

Research Article

Role of 3-Dimensional Atlas in Learning Anatomy.

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ABSTRACT

Background: Effective anatomy learning requires an understanding of three-dimensional spatial relationships, orientation, and anatomical structures. Conventional teaching methods, although essential, may present difficulties in developing accurate three-dimensional mental representations. Interactive three-dimensional (3D) anatomical atlases may provide an effective complementary learning resource.

Aim: To evaluate the effectiveness of an interactive 3D anatomical atlas as an adjunct to conventional anatomy teaching among first-year MBBS students.

Materials and Methods: A prospective pilot study was conducted among 114 first-year MBBS students in the Department of Anatomy, S.N. Medical College, Agra. Randomization was performed using a computer-generated random number sequence. Each participant was assigned a unique identification number, and the randomization sequence was generated independently to allocate students to either the conventional teaching group (Group A, n = 64) or the 3D atlas supplemented teaching group (Group B, n = 50). received conventional teaching supplemented with an interactive 3D anatomical atlas. Pre-test and post-test assessments were conducted to evaluate anatomical knowledge, identification of structures, and understanding of spatial relationships. Data were expressed as mean $\pm$ standard deviation and analyzed using paired and independent-samples t-tests.

Results: The mean pre-test scores were comparable between Group A (18.5 ± 2.4) and Group B (18.6 ± 2.3). Following the intervention, the mean post-test score increased to 26.5 ± 2.5 in Group A and 32.5 ± 2.5 in Group B. Both groups demonstrated significant improvement from pre-test to post-test ($p < 0.001$). However, the improvement was greater in Group B (13.9 points) than in Group A (8.0 points). The between-group difference in post-test scores was 6.0 points and was statistically highly significant ($t = 12.04$, $p < 0.001$). Group B showed a 22.6% higher post-test performance compared with Group A.

Conclusion: The use of an interactive 3D anatomical atlas as an adjunct to conventional anatomy teaching significantly improved students' academic performance. Interactive visualization through rotation, zooming, isolation, and layer removal may enhance understanding of anatomical structures and spatial relationships. Therefore, 3D atlas-based learning can be effectively incorporated as a complementary approach in undergraduate anatomy education.

Keywords: Anatomy education, three-dimensional atlas medical education, spatial visualization, MBBS students, anatomy teaching, digital learning.

Introduction:

Human anatomy is a fundamental component of undergraduate medical education and provides the structural basis for understanding physiology, pathology, radiology, surgery and other clinical disciplines.¹ Effective learning of anatomy requires more than memorization of individual structures; students must also develop an understanding of their three-dimensional organization, orientation, relative position and spatial relationships.² Traditionally, anatomy education has relied on cadaveric dissection, prosection, lectures, textbooks and two-dimensional anatomical atlases. Although these methods remain essential, students may experience difficulty in converting static two-dimensional representations into accurate three-dimensional mental images, particularly when dealing with deep, small, superimposed or anatomically complex structures.^{3,4}

Spatial visualization is therefore an important component of anatomical learning. It involves the ability to mentally manipulate, rotate and interpret anatomical structures from different perspectives. Interactive three-dimensional (3D) anatomical applications provide learners with the opportunity to rotate models, zoom into structures, remove overlying layers and isolate individual anatomical components.⁵ These features may facilitate a more direct understanding of anatomical relationships and reduce the cognitive effort required to construct three-dimensional representations from conventional two-dimensional images. Studies comparing 3D applications with conventional atlases have reported improved anatomical identification and learning performance among students using interactive digital resources.⁶

In recent years, the use of 3D visualization, virtual reality, augmented reality and 3D-printed models has increased in medical education. Randomized studies have reported improvements in anatomical knowledge and spatial understanding following 3D-based teaching, while systematic reviews and meta-analyses have demonstrated beneficial effects of immersive technologies on learning outcomes and student engagement.⁷⁻¹⁰ However, the available evidence is heterogeneous, and the effectiveness of digital technologies may depend on the learning objectives, instructional design and manner in which these resources are integrated into the curriculum.^{11,12}

Three-dimensional anatomical resources should therefore be regarded as complementary tools rather than replacements for conventional anatomy teaching.^{13,14} Cadaveric dissection provides direct exposure to anatomical

structures and their variations, while textbooks and conventional atlases provide standardized anatomical representations.¹⁵ Interactive 3D atlases can complement these methods by providing dynamic visualization, repeated exploration and opportunities for self-directed learning and revision.^{16,17}

Materials and Methods

Study Design and Setting

A prospective pilot study was conducted in the Department of Anatomy, S.N. Medical College, Agra, among first-year MBBS students to evaluate the effectiveness of an interactive three-dimensional (3D) anatomical atlas as an adjunct to conventional anatomy teaching. The study was conducted after obtaining permission from the concerned institutional authorities and following appropriate ethical principles.

Study Participants

A total of 114 first-year MBBS students participated in the study. Students who participated in the scheduled anatomy teaching and assessments were included in the study. Students who were absent during the intervention or relevant assessment were excluded from the analysis.

Randomization:

The 114 eligible first-year MBBS students were randomly allocated into two groups before commencement of the teaching intervention. Randomization was performed using a computer-generated random number sequence. Each participant was assigned a unique identification number, and the randomization sequence was generated independently to allocate students to either the conventional teaching group (Group A, n = 64) or the 3D atlas supplemented teaching group (Group B, n = 50). The allocation sequence was prepared before the intervention, and students were informed of their respective teaching method after allocation. This procedure was adopted to minimize selection bias and ensure comparable allocation of participants between the two groups.

Group Allocation

The participants were divided into two groups:

- Group A (n = 64): Received conventional anatomy teaching alone.
- Group B (n = 50): Received conventional anatomy teaching supplemented with an interactive 3D

anatomical atlas.

Students were randomized into the two groups before commencement of the teaching intervention. Both groups were taught the same selected anatomical topics and were provided with comparable instructional time.

Teaching Intervention

The selected anatomy topics were taught using conventional teaching methods, including didactic teaching, textbooks, conventional anatomical atlases and practical/prosection-based demonstrations. In addition to these methods, students in Group B were provided access to an interactive 3D anatomical atlas.

The 3D atlas enabled students to visualize anatomical structures from multiple perspectives through rotation, zooming, isolation of individual structures and removal of overlying anatomical layers. This allowed students to appreciate the spatial relationships and three-dimensional orientation of anatomical structures more effectively.

Pre-test and Post-test Assessment

A pre-test was conducted before the teaching intervention to assess the baseline anatomical knowledge of the participants. Following completion of the selected teaching sessions, a post-test was administered to both groups.

The assessment consisted primarily of questions related to:

1. Identification of anatomical structures
2. Spatial orientation and relationships of anatomical structures

Result:

Table 1. Distribution of study participants.

Group	Teaching method	N	Percentage (%)
Group A	Conventional teaching alone	64	56.1
Group B	Conventional teaching + 3D atlas	50	43.9
Total	-	114	100.0

The study included a total of 114 first-year MBBS students, of whom 64 (56.1%) were assigned to Group A, receiving conventional anatomy teaching alone, while 50 (43.9%) were assigned to Group B, receiving conventional teaching supplemented with an interactive 3-dimensional (3D) anatomy atlas. Thus, Group A comprised the larger proportion of participants, whereas Group B represented 43.9% of the total study population. The distribution reflects the study allocation used for comparing conventional teaching with 3D atlas-assisted anatomy teaching.

3. Recognition of structures from different anatomical perspectives

The same assessment framework was used for both groups. Scores obtained in the pre-test and post-test were recorded for statistical analysis.

Outcome Measures

The primary outcome was the difference in post-test performance between students receiving conventional teaching alone and those receiving conventional teaching supplemented with the 3D atlas.

Secondary outcomes included:

- Improvement in scores from pre-test to post-test.
- Ability to identify anatomical structures.
- Understanding of three-dimensional spatial orientation and anatomical relationships.

Statistical Analysis

The collected data were entered and analyzed using appropriate statistical software. Continuous variables were expressed as mean $\pm$ standard deviation (SD).

The paired t-test was used to compare pre-test and post-test scores within the same group. The independent-samples t-test was used to compare scores between Group A and Group B, particularly for comparison of post-test performance. Pre-test scores between the two groups were also compared using an independent t-test to assess baseline comparability.

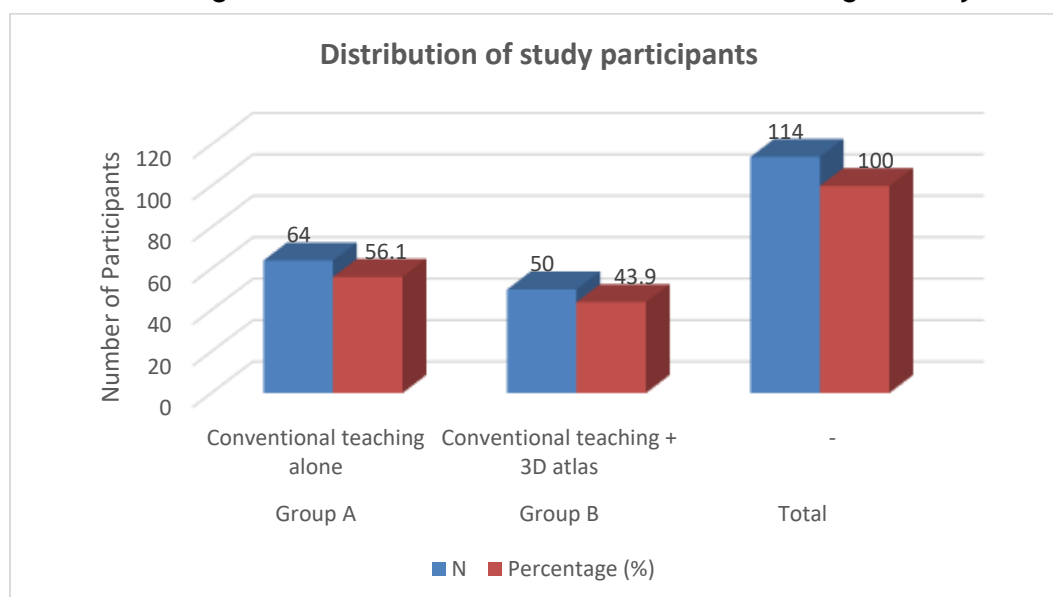


Fig: 1 Graphical represents distribution of study participants.

Table 2. Pre-test and post-test scores.

Group	N	Pre-test Mean ± SD	Post-test Mean ± SD	Mean improvement
Group A	64	18.5 ± 2.4	26.5 ± 2.5	8.0
Group B	50	18.6 ± 2.3	32.5 ± 2.5	13.9
Overall	114	18.55 ± 2.35	29.13 ± 3.80	10.58

Group A improved from 18.5 ± 2.4 to 26.5 ± 2.5 , with a mean improvement of 8.0 points. Group B improved from 18.6 ± 2.3 to 32.5 ± 2.5 , with a greater improvement of 13.9 points. Overall, the findings indicate better improvement in the 3D atlas-assisted teaching group.

Table 3. Comparison Analysis of Pre-Test and Post-Test Academic Performance Within and Between the Study Groups.

Group	Pre-test	Post-test	Mean difference	Paired <i>t</i>	<i>P</i> value
Group A	18.5 ± 2.4	26.5 ± 2.5	8.0	20.12*	<0.001*
Group B	18.6 ± 2.3	32.5 ± 2.5	13.9	31.45*	<0.001*

Both groups showed a statistically significant improvement from pre-test to post-test. Group A improved by 8.0 points, while Group B showed a greater improvement of 13.9 points. The paired t-test was significant in both groups ($p < 0.001$), indicating significant improvement in academic performance after teaching.

Table 4. Between-group comparison of post-test scores

Parameter	Group A (n=64)	Group B (n=50)	Mean difference	<i>t</i>	<i>P</i>
Post-test score	26.5 ± 2.5	32.5 ± 2.5	6.0	12.04	<0.001*

Group B demonstrated a higher mean post-test score (32.5 ± 2.5) compared with Group A (26.5 ± 2.5). The mean difference was 6.0 points, and the difference was statistically significant ($t = 12.04$, $p < 0.001$), indicating better academic performance in the 3D atlas-assisted teaching group.

Table 5. Comparative Percentage Improvement in Post-Test Academic Performance Between Conventional Teaching and 3-Dimensional Atlas-Supplemented Teaching.

Parameter	Group A	Group B
Mean post-test score	26.5 ± 2.5	32.5 ± 2.5
Absolute difference	6.0	
Percentage improvement compared with Group A	22.6%	
<i>t</i> value	12.04	
<i>P</i> value	<0.001	
Statistical test	Independent-samples <i>t</i> -test	
Interpretation	Statistically highly significant	

Group B had a higher mean post-test score (32.5 ± 2.5) than Group A (26.5 ± 2.5), showing an absolute improvement of 6.0 points and a 22.6% increase compared with Group A. The difference was statistically highly significant ($t = 12.04$, $p < 0.001$), indicating better academic performance with 3D atlas-assisted teaching.

Discussion: The present study demonstrated significantly better academic performance in the 3D atlas-assisted group than in the conventional teaching group, with post-test scores of 32.5 ± 2.5 and 26.5 ± 2.5, respectively ($p < 0.001$). Group B also showed greater mean improvement (13.9 points) compared with Group A (8.0 points). These findings are consistent with Scheidt et al. and Stouthandel et al., who reported benefits of 3D anatomy applications in anatomical learning. Similarly, García-Robles et al. and Salimi et al. reported positive effects of 3D and immersive technologies on anatomy education. The improved performance may be attributed to 3D atlas features such as rotation, zooming, isolation and visualization from multiple perspectives, which facilitate better understanding of anatomical relationships. Overall, the findings support the use of 3D atlas technology as a complementary tool to conventional anatomy teaching.

Conclusion: The present study concludes that the use of an interactive 3-dimensional atlas as an adjunct to conventional anatomy teaching

significantly improves students' academic performance and understanding of anatomical structures. The 3D atlas provides better visualization of spatial relationships through rotation, zooming and layer isolation. Therefore, 3D atlas-based learning can be effectively incorporated into anatomy education as a complementary tool to traditional teaching methods.

Conflict of Interest

The authors declare that there is no conflict of interest associated with this study.

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