable rapid procurement of clean bone specimens from embalmed cadavers for educational and research use
Lai PS et al., [17]	2015	Malaysia	Entomological bone cleaning using maggots, especially Chrysomyia rufifacies, was more time- and cost-effective than chemical methods, such as detergent and H2O2, and better preserved bone integrity. Forensic specialists also preferred it for skeletal examination.
Couse T and Connor M [18]	2015	USA	Evaluated the effectiveness of six maceration techniques applied to skeletal samples, including simmering with two degreasing agents (Dawn® and Greased Lightning®), power washing, insect scavenging, microwave maceration, and physical maceration and found warm water maceration methods were most effective
Current study	2026	Kota, Rajasthan, India	Used 4 different techniques -bleaching powder, sodium hypochlorite, detergent boiling and sundrying for cleaning bones all with high student satisfaction scores indicating employing of the procedures as per feasibility.

[Table/Fig-8]: Comparison of different bone cleaning techniques by different authors [6-8,15-18].

Limitation(s)

The study was limited by the absence of standardised boiling equipment with fixed timers, which restricted the precise time-controlled application of the boiling technique. Additionally, the unavailability of high-precision automated chemical dispensing instruments required all reagents to be manually measured using a digital balance, which may have introduced minor variability in chemical preparation.

CONCLUSION(S)

Based on the Student Satisfaction Index (SSI), the bleaching powder technique achieved the highest satisfaction among the locally prepared methods, indicating better specimen cleanliness, appearance, and handling quality.

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