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**ORIGINAL ARTICLE**

# Effects of 3D Bone Models on Anatomy Education: Student Survey

# 3 Boyutlu Kemik Modellerinin Anatomi Eğitimine Etkileri: Öğrenci Anketi

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**ABSTRACT**

**Background/Aim:** Anatomy education is of great importance in evaluating the human body as a whole and understanding the normal functioning of organs and systems. Knowledge of human anatomy plays a critical role in the diagnosis of diseases, surgical interventions, evaluation of the health status of patients and interpretation of the results of advanced imaging techniques. This study aims to evaluate the satisfaction of learning anatomy with three-dimensional virtual anatomy atlas we developed, and to investigate the effect of virtual three-dimensional applications on learning compared to traditional materials.
**Methods:** The 3D applied atlas we developed was sent to the Faculty of Medicine Grade 1-2, Dentistry Grade 1, and Physiotherapy and Rehabilitation Grade 1 students. Students were asked to use the 3D applied atlas in addition to traditional medical education materials in their anatomy learning process. A 9-question Google Forms survey was prepared to evaluate their satisfaction of the application.
**Results:** 471 participants from the Faculty of Dentistry, Medicine Grade 1-2, and Physiotherapy Rehabilitation classes participated in our survey. Of the participants, 140 were Faculty of Dentis-try students, 70 were Physical Therapy and Rehabilitation (PTR), 172 were Faculty of Medicine 1st grade and 89 were Faculty of Medicine 2nd grade. The number of students who found two-dimensional atlases useful was 198, while the number of students who found 3D models useful was 231. The number of students who found the cadaver model useful was 161.
**Conclusion:** Based on the survey data we obtained, we can say that the students are satisfied with our 3D atlas application and have a positive attitude towards three-dimensional educational materials.

**Keywords:** Anatomy education, Anatomy atlas, 3D anatomy, bone anatomy

**ÖZ**

**Amaç:** Anatomi eğitimi, insan vücudunu bir bütün şeklinde değerlendirmek, organ ve sistemlerin normal işleyişini özümsemek açısından büyük bir öneme sahiptir. Hastalıkların teşhisinde, cerrahi müdahalelerde, hastaların sağlık durumlarının değerlendirilmesinde, ileri görüntüleme teknikle-rinin sonuçlarının yorumlanmasında; insan anatomisinin bilinmesi kritik bir rol oynamaktadır. Bu çalışma, geliştirdiğimiz üç boyutlu sanal anatomi atlasının anatomi öğrenme konusundaki mem-nuniyeti değerlendirmeyi ve geleneksel materyallere kıyasla sanal üç boyutlu uygulamaların öğrenmeye etkisini araştırmayı amaçlamaktadır.
**Metod:** Geliştirdiğimiz 3D uygulamalı atlas, dönemin başında Tıp Fakültesi Dönem 1-2, Diş Hekimliği Dönem 1 ve Fizyoterapi ve Rehabilitasyon Dönem 1 öğrencilerine gönderildi. Öğren-cilerin, anatomiyi öğrenme süreçlerinde geleneksel tıp eğitimi materyallerine ek olarak 3D uygu-lamalı atlası da kullanmaları istendi. Uygulamanın memnuniyetinin değerlendirilebilmesi için 9 soruluk bir Google forms anketi hazırlandı.
**Bulgular:** Anketimize; Diş Hekimliği, Tıp Dönem1-2 ve Fizyoterapi Rehabilitasyon sınıflarından toplam 471 kişi katıldı. Katılımcıların 140'ı Diş Hekimliği Fakültesi, 70'i Fizik Tedavi ve Rehabili-tasyon (FTR), 172'si Tıp Fakültesi 1. Dönem ve 89'u Tıp Fakültesi 2. Dönem öğrencisiydi. İki boyutlu atlas kullanımını faydalı bulan öğrenci sayısı 198, 3 boyutlu modelleri faydalı bulan öğrenci sayısı ise 231 oldu. Kadavra modelini faydalı bulan öğrenci sayısı ise 161 oldu.
**Sonuç:** Elde ettiğimiz anket verileri doğrultusunda, öğrencilerin 3D atlas uygulamamızdan mem-nun kaldıklarını, üç boyutlu eğitim materyallerine olumlu yaklaştıklarını söyleyebiliriz.

**Anahtar Kelimeler:** Anatomi eğitimi, Anatomi atlası, 3D anatomi, Kemik anatomisi

## Introduction

Anatomy is the science that studies the structural features of organisms and the location, size and shape of their organs. Anatomy education is essential in evaluating the human body and understanding the normal functioning of organs and systems. Anatomy education should be provided in the most understandable way, especially in medical faculties and faculties that train qualified personnel for human health professions such as dentistry, physiotherapy and rehabilitation. Knowledge of human anatomy plays a critical role in the diagnosis of diseases, surgical interventions, evaluation of the health status of patients and interpretation of the results of advanced imaging techniques (1).

Two-dimensional atlases, three-dimensional anatomical body models made of plastic or wooden materials, and cadavers are frequently used materials in anatomy education. Cadaver dissections are especially useful for enriching three-dimensional thinking. However,

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today, alternative methods have been sought due to the difficulties in obtaining cadavers and the students' access to educational materials outside the laboratory environment (2,3). During the COVID-19 pandemic period, with the necessity of student education to evolve into distance education, students who were away from laboratories could not conceptualize anatomical structures with classical methods in online education. This made establishing a good anatomy basis difficult and created deficiencies in integrating information in the clinical approach (4). Situations such as the limited time students spend in laboratories and insufficient existing materials also reveal the necessity of new methods in anatomy education. Some countries (United Kingdom and France) have shortened the time spent on anatomy courses to reduce the burden on medical education, resulting in the inadequacy of traditional teaching materials. Therefore, the need for different learning methods to increase learning efficiency has emerged (5-7).

Three-dimensional imaging of anatomical structures has improved with developing technology. Interactive computer programs and virtual simulations are increasingly used in anatomy education. Three-dimensional anatomy atlases and applications integrated with virtual reality (or augmented reality) facilitate understanding anatomical structures, especially incredibly complex and smaller ones. It is argued that they contribute more to understanding the relationships of organs and other formations with each other and the locations of these structures. In addition, students can access educational materials outside the laboratory environments thanks to these applications, which can be easily accessed through smart phones, tablets, or computers (8).

This study aims to evaluate the satisfaction of the three-dimensional virtual anatomy atlas we developed with the anatomy learning of the students of the Faculty of Medicine, Dentistry, Physiotherapy and Rehabilitation, where we teach skeletal system anatomy, and to investigate the effect of virtual three-dimensional applications on learning compared to traditional materials.

**Material and Methods**

Computed Tomography (CT) images obtained retrospectively from Selcuk University Faculty of Medicine, Department of Radiology, were turned into 3D models using the Mimics Basic application in the computer environment. For the 3D modeled bones, the structures of anatomical importance were given a color using the Map-Texture technique. The application interface and texts were prepared in Turkish, paying attention to anatomical terminology. Firstly, 3D modeling of the humerus, radius, ulna, and scapula, which are the junction bones of the upper extremity, and the sternum bones of the torso skeleton, were made (Figure 1).

The names of the anatomical formations on the bone were explained under the heading 'teorik' (theoretical in English) and the information about these formations under the heading 'pratik' (practical in English). The information in the practical section was designed to be audible so that students could listen (Figure 2).

Ten questions were added to our 3D atlas application so that students can evaluate their achievements (Figure 3).

The 3D applied atlas we developed was sent to the Faculty of Medicine Grade 1-2, Dentistry Grade 1, and Physiotherapy and Rehabilitation Grade 1 students at the beginning of the semester. Students were asked to use the 3D applied atlas in addition to traditional medical education materials in their anatomy learning process. A 9-item Google Forms survey was prepared to evaluate their satisfaction of the application. After students completed the bone education, survey forms were sent online. Since participation in the survey was voluntary, a consent form was added to indicate whether students agreed to participate (Figure 4).

The nine questions we asked to be evaluated in the survey were as follows:

Question 1 (Q1). I benefited from anatomy atlases for the anatomy course.

Question 2 (Q2). I benefited from applications containing 3D models for the anatomy course.

Question 3 (Q3). 3D bone models were effective in learning the anatomy course.

Question 4 (Q4). 3D bone models strengthened my visual memory.

Question 5 (Q5). 3D bone models were effective in improving my clinical knowledge.

Question 6 (Q6). 3D bone models were effective in learning anatomical terms.

Question 7 (Q7). 3D bone models helped me compare similar formations in different bones.

Question 8 (Q8). 3D bone models were as useful as ready-made bone models.

Question 9 (Q9). Cadaver courses were effective for my anatomy education.

The students were asked to rate the questions on a scale of 1 to 5: 1- Strongly disagree, 2 - Disagree, 3 - Undecided, 4 - Agree, 5 - Strongly agree.

**Statistical Analysis**

Data obtained from Google Forms was transferred to the Microsoft Excel table. Statistical analyses were performed using the SPSS 27.0 (IBM Inc, Chicago, IL, USA) program. Descriptive statistics of the numerical and categorical data were analyzed and numerical parameters were expressed as quartiles, median (min-max), and categorical variables were expressed as frequency and percentage. Kolmogrov-Smirnov test, histogram analysis, and skewness/kurtosis data were used to evaluate the suitability of numerical or ordinal variables for normal distribution. Mann-Witney U test was employed to compare two independent groups. Intergroup relationships were compared with the Kruskal-Wallis H test in multiple group comparisons. Bonferroni correction was performed during pairwise comparisons with post hoc analysis. Internal reliability analysis was utilized for the appropriate survey questions, and Cronbach's alpha value was calculated. Pearson chi-square analysis was used to analyze the relationship between binary categorical groups. The correlations between the survey questions were evaluated using Spearman correlation analysis. In the study, the type-I error rate was taken as 5%, and a p-value of <0.05 was considered significant.

**Results**

A total of 471 participants from the Faculty of Dentistry, Medicine Grade 1-2, and Physiotherapy Rehabilitation classes participated in our survey. Of the participants, 140 were Faculty of Dentistry students, 70 were Physical Therapy and Rehabilitation (PTR) students, 172 were Faculty of Medicine 1st Grade students, and 89 were Faculty of Medicine 2nd Grade students. The class distribution of the participating students is shown in Table 1.

61.8% of the students participating in the survey were female (291 people) and 38.2% were male (180 people).

Table 2 shows the answers given by the students who participated in the survey. Questions 2-8 were related to 3D modeling. Cronbach's analysis of the answers to these questions checked internal reliability. It was determined that the answers to questions 2-8 were consistent with each other. This indicated the reliability of the answers to our survey questions (Cronbach's α = 0.956).

When the answers of the surveyed students were compared according to their gender, there was no significant difference (all p values >0.05) (Table 3).

As a result of comparing the survey answers according to classes, there was a statistically significant difference between the answers given by the Faculty of Dentistry students and the answers given by the Faculty of Medicine Grade 1 students for the 3rd question (p = 0.004). Accordingly, 3D bone models were found to be more useful in teaching anatomy courses by Faculty of Dentistry students than Faculty of Medicine Grade 1 students. 3-dimensional bone models were found significantly more successful in strengthening visual memory by Faculty of Dentistry students than Faculty of Medicine Grade 1 students (p=0.012). 3D bone models significantly improved clinical knowledge in Dentistry and PTR students than in Faculty of Medicine Grade 1 students (p<0.05). PTR students found 3D bone models as useful as ready-made ones compared to Faculty of Medicine Grade 1 students (p<0.05). The comparison of all questions according to classes is given in tables and diagrams (Table 4) (Figures 5-9).

There was a moderate and strong positive correlation between all survey questions. There was a moderate and low consistent positive correlation between questions 1-2-9. The correlations between questions are given in Table 5.

The number of students who found two-dimensional atlases useful was 198, while the number of students who found 3D models useful was 231. The number of students who found the cadaver model useful was 161. The distribution of the other answers given by the participants is given as a heat map (Tables 6,7).

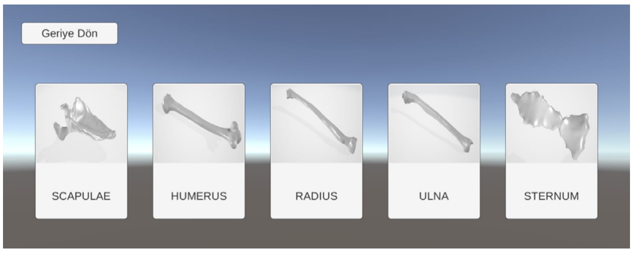


**Figure 1.** 3D modeled atlas images of scapulae, humerus, radius, ulna and sternum.

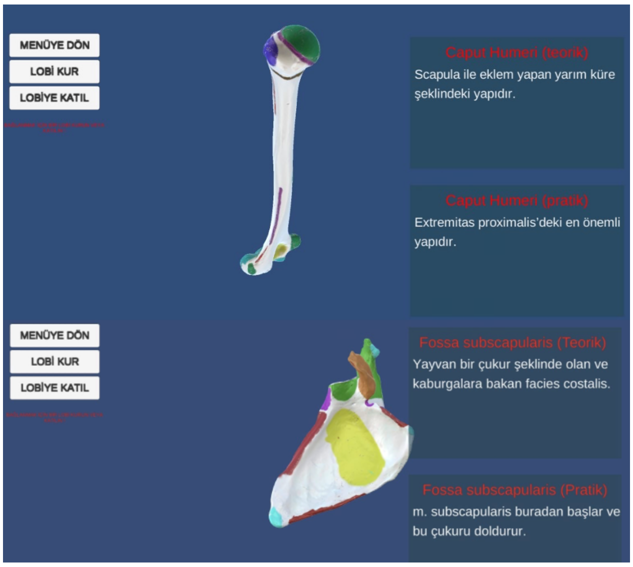


**Figure 2.** Representation of each of the anatomical formations in bones with different colors of paint and images of theoretical and practical information about these formations.

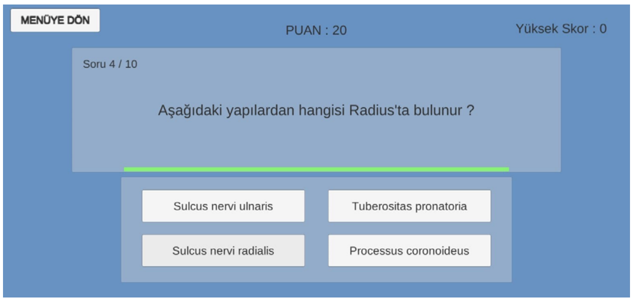


**Figure 3.** An example of questions in the application.

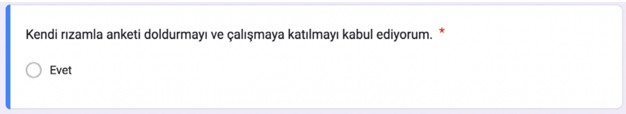
Kendi rızamla anketi doldurmayı ve çalışmaya katılmayı kabul ediyorum. *
Evet

**Figure 4.** Image showing students' willingness to participate in the survey.

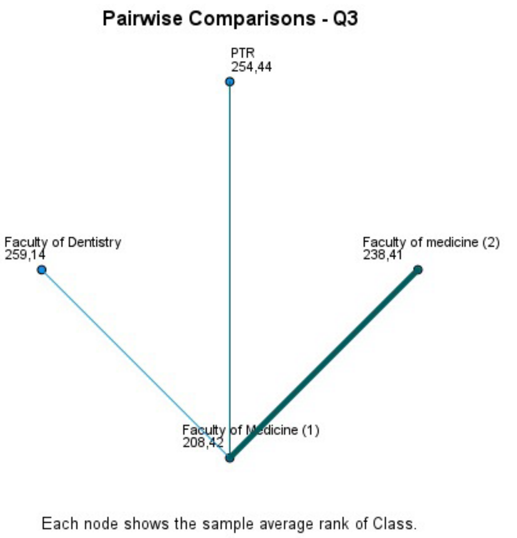


**Figure 5.** Comparison of Question 3 by binary classes and summary diagram of weight scores. The diagram shows the degree of significance from darker to lighter colors. The lightest colored line reflects a significant difference.

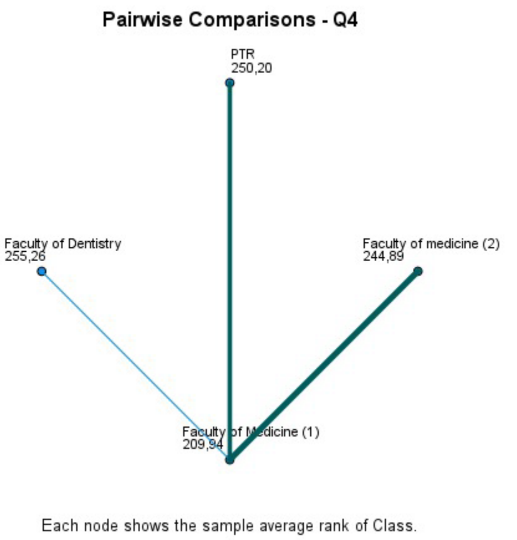


**Figure 6.** Comparison of Question 4 by binary classes and summary diagram of weight scores. The diagram shows the degree of significance from darker to lighter colors. The lightest colored line reflects a significant difference.

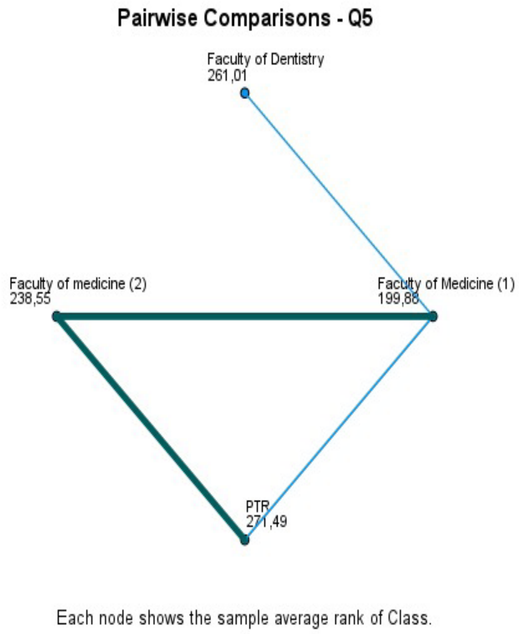


**Figure 7.** Comparison of Question 5 by binary classes and summary diagram of weight scores. The diagram shows the degree of significance from darker to lighter colors. The lightest colored line reflects a significant difference.

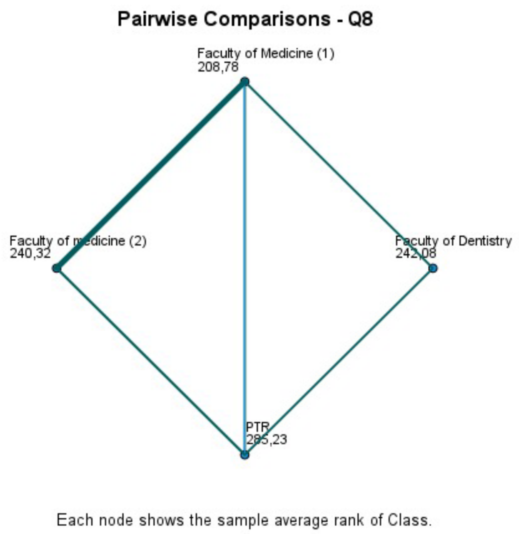


**Figure 8.** Comparison of Question 8 by binary classes and summary diagram of weight scores. The diagram shows the degree of significance from darker to lighter colors. The lightest colored line reflects a significant difference.

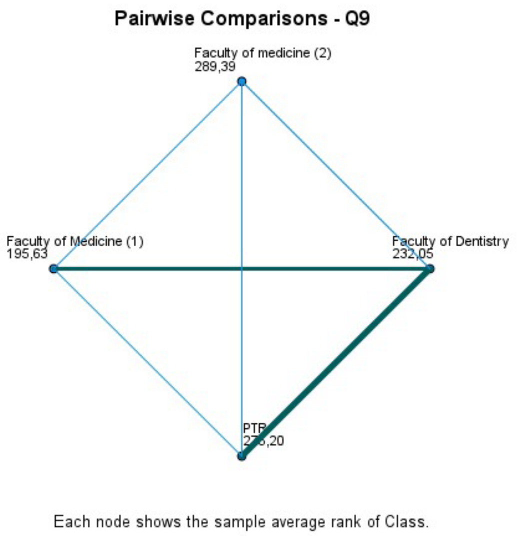


**Figure 9.** Comparison of Question 9 by binary classes and summary diagram of weight scores. The diagram shows the degree of significance from darker to lighter colors. The lightest colored line reflects a significant difference.

**Table 1.** Class distribution of the students participating in the survey.

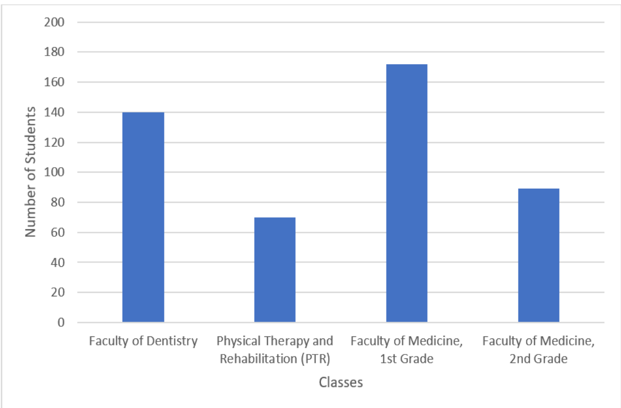


**Table 2.** Distribution of answers according to the survey results.

| Evaluation | Answer | N(%) | Evaluation | Answer | N(%) |
|---|---|---|---|---|---|
| Question 1 | Strongly disagree | 77 (%16.3) | **Question 6*** | Strongly disagree | 39 (%8.3) |
| | Disagree | 86 (%18.3) | | Disagree | 52 (%11) |
| | Undecided | 110 (%23.4) | | Undecided | 142 (%30.1) |
| | Agree | 118 (%25.1) | | Agree | 142 (%30.1) |
| | Strongly agree | 80 (%17) | | Strongly agree | 96 (%20 .4) |
| Question 2* | Strongly disagree | 57 (%12.1) | **Question 7*** | Strongly disagree | 43 (%9.1) |
| | Disagree | 70 (%14.9) | | Disagree | 69 (%14.6) |
| | Undecided | 113 (%24) | | Undecided | 124 (%26.3) |
| | Agree | 132 (%28) | | Agree | 140 (%29.7) |
| | Strongly agree | 99 (%21) | | Strongly agree | 95 (%20 .2) |
| Question 3* | Strongly disagree | 39 (%8.3) | **Question 8*** | Strongly disagree | 45 (%9.6) |
| | Disagree | 50 (%10.6) | | Disagree | 76 (%16.1) |
| | Undecided | 117 (%24.8) | | Undecided | 136 (%28.9) |
| | Agree | 152 (%32.3) | | Agree | 135 (%28.7) |
| | Strongly agree | 113 (%24) | | Strongly agree | 79 (%16.8) |
| Question 4* | Strongly disagree | 40 (%8.5) | Question 9 | Strongly disagree | 112 (%23.8) |
| | Disagree | 49 (%10.4) | | Disagree | 48 (%10.2) |
| | Undecided | 111 (%23.6) | | Undecided | 150 (%31.8) |
| | Agree. | 158 (%33.5) | | Agree | 87 (%18.5) |
| | Strongly agree | 113 (%24) | | Strongly agree | 74 (%15,7) |
| Question 5* | Strongly disagree | 43 (%9.1) | | | |
| | Disagree | 69 (%14.6) | | | |
| | Undecided | 129 (%27.4) | | | |
| | Agree | 140 (%29.7) | | | |
| | Strongly agree | 90 (%19.1) | | | |

**Internal reliability analysis was conducted for the 3D model evaluation questions (for questions 2-8). and Cronbach's α = 0.956*

**Table 3.** Comparison of survey answers by gender in the general sample.

| | Gender | | P |
|---|---|---|---|
| Evaluation | Female | Male | |
| Question 1 | 3 (1-5) | 3 (1-5) | 0.212 |
| Question 2 | 3 (1-5) | 3 (1-5) | 0.706 |
| Question 3 | 4 (1-5) | 4 (1-5) | 0.185 |
| Question 4 | 4 (1-5) | 4 (1-5) | 0.182 |
| Question 5 | 4 (1-5) | 3 (1-5) | 0.074 |
| Question 6 | 4 (1-5) | 3 (1-5) | 0.546 |
| Question 7 | 3 (1-5) | 4 (1-5) | 0.911 |
| Question 8 | 3 (1-5) | 3 (1-5) | 0.457 |
| Question 9 | 3 (1-5) | 3 (1-5) | 0.50 |

**Ordinal data are expressed as IQR (quartiles [median, min-max]).*

**Table 4.** Comparison of survey answers by classes.

| | Class | | | | P |
|---|---|---|---|---|---|
| Evaluation | Dentistry | PTR | Faculty of Medicine 1st Grade | Faculty of Medicine 2nd Grade | |
| Question 1 | 3 (1-5) | 3 (1-5) | 3 (1-5) | 3 (1-5) | 0,073 |
| Question 2 | 4 (1-5) | 4 (1-5) | 3 (1-5) | 4 (1-5) | 0,053 |
| Question 3 | 4 (1-5) [b] | 4 (1-5) | 3 (1-5)[a] | 4 (1-5) | 0,004 |
| Question 4 | 4 (1-5) [b] | 4 (1-5) | 4 (1-5) [a] | 4 (1-5) | 0,012 |
| Question 5 | 4 (1-5) [b] | 4 (1-5) [c] | 3 (1-5) [a, d] | 4 (1-5) | <0,001 |
| Question 6 | 4 (1-5) | 3 (1-5) | 3 (1-5) | 4 (1-5) | 0,068 |
| Question 7 | 4 (1-5) | 3 (1-5) | 3 (1-5) | 4 (1-5) | 0,129 |
| Question 8 | 3 (1-5) | 4 (1-5) [b] | 3 (1-5) [a] | 3 (1-5) | 0,001 |
| Question 9 | 3 (1-5) | 3 (1-5) [a,f] | 3 (1-5) [b,c] | 4 (1-5) [d,e] | <0,001 |

**Ordinal data are expressed as IQR (quartiles [median, min-max]).*

**Bonferroni correction was performed and compared in pairwise comparison. Paired signs (a-b), (c-d) and (e-f) indicate the classes where significant differences were observed.*

**Table 5.** Examination of correlation directions and correlation strengths between survey questions

| | | Question 1 | Question 2 | Question 3 | Question 4 | Question 5 | Question 6 | Question 7 | Question 8 | Question 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Question 1 | rho | | 0.590 | 0.572 | 0.526 | 0.503 | 0.510 | 0.552 | 0.512 | 0.456 |
| | P | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Question 2 | rho | 0.590 | 1.000 | 0.707 | 0.693 | 0.628 | 0.659 | 0.660 | 0.604 | 0.443 |
| | P | <0.001 | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Question 3 | rho | 0.572 | 0.707 | | 0.876 | 0.769 | 0.790 | 0.781 | 0.725 | 0.464 |
| | P | <0.001 | <0.001 | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Question 4 | rho | 0.526 | 0.693 | 0.876 | | 0.764 | 0.811 | 0.788 | 0.686 | 0.449 |
| | P | <0.001 | <0.001 | <0.001 | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Question 5 | rho | 0.503 | 0.628 | 0.769 | 0.764 | | 0.811 | 0.793 | 0.733 | 0.522 |
| | P | <0.001 | <0.001 | <0.001 | <0.001 | | <0.001 | <0.001 | <0.001 | <0.001 |
| Question 6 | rho | 0.510 | 0.659 | 0.790 | 0.811 | 0.811 | | 0.828 | 0.733 | 0.464 |
| | P | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | <0.001 | <0.001 | <0.001 |
| Question 7 | rho | 0.552 | 0.660 | 0.781 | 0.788 | 0.793 | 0.828 | | 0.773 | 0.516 |
| | P | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | <0.001 | <0.001 |
| Question 8 | rho | 0.512 | 0.604 | 0.725 | 0.686 | 0.733 | 0.733 | 0.773 | | 0.522 |
| | P | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | <0.001 |
| Question 9 | rho | 0.456 | 0.443 | 0.464 | 0.449 | 0.522 | 0.464 | 0.516 | 0.522 | |
| | P | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | |

**Table 6.** Cross-tabulation relationship between Questions 1 and 2 and heat map of answers

| | | **I benefited from applications containing 3D models** | | | | | Total |
|---|---|---|---|---|---|---|---|
| Strongly disagree | | **Disagree** | **Undecided** | **Agree** | **Strongly agree** | | |
| **I benefited from anatomy atlases for the anatomy course** | Strongly disagree | 34 | 17 | 12 | 6 | 8 | 77 |
| | **Disagree** | 13 | 26 | 25 | 15 | 7 | 86 |
| | **Undecided** | 4 | 20 | 51 | 22 | 13 | 110 |
| | **Agree** | 5 | 5 | 21 | 72 | 15 | 118 |
| | **Strongly agree** | 1 | 2 | 4 | 17 | 56 | 80 |
| Total | | 57 | 70 | 113 | 132 | 99 | 471 |

**Table 7.** Cross-tabulation relationship between Questions 2 and 9 and heat map of answers

| | | **Cadaver courses were effective for my anatomy education** | | | | | Total |
|---|---|---|---|---|---|---|---|
| Strongly disagree | | Disagree | Undecided | Agree | Strongly agree | | |
| **I benefited from applications containing 3D models** | Strongly disagree | 34 | 8 | 8 | 2 | 5 | 57 |
| | Disagree | 20 | 22 | 18 | 2 | 8 | 70 |
| | Undecided | 29 | 7 | 50 | 19 | 8 | 113 |
| | Agree | 21 | 5 | 49 | 46 | 11 | 132 |
| | Strongly agree | 8 | 6 | 25 | 18 | 42 | 99 |
| Total | | 112 | 48 | 150 | 87 | 74 | 471 |

## Discussion

In anatomy learning, in addition to traditional methods such as two-dimensional atlases, two-dimensional PowerPoint presentations, and books, three-dimensional anatomical body models and cadavers are used to add dimension to thinking. However, today, virtual applications and environments with augmented reality, such as three-dimensional atlases, are also being used to support learning. Therefore, instructors have recently conducted many studies investigating which methods students are satisfied with (8). We conducted a satisfaction survey with four classes studying anatomy at our university to understand the benefits of the 3D atlas model we developed for students. According to the results we obtained from our study, a high percentage (52%) of Medicine, Dentistry, and Physiotherapy Rehabilitation students were satisfied with the 3D atlas application. 42.1% were satisfied with two-dimensional atlas learning, and 34.2% with cadaver training. Examining these results, we can deduce that students are willing to use 3D applications in addition to traditional materials. Like our study, Martin G. et al. presented students with two-dimensional presentations and three-dimensional applications about upper extremity muscles and then distributed a satisfaction survey. Students were mostly satisfied with the three-dimensional application (9). A study conducted with 49 Dentistry students in Pakistan investigated the effect of two-dimensional presentations and 3D anatomy atlases on students' academic performance. It was found that the academic success of the group trained using 3D atlases was higher. It was argued that retention of anatomical information learned through 3D atlases increases in the short and long term (4). De Faria et al. compared the virtual and stereoscopic anatomy education model between groups in neuroanatomy education. They stated that this model encouraged knowledge development and was more effective in learning (10).

Contrary to these studies, Donnelly et al. randomly divided the faculty of medicine Grade 1 students into two groups and exposed one group to the projection containing dissection materials and the other to the virtual human dissector application. They conducted an exam to evaluate the learning level between the two groups. Since the exam results were similar between the two groups, they argued that the virtual human dissector application could be used as an alternative to traditional education methods. However, it was not more effective in learning (11).

According to our survey, 57.5% of students gave feedback that the 3D Atlas application improved their visual memory. The number of Dentistry students who thought their visual memory had improved was significantly higher than the number of faculty of Medicine Grade 1 students. Although there was a higher number of positive feedback from dentistry students than the other two classes, there was no significant difference between them. Eroğlu et al. compared students' ability to retain information in the short and long term by using 3D PDF and 2D atlas materials. They concluded that using three-dimensional materials for organs with complex anatomy was more beneficial and learning was more memorable in the short and long term (12).

Although three-dimensional educational materials facilitate comprehension, some studies in which students were tested suggested that the use of both two-dimensional and three-dimensional learning materials did not create a statistically significant difference in the exam results (13).

The contribution of 3D anatomy atlases to clinical knowledge is also controversial in the literature, as it is pretty complex to investigate the relationship between anatomy education and professional practices. In professional practice, the ability to internalize the information and use it effectively in practice is as important as the adequacy of the theoretical education received. This suggests that individual differences should also be considered (14,15). In our survey, 230 students (48.8%) reported that our 3D Atlas application contributed to their clinical knowledge. It can be said that dentistry and PTR students especially benefit from 3D atlases in improving their clinical skills. According to the data obtained from a survey study conducted on new specialists to investigate the effect of anatomy knowledge on clinical performance, almost half of the participants gave feedback that they did not receive adequate anatomy education (16). This makes it questionable how well traditional learning methods work in clinical integration. Increasing concerns about the inadequacy of traditional materials have also encouraged the development of new learning models (17).

Judit Beerman et al. showed the complex liver surgical anatomy with two-dimensional and three-dimensional materials to 4th and 5th-grade medicine students and then distributed questions for them to answer. The results reported that men benefited significantly more from 3D presentations than women (18). In our study, there was no significant difference between the survey answers of men and women who participated in the survey.

As a result, in line with the survey data we obtained, the students are satisfied with our 3D atlas application and have a positive attitude towards three-dimensional educational materials. It is also clear that students in education still request two-dimensional atlas and cadaver materials. Therefore, we can conclude that the use of three-dimensional educational materials in a way that supports traditional materials will help students develop more comprehensive thinking skills in the clinic and facilitate the understanding of anatomical formations, especially those with more complex structures. For this reason, developing our 3D anatomy atlas by converting the images obtained from cadavers into 3D images to include all body systems will increase its contribution to the clinical training of students. It would be useful for academician to use three-dimensional materials in addition to two-dimensional PowerPoint presentations to deepen two-dimensional perception and improve the ability of the brain to perceive while creating course materials.

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**Ethical approval:** All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval (approval number 2021/499) was given by the Local Ethics Committee of the Medical Faculty.

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