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Beyond the scalpel: clay modeling as an innovative and engaging approach to teaching facial muscle anatomy to medical students

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Abstract: Introduction: Traditional methods of teaching facial muscle anatomy to medical students, particularly cadaveric dissection, face challenges such as resource limitations and emotional impact. This study explores the efficacy and student experience of using clay modeling as an alternative pedagogical tool for learning facial muscle anatomy.

Methods: A qualitative study was conducted with medical students participating in a hands-on clay modeling exercise focused on facial muscles, utilizing concrete skulls and sculpting clay. Student feedback was collected through qualitative methods and analyzed using thematic analysis [12, 13, 15, 16] to identify key learning experiences and perceptions.

Results: Clay modeling proved to be an effective and engaging method for teaching facial muscle anatomy, enhancing students' visualization, spatial internalization, and memory retention. Four core themes emerged from student feedback: Fun, Collaboration, Active Learning, and Bittersweetness. Students reported improved understanding, heightened engagement, and reinforced team-based skills through collaborative modeling. The "Bittersweetness" theme highlighted the emotional and humanistic connection students formed with the anatomical structures, reflecting on the sanctity of human anatomy and the life-death cycle. This multisensory approach (tactile, visual, kinesthetic) bolstered anatomical literacy and offers a cost-effective, scalable solution, particularly

relevant during cadaver shortages [2, 11, 17, 18, 19, 20]. Students also recommended expanding this technique to other anatomical regions.

Conclusion: Clay modeling is a valuable, multifaceted pedagogical tool that not only enhances anatomical knowledge and retention but also fosters emotional intelligence and professionalism in medical students. Its cost-effectiveness, scalability, and ability to bridge technical and humanistic aspects make it a highly recommended approach for modern anatomy education.

Keywords: Clay modeling, Anatomy education, Facial muscles, Medical students, Hands-on learning, Qualitative study, Humanistic education.

Introduction: 1.1 Importance of Facial Anatomy in Medical Practice

The intricate anatomy of the human face is fundamental to a vast array of medical disciplines, making its comprehensive understanding an indispensable component of medical education. Beyond its role in personal identity and non-verbal communication, the facial region houses a complex network of muscles, nerves, and vessels that are critical for essential functions such as mastication, speech, and facial expression [1]. For medical students, a profound grasp of facial anatomy is not merely an academic exercise but a prerequisite for clinical competence across numerous specialties. In aesthetic surgery, for instance, a detailed knowledge of facial fat compartments and muscle layers is paramount for successful interventions and avoiding complications [1, 3]. Similarly, reconstructive surgery relies heavily on the precise understanding of facial structures to restore form and function following trauma, disease, or congenital anomalies. Neurologists depend on this anatomical knowledge to diagnose conditions affecting facial nerves and muscles, while general practitioners and emergency physicians frequently encounter facial injuries or infections requiring accurate anatomical localization. The complexity of facial musculature, with its nuanced origins, insertions, and actions, demands a teaching approach that facilitates not just rote memorization but true spatial internalization and functional understanding.

1.2 Challenges and Limitations of Traditional Anatomy Education

For centuries, cadaveric dissection has been the cornerstone of anatomical education, offering an unparalleled three-dimensional appreciation of human structures [7]. The tactile experience, the ability to explore anatomical variations, and the direct engagement with human form have long been considered invaluable for medical students [21]. However, traditional cadaveric dissection, while profoundly beneficial, is increasingly facing significant challenges and inherent limitations in modern medical curricula. The most pressing of these include the escalating costs associated with cadaver procurement, maintenance, and disposal, as well as the global scarcity of cadaveric material [6, 21]. This shortage has been particularly exacerbated by global events, such as the COVID-19 pandemic, which placed immense strain on supply chains and access to traditional dissection facilities.

Beyond logistical hurdles, cadaveric dissection also presents ethical considerations and can evoke significant emotional responses in students [27, 28, 29]. While many students value the experience, some may find the encounter with death and human remains emotionally challenging, potentially impacting their learning experience and psychological well-being [26, 31]. Furthermore, while dissection provides a macroscopic view, it can be destructive, making it difficult to repeatedly observe delicate structures or reconstruct complex spatial relationships, especially in regions like the face where muscles are often thin and intimately interwoven [23]. Two-dimensional resources, such as textbooks, anatomical atlases, and digital images, serve as essential complements but inherently struggle to convey the intricate three-dimensional spatial relationships of anatomical structures, which is particularly challenging for complex regions like the facial muscles [10]. Students often find it difficult to translate flat images into a mental model of depth and spatial arrangement, leading to a superficial understanding rather than true internalization. These limitations necessitate the exploration and integration of alternative or complementary pedagogical tools that can address these challenges while maintaining or enhancing learning outcomes.

1.3 Introduction to Clay Modeling as an Alternative/Complementary Pedagogical Tool

In response to the evolving landscape of medical education and the limitations of traditional methods, innovative approaches that foster active, hands-on learning have gained increasing traction. Art, in its various forms, has historically been intertwined with anatomical study, with artists often serving as pioneering anatomists [5]. This historical connection underscores the potential for creative, hands-on methodologies in contemporary anatomy education. Clay modeling, in particular, has emerged as a promising pedagogical tool, leveraging tactile and visual engagement to facilitate a deeper understanding of

anatomical structures [18].

Previous studies have demonstrated the efficacy of clay modeling across various anatomical contexts. Kooloos et al. (2014) found that anatomical knowledge gain through clay modeling exercises was comparable to or even superior to live and video observations [2]. Oh et al. (2009) highlighted the benefits of using clay models for learning cross-sectional anatomy, suggesting improved spatial reasoning [9]. Motoike et al. (2009) reported positive outcomes in community college students using clay modeling to learn human muscles, indicating its broad applicability [11]. More recently, studies have explored its utility for complex regions like the periventricular structures of the human brain [19] and pelvic floor anatomy [20], consistently demonstrating enhanced understanding and engagement. These findings suggest that clay modeling can significantly improve students' ability to visualize and internalize complex spatial anatomy, offering a tangible, three-dimensional learning experience that bridges the gap left by 2D resources. Its hands-on nature encourages active construction of knowledge, moving beyond passive reception of information.

1.4 Rationale and Aim of the Study

Despite the growing body of evidence supporting clay modeling in anatomy education, its specific application and efficacy in teaching the intricate anatomy of the facial muscles to medical students remain an area ripe for further investigation. The facial region, with its numerous small, interconnected muscles responsible for subtle expressions, presents unique challenges in anatomical comprehension. Given the current constraints on cadaveric resources and the recognized limitations of purely 2D learning, there is a compelling need for effective, scalable, and engaging alternatives.

This study was therefore designed to investigate the effectiveness and student perceptions of using clay modeling specifically for teaching facial muscle anatomy to medical students. We aimed to explore how this hands-on approach influences students' understanding, memory retention, engagement, and emotional connection to the subject matter. Our central hypothesis was that clay modeling would offer an effective, engaging, and emotionally resonant alternative or complement to traditional methods, enabling students to better visualize and internalize the spatial anatomy of facial muscles, while also fostering crucial professional and humanistic competencies. By focusing on the facial muscles, a region of high clinical relevance and anatomical complexity, this study seeks to provide robust evidence for the integration of clay modeling into medical curricula as a valuable pedagogical innovation.

METHODS

2.1 Study Design

This study adopted a qualitative research approach to deeply explore and understand the experiences and perceptions of medical students participating in a clay modeling exercise focused on facial muscle anatomy. Qualitative methodologies are particularly suited for uncovering nuanced insights, subjective meanings, and the rich contextual details of human experiences [13, 15]. Thematic analysis, as described by Braun and Clarke [13, 16], was chosen as the primary method for data analysis, allowing for the identification, analysis, and reporting of patterns (themes) within the qualitative data collected from student feedback. This approach provided a flexible yet rigorous framework to systematically categorize and interpret the diverse range of student responses.

2.2 Participants and Setting

The study involved a cohort of medical students enrolled in their preclinical years, who were undertaking their foundational anatomy course. These students had prior exposure to basic anatomical concepts through lectures and 2D resources but had limited or no prior experience with cadaveric dissection of the facial region. The clay modeling exercise was integrated into their anatomy curriculum as a supplementary, hands-on workshop designed to enhance their understanding of facial musculature. The workshop was conducted in a dedicated anatomy laboratory setting, providing a conducive environment for practical learning. The specific number of participants and their demographic details were recorded to provide context for the study's findings, though individual identifying information was strictly anonymized to ensure confidentiality.

2.3 Intervention: Clay Modeling Exercise

The core intervention of this study was a structured clay modeling exercise focused on the muscles of facial expression and mastication. Students were provided with concrete skulls, serving as accurate, reusable anatomical templates, and high-quality sculpting clay. The choice of concrete skulls offered a robust and readily available substitute for cadaveric material, addressing concerns of cost and availability, and allowing for repeated use [4]. Each student or small group (depending on the collaborative structure) was given a skull and a sufficient quantity of clay.

The exercise began with a brief review of the osteological landmarks of the skull relevant to facial muscle attachments. Students were then guided, through a combination of visual aids (e.g., anatomical diagrams, 3D models) and verbal instructions, to sculpt

individual facial muscles onto the concrete skulls. The process involved identifying the origin and insertion points of each muscle, understanding its fiber direction, and then physically building up the muscle mass with clay. Key muscles covered included the orbicularis oculi, orbicularis oris, zygomaticus major and minor, buccinator, temporalis, masseter, and platysma, among others. Emphasis was placed on understanding the spatial relationships between muscles, their layering, and their functional roles in facial expression and movement. The duration of the exercise was approximately three hours, allowing ample time for students to engage deeply with the material and complete their models. Students were encouraged to articulate their understanding as they sculpted, fostering active recall and peer discussion.

2.4 Data Collection

To capture the richness of student experiences and perceptions, multiple methods of data collection were employed following the clay modeling exercise. These included:

- Post-Activity Surveys: Anonymous surveys were distributed to all participants immediately after the workshop. These surveys contained a mix of open-ended questions designed to elicit detailed qualitative feedback on their learning experience, engagement levels, perceived benefits, and any challenges encountered. Questions specifically probed their understanding of spatial anatomy, memory retention, and comparison to other learning methods.
- Focus Group Discussions: A subset of students volunteered to participate in semi-structured focus group discussions. These sessions, facilitated by a researcher, allowed for deeper exploration of emergent themes, encouraged peer interaction, and provided a platform for students to elaborate on their individual experiences and collective insights. Prompts included questions about the most valuable aspects of the exercise, how it differed from other learning modalities, and their emotional responses.
- Reflective Essays: Students were given the option to submit short, reflective essays within a week of the workshop. This allowed for individual contemplation and a more personal articulation of their learning journey, including any emotional or humanistic insights gained.

All data collection methods were designed to be non-leading, encouraging students to provide authentic and unfiltered responses.

2.5 Data Analysis

The qualitative data collected from surveys, focus groups, and reflective essays underwent a systematic thematic analysis, following the six-phase guide by Braun and Clarke [13, 16]:

1. Familiarization with the Data: Researchers repeatedly read through all collected data (transcripts, survey responses, essays) to gain a comprehensive understanding of the content and identify initial patterns and interesting points.
2. Generating Initial Codes: Relevant segments of text were systematically coded. Codes were descriptive labels assigned to features of the data that appeared interesting or relevant to the research question. This was done inductively, without preconceived categories, allowing themes to emerge directly from the data [12].
3. Searching for Themes: Codes were then grouped into potential themes based on their coherence and relevance to the overall dataset. This involved looking for broader patterns and relationships among the initial codes.
4. Reviewing Themes: The potential themes were reviewed against the entire dataset to ensure they accurately reflected the data and that no significant data was overlooked. Themes were refined, merged, or discarded as necessary to ensure distinctiveness and internal consistency.
5. Defining and Naming Themes: Each theme was clearly defined, and a concise name was assigned that captured its essence. This phase involved articulating the story each theme told and how it contributed to the overall understanding of the students' experiences.
6. Producing the Report: The final themes were presented with illustrative quotes from the data, providing empirical evidence for each theme and linking them back to the research questions.

Two independent researchers conducted the coding and thematic analysis to enhance reliability and reduce potential bias, with discrepancies resolved through discussion and consensus.

2.6 Ethical Considerations

The study adhered to all relevant ethical guidelines. Approval was obtained from the Institutional Review Board (IRB) prior to the commencement of data collection. All participating medical students provided informed consent, ensuring they understood the purpose of the study, the nature of their involvement, and their right to withdraw at any time without penalty. Strict measures were implemented to ensure the anonymity and confidentiality of all collected data. Student responses were de-identified, and data was stored securely, accessible only to the research team. No personal identifying information was collected or linked to the qualitative feedback, safeguarding the privacy of the participants.

RESULTS

The qualitative analysis of student feedback revealed that the clay modeling exercise was a highly effective and engaging pedagogical tool for teaching facial muscle anatomy. The findings coalesced around several key areas, demonstrating enhanced learning outcomes, the emergence of four distinct core themes, practical benefits, and clear student recommendations for broader application.

3.1 Enhanced Learning Outcomes and Engagement

Students consistently reported a significant improvement in their understanding, visualization, and memory retention of facial muscle anatomy following the clay modeling activity. The hands-on, three-dimensional nature of the exercise proved to be a powerful catalyst for learning, moving beyond the limitations of passive observation or two-dimensional resources. Many students articulated that the act of physically constructing the muscles allowed them to internalize spatial relationships in a way that lectures or anatomical atlases could not. For instance, one student commented, "Building the muscles layer by layer, seeing how they attach to the skull and to each other, made the spatial anatomy click in a way that just looking at diagrams never did." This aligns with previous research highlighting the benefits of active construction of knowledge in anatomy education [2, 9, 11, 17].

The activity fostered increased student engagement, with participants describing the experience as highly interactive and stimulating. The multisensory nature of the learning process was frequently emphasized. The tactile engagement of manipulating clay, the visual feedback of seeing the 3D model take shape, and the kinesthetic experience of mimicking muscle actions with their hands all contributed to a deeper reinforcement of anatomical detail and the development of anatomical literacy [4, 14]. A participant noted, "It wasn't just about memorizing names; it was about feeling the shape, understanding the movement, and seeing the connections. It made anatomy come alive." This active, experiential learning contrasted sharply with the often-passive nature of traditional lectures or solitary study with textbooks, leading to a more profound and memorable learning experience [8].

3.2 Emergence of Four Core Themes from Student Feedback

Four overarching themes consistently emerged from the thematic analysis of student feedback: Fun, Collaboration, Active Learning, and Bittersweetness. These themes collectively capture the multifaceted impact of the clay modeling exercise on the students' learning and emotional experiences.

3.2.1 Theme 1: Fun

A recurring sentiment among students was the sheer enjoyment and positive attitude they held towards the clay modeling activity. The element of "fun" was not merely about entertainment but was intrinsically linked to enhanced engagement and a more positive learning environment. Students found the hands-on, creative aspect of sculpting to be a refreshing departure from conventional study methods. This enjoyment translated into a willingness to spend more time on the task, explore details, and persist through challenges. As one student put it, "It didn't feel like studying. It felt like playing, but I was learning so much without even realizing it." This highlights the pedagogical power of integrating enjoyable and novel activities into the curriculum, which can significantly boost motivation and reduce the perceived burden of learning complex subjects.

3.2.2 Theme 2: Collaboration

The collaborative nature of the clay modeling exercise, particularly when students worked in small groups, significantly reinforced team-based skills, communication, and peer learning. Students reported actively engaging in shared problem-solving, discussing anatomical landmarks, muscle origins, and insertions, and collectively troubleshooting challenges as they sculpted. This peer-to-peer interaction facilitated a deeper understanding, as students explained concepts to one another, corrected misconceptions, and learned from diverse perspectives. "Working together, we could bounce ideas off each other," one student explained. "If someone was stuck on a muscle, another person could explain it differently, or we'd figure it out as a team." This collaborative environment mirrors the interdisciplinary nature of clinical practice, where effective communication and teamwork are paramount [25]. The exercise thus served as a practical platform for developing essential competencies beyond pure anatomical knowledge.

3.2.3 Theme 3: Active Learning

The theme of "Active Learning" underscored students' perception of deep, hands-on engagement leading to a superior internalization of spatial anatomy. Unlike passive methods where information is received, clay modeling required students to actively construct their knowledge. This involved critical thinking, problem-solving, and a continuous process of hypothesis testing as they shaped the clay to represent anatomical structures accurately. Students noted that the act of physically building the muscles forced them to think critically about their three-dimensional relationships, their depth, and their connections to the underlying

bone. "You can look at a picture a hundred times, but until you actually build it, you don't truly understand how it fits," a student reflected. This active construction of knowledge promotes deeper cognitive processing and long-term retention, moving beyond superficial memorization to a genuine understanding of anatomical form and function.

3.2.4 Theme 4: Bittersweetness

Perhaps the most profound and unexpected theme that emerged was "Bittersweetness," which captured the complex emotional responses students experienced, particularly when it came time to dismantle their meticulously crafted clay models. This act, though necessary for the exercise's completion, evoked feelings of loss, reflection on the sanctity of human anatomy, and a contemplation of the life-death cycle. Students described the dismantling process as "sad" or "bittersweet," likening the destruction of their models to the transient nature of life or the respect due to human remains. One student poignantly stated, "It was bittersweet to take it apart. You put so much effort into creating something that represents life, and then you have to destroy it. It made me think about the cadavers and the respect they deserve." This emotional connection, fostered through the act of creation and subsequent deconstruction, provided a unique platform for humanistic and professional development [28, 29, 30, 31]. It subtly introduced concepts of respect for the human body, the ephemeral nature of life, and the ethical responsibilities inherent in medical practice, aspects often implicitly conveyed in cadaver labs but rarely explicitly discussed in other learning modalities [24, 26, 32].

3.3 Practical Benefits and Scalability

Beyond its pedagogical and emotional impact, the clay modeling exercise demonstrated significant practical advantages, particularly in terms of cost-effectiveness and scalability. The use of durable concrete skulls as templates, combined with reusable sculpting clay, presented a highly viable and sustainable alternative to cadaveric material [4]. This approach drastically reduces the prohibitive costs associated with cadaver procurement, preservation, and disposal, making it an attractive option for resource-limited institutions or those facing budget constraints. Furthermore, the materials are readily available and can be reused multiple times, contributing to the sustainability of the educational program.

The scalability of the intervention is another notable benefit. Unlike cadaveric dissection, which requires specialized facilities and limited availability, clay modeling workshops can be easily replicated for large cohorts of students. The materials are transportable, allowing for adaptability to various learning environments, including potential remote learning setups or decentralized workshops. This flexibility makes clay modeling a robust solution for ensuring consistent and high-quality anatomy education, especially in times of unforeseen disruptions or cadaver shortages.

3.4 Student Recommendations for Broader Application

The positive reception of the clay modeling exercise was further underscored by student recommendations for its broader application across other complex anatomical systems. Many participants spontaneously suggested that the technique would be highly beneficial for learning other intricate regions of the body, such as the hand or the pelvis. As one student articulated, "If we could do this for the hand, with all its tiny bones and muscles, it would be so much easier to understand than just looking at a book." This specific recommendation for the pelvis aligns with existing literature that has successfully applied clay modeling to this region [20], further validating the perceived utility and transferability of the method. These unsolicited suggestions from the students themselves serve as strong evidence of the perceived value and applicability of clay modeling as a versatile and effective pedagogical tool in anatomy education.

DISCUSSION

4.1 Summary of Key Findings

This study provides compelling evidence that clay modeling is an effective, engaging, and emotionally impactful method for teaching facial muscle anatomy to medical students. Our findings demonstrate that this hands-on approach significantly enhances students' understanding, visualization, and memory retention of complex spatial anatomy. The qualitative analysis revealed four core themes: Fun, Collaboration, Active Learning, and Bittersweetness, each highlighting distinct benefits of the intervention. Students reported increased enjoyment and engagement, improved team-based skills through collaborative sculpting, and a deeper internalization of anatomical knowledge through active construction. Crucially, the "Bittersweetness" theme unveiled a unique dimension of emotional and humanistic development, as students reflected on the sanctity of human anatomy and the life-death cycle during the dismantling of their models. Furthermore, the exercise proved to be a cost-effective and scalable educational resource, offering a viable alternative, particularly in contexts of cadaver shortages.

4.2 Comparison with Existing Literature

Our findings corroborate a growing body of literature that advocates for hands-on, three-dimensional learning modalities in anatomy education. Previous studies have consistently shown that active engagement with physical models can improve spatial understanding and knowledge retention more effectively than passive observation or two-dimensional representations [2, 9, 10, 11, 14, 17, 18, 19, 20]. The enhanced visualization and spatial internalization reported by our students align directly with these prior investigations, reinforcing the idea that tactile and kinesthetic learning pathways are crucial for comprehending complex anatomical relationships. Specifically, the success in teaching facial muscles, a region known for its intricate layering and functional nuances, adds to the evidence base for clay modeling's utility in highly detailed anatomical areas, similar to its application in pelvic anatomy [20] or brain structures [19].

This study also highlights the practical advantages of clay modeling in contrast to the limitations of traditional cadaveric dissection. While cadavers offer an invaluable experience [7], their increasing scarcity, high costs, and logistical challenges, particularly exacerbated by global events, necessitate viable alternatives [6, 21]. Clay modeling provides a sustainable, cost-effective, and reusable solution [4], addressing these resource constraints while maintaining high educational value. It offers a complementary approach that can bridge the gap when cadaveric material is limited or unavailable, ensuring that students still gain a robust three-dimensional understanding of anatomy.

4.3 Pedagogical Implications

The successful integration of clay modeling into the curriculum for teaching facial muscle anatomy carries significant pedagogical implications for modern medical education. Firstly, it offers a robust solution to the persistent challenges of cadaver shortages and the limitations of purely two-dimensional learning resources [21, 22]. By providing a hands-on, tangible experience, clay modeling directly addresses the difficulty students often face in translating flat images into a comprehensive mental model of complex anatomical structures.

Secondly, the value of multisensory learning is profoundly demonstrated. The tactile manipulation of clay, the visual feedback of constructing a 3D model, and the kinesthetic engagement involved in understanding muscle actions collectively create a rich learning environment. This integrated sensory input reinforces anatomical detail and significantly enhances anatomical literacy, leading to deeper encoding and better long-term retention of knowledge. This approach caters to diverse learning styles, ensuring a more inclusive and effective educational experience for all students. The positive emotional responses, particularly the "Fun" theme, suggest that incorporating engaging and creative activities can transform the learning experience, fostering intrinsic motivation and a more positive attitude towards challenging subjects like anatomy.

4.4 Humanistic and Professional Development

Perhaps one of the most compelling and unique contributions of this study is the emergence of the "Bittersweetness" theme, which underscores the profound potential of clay modeling to foster humanistic and professional development in medical students. The emotional responses evoked by the dismantling of their models—a process that mirrored the transient nature of life and the respect due to human remains—provided an unique yet powerful platform for ethical reflection and empathy. This experience subtly introduces students to the emotional complexities associated with handling human anatomy and confronting mortality, aspects typically encountered in the cadaver lab [26, 27, 28, 29, 30, 31].

By engaging in an activity that elicits feelings of connection and then loss, students are implicitly encouraged to contemplate the sanctity of the human body and the profound responsibility that comes with their future profession. This goes beyond mere anatomical knowledge, cultivating emotional intelligence and empathy, which are critical attributes for compassionate medical practice [24, 32]. The clay modeling exercise thus provides a unique opportunity to integrate ethical reflection and professionalism directly into the anatomy curriculum, preparing students not just technically, but also emotionally and ethically, for the realities of patient care. It offers a safe and controlled environment to explore these deep themes, complementing the often intense and direct exposure in the cadaver lab.

4.5 Strengths and Limitations of the Study

A significant strength of this study lies in its detailed qualitative approach, which allowed for a rich and nuanced understanding of student experiences and perceptions. By employing thematic analysis on diverse data sources (surveys, focus groups, reflective essays), we were able to uncover deep insights into the pedagogical and emotional impacts of clay modeling, particularly the unique "Bittersweetness" theme. The specific focus on facial muscle anatomy, a clinically relevant yet anatomically challenging region, adds valuable evidence to the literature on applied anatomy teaching methods. Furthermore, the study highlights

practical, scalable implications for medical education, offering a tangible solution to current resource constraints.

However, the study is not without limitations. As a qualitative study conducted with a specific cohort of medical students, the findings, while rich in detail, may not be broadly generalizable to all medical student populations or educational settings. The sample size, while adequate for qualitative inquiry, limits quantitative statistical analysis. There is also a potential for a novelty effect [10], where the initial enthusiasm for a new teaching method might temporarily inflate perceived benefits. Future research could address this by conducting longitudinal studies to assess long-term knowledge retention and by comparing clay modeling outcomes with other innovative or traditional teaching modalities in a more controlled, quantitative manner.

4.6 Future Research Directions

Based on the promising results of this study, several avenues for future research emerge. Longitudinal studies are warranted to assess the long-term knowledge retention and clinical application of anatomical knowledge gained through clay modeling, comparing it with traditional methods over extended periods. Comparative studies, potentially employing mixed-methods designs, could quantitatively evaluate the effectiveness of clay modeling against other teaching modalities, such as virtual reality, plastinated specimens [14], or advanced imaging techniques, across different anatomical regions.

Furthermore, exploring the application of clay modeling to other complex anatomical systems, as suggested by the students themselves (e.g., the hand, the pelvis, or the nervous system), would provide valuable insights into its versatility and transferability. Research could also investigate the optimal integration of clay modeling within existing curricula, determining the ideal timing, duration, and collaborative structures for maximum pedagogical benefit. Finally, further qualitative research could delve deeper into the "Bittersweetness" theme, exploring how these emotional responses evolve throughout medical training and how such humanistic aspects can be intentionally fostered and integrated into professionalism curricula.

CONCLUSION

5.1 Reiteration of Main Argument

In conclusion, this study unequivocally demonstrates that clay modeling serves as a highly valuable and versatile tool for teaching facial muscle anatomy to medical students. It transcends the limitations of traditional 2D resources and offers a practical, engaging alternative to cadaveric dissection, particularly pertinent in an era of increasing resource constraints.

5.2 Synthesis of Benefits

The multifaceted benefits of clay modeling encompass enhanced pedagogical effectiveness through improved spatial understanding, visualization, and memory retention; heightened student engagement and enjoyment; the cultivation of essential collaborative and active learning skills; and, uniquely, a profound contribution to students' emotional intelligence and professional development by fostering a humanistic connection to anatomy. Its cost-efficiency and scalability further underscore its practical utility as a sustainable educational resource.

5.3 Call for Broader Adoption

Given its demonstrated efficacy, engagement, and unique capacity to bridge the technical and humanistic aspects of anatomical learning, we strongly advocate for the broader integration of clay modeling into medical curricula. This robust and innovative approach offers a powerful means to sculpt not just anatomical knowledge, but also the empathetic and professional qualities essential for future medical practitioners.

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