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Original Research

Impact of audio-visual 3D animation on students' depth of knowledge of surgical anatomy of maxillofacial spaces

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Abstract

Background and Objectives: The study aims to augment the conventional teaching of maxillofacial spaces by developing audio-visual animation videos and evaluate its advantages in terms of student satisfaction and depth of knowledge attained by final year dental students.

Method: Nine videos on maxillofacial spaces were designed using the Mimics-in-Suite Software. The final year batch of dental students (n=42) were divided in two groups: Group 1 (n=21) and Group 2 (n=21). Group 1 served as the control group, solely receiving instruction through chalkboard and PowerPoint presentation, and the Group 2 served as the experiment group, where the conventional teaching was reinforced with the animation videos. The depth of knowledge gained by both the groups was recorded through a 30 marks multiple choice questionnaire and compared. Group 2 students' satisfaction with the animation module was also noted.

Results: Group 2 students outperformed Group 1 students in the depth of knowledge assessment in all levels except for the Level 1. Significantly high scores were achieved in Level 4 questions and the grand total score. Students positively perceived the animation module. They were satisfied with the animation's quality, content, relevancy, utility, and knowledge obtained.

Conclusion: Altogether, the results illustrate that animation was useful to simplify the anatomy of maxillofacial spaces as it deepens their understanding of the material and was intercepted satisfactorily by the students.

Keywords: *anatomy, depth of knowledge, education, maxillofacial spaces, space infection,*

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Introduction

Anatomy is the foundation of all healthcare sciences. By bringing the hazy configuration of the human form into sharp focus, it sparks the way for accurate diagnosis, clinical assessment, as well as assiduous management and treatment [1]. Anatomy is one of the most elusive and enigmatic subject that becomes increasingly difficult as one delves deeper. The complexity of the subject as a result of the myriad of diverse overlapping structures nestled in one small area, makes it challenging for students to visualize and identify them [2]. Students are overwhelmed by the subject's preponderance of theoretical information, and stumble when required to correlate 2D textbook illustrations with 3D patients [2,3]. Consequently, newly qualified doctors possess suboptimal anatomical knowledge to safely practice medicine [4-6].

For years, anatomy was taught using diagrams drawn with colourful chalk on a blackboard, and despite teachers' best effort, it has been difficult to understand the spatial relationship between innumerable structures [7,8]. And even though blackboard teaching encourages student-teacher interaction, its effectiveness dwindles with increasing students and fails to seize the attention of students [9]. But, reassuringly, the past decade has witnessed the burgeoning of technology and its integration with medical and dental education. Anatomy pedagogy has adopted the use of 3D animations [10], serious games [11], 3D printed models [12], social media, web-based learning, computer-based education programs, virtual dissection, 3D stereoscopy high-fidelity simulation, virtual reality, augmented reality and haptic technology [13] to facilitate learning.

Head and neck anatomy was one of the topic found to be particularly challenging for students [2], triggering a lack of confidence when tested on it [14]. Hence, majority of students covet the topics of head and neck anatomy to be morphed into 3D technology [15]. And one such topic that this study intends to focus on is maxillofacial spaces, in an attempt to interpolate anatomical theory in maxillofacial surgery training. Facial space infections are caused by an odontogenic source and, if not treated promptly, may precipitate life-threatening situations like airway obstruction, septicemia [16], necrotizing fasciitis [17], and spread to cavernous sinus, orbit, and mediastinum [16]. As a result, early detection and expeditious management are crucial. To diagnose the space involved and hence perform the proper incision for drainage while conserving nearby vital structures, the student must be well-versed in its anatomy [17]. Each space amidst different muscles at different strata, with distinctive boundaries yet interconnected in the labyrinth of bones and muscles seems to be a highly suited topic to be translated into 3D animation tool. Previously, maxillofacial spaces have been attempted to be taught only by air dissection technique in frozen cadavers where compressed air was instilled to highlight the spaces [18]. Hence, the study intends to create a 3D audio-visual animation tool to allow and simplify visualization of different spaces from different perspectives, unhindered by the visual restrictions of surrounding tissue, and assess students' satisfaction and the depth of knowledge gained through this tool.

Materials and methods

The study aspires to design an audio-visual 3D animation tool that delineates the boundaries, important surrounding structures, and contents of the buccal, canine, superficial and deep temporal, infratemporal, submasseteric, submental, sublingual, submandibular and pterygomandibular space, assess students' perception using a student satisfaction questionnaire and analyze whether the depth of knowledge improved after implementation of this tool.

Content designing

A proper design is conducive to effective learning [19, 20]. Previous research has paved the way for creating an effective animation tool by configuring a few parameters. As visualization is an integral part of understanding anatomy [21], an animation tool imbued with a myriad of different colours helps in engagement, recall, and understanding [22]. The material should not be overloaded or redundant [23] and must be given sequentially [24]. Learner-directed study of structures from numerous orientations impedes learning; thus, passive control is more effective than active control [25], especially for students with low spatial ability [26]. Furthermore, animation with narration in conversational speaking style is preferable to animation with onscreen text [24].

So, with all the aforementioned points in consideration, an animation video was developed utilizing the software Mimics Innovation Suite. A 3D skull was segmented through the CBCT data and different muscles circumscribing the facial spaces, parotid gland and mandibular nerve were crafted using the software tools. Nine videos were recorded in total, one for each space. The buccal, canine, superficial and deep temporal, infratemporal, submasseteric, submental, sublingual, submandibular, and pterygomandibular spaces were all covered in the 1 to 4 minutes films. The recording with voice-over narration, allowed visualization from different perspectives and explained the boundaries and contents of facial spaces. (Figure 1)

Student Satisfaction Questionnaire

Feedback from students was obtained through an 8-item questionnaire with 5-point Likert scale, inquiring about the content's quality, delivery, relevance and student's expectation and satisfaction with the 3D educational tool. (Figure 2)

Depth of Knowledge Questionnaire

Students can apply their knowledge in challenging settings, only if they have a thorough understanding of the subject [27]. And as the purpose of our study was to develop a tool that provided deeper learning, we assessed it using a multiple-choice questionnaire based on Webb's Depth Of Knowledge (DOK) model. (Figure 3) This paradigm provides a framework for assessing the content and the depth to which students understand that content [28]. It includes four levels. Level 1 attributes to recall and reproduction; students need to only recite facts and have a shallow understanding of the topic. It contains keywords like "identify," "recall," "recognise," "use," and "measure". The student either knows or does not know the information. Level 2 is concerned with skills and concepts. It is more complex than level 1 and requires mental processing beyond recalling. Level 3 corresponds with strategic thinking and more demanding reasoning. It requires reasoning, planning, evidence use, and a greater level of thinking than the previous two levels. Level 4 commensurate with extended thinking, is very complex and requires high cognitive demands. Students are required to connect and relate various ideas [29].

Accordingly, the Depth of knowledge questions for maxillofacial spaces was devised. Level 1 included identification of the location of spaces, based on recall and memory. Level 2 focused on correlating the anatomy of different spaces. The more complex Level 3 asked students to correlate the information clinically, whereas Level 4 tested students' ability to connect the information to real-life scenarios, focusing on the end learning objective the animation series wishes to achieve: diagnosis. Three multiple-choice questions were made for each level, with a total of twelve questions. Because questions were more complex as the level went up, they had more weight in the final score. Hence, Level 1 questions were worth 1 point, Level 2 questions were 2 points, Level 3 questions were 3 points, and Level 4 questions were worth 4 points, for a total of 30 points. (Figure 4). The content of the questionnaire was validated by a panel of experts in oral and maxillofacial surgery and anatomy.

Using a PowerPoint presentation and animations, group 2 students received instructions on the same topic twice. Therefore, the depth of knowledge questionnaire was tested for both groups after two weeks of the respective intervention to remove any bias related to this double exposure.

Study Design

The study, approved by the ethical committee of the institution (No.69/Ethics/2021), evaluates the intervention's influence on final-year students. The final year dental students (42 students) were divided into two groups: Group 1 (21 students) acting as the control group and Group 2 (21 students) as the experimental group. The study is in accordance with previous research that hails the employment of animation as an adjunct rather than a replacement for conventional teaching [31-33]. Hence, control group 1 was taught maxillofacial spaces using chalkboard and PowerPoint presentations, while experimental group 2 was exposed to a 3D animation tool in addition to traditional learning. Without prior notice, the depth of knowledge was assessed for both groups and compared. A student satisfaction questionnaire was also administered to group 2 students to ascertain their opinion of the created tool.

Results

Depth of Knowledge

The Wilcoxon Signed Rank test was applied to analyze and compare the scores of both groups at each level. The mean score of level 1 for group 1 was 2.48±0.81 while for group 2 it was 2.19±0.81. No significant difference was found in mean score of the two methods (z-1.05,p-0.293). For group 1, the average level 2 score was 4.10±0.99, while for group 2, it was 4.57±1.12. The mean score between the two approaches did not differ significantly (z--1.51, p- 0.132).

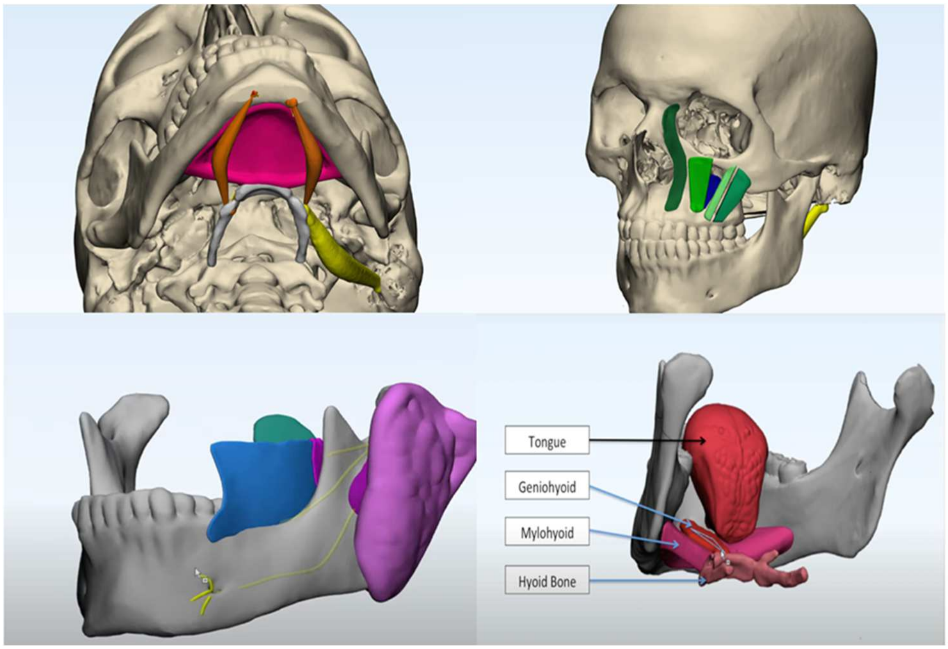

Figure 1: Animated Maxillofacial spaces

	1	2	3	4	5
Please tick (√) the most appropriate box.	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1. Overall quality of instructions and reading material of the teaching-learning session were good					
2. All the content was well explained and well presented					
3. The new modification is relevant for BDS					
4. The new modification is relevant as it helps to observe our performance on the patient and learn.					
5. The new modification is useful in practically implementation					
6. The teaching-learning session achieved the objectives specified at the beginning					
7. Knowledge gained from the session definitely met my expectations					
8. Knowledge gained from the session helped in changing my understanding of the topics					

Figure 2: Student satisfaction Questionnaire

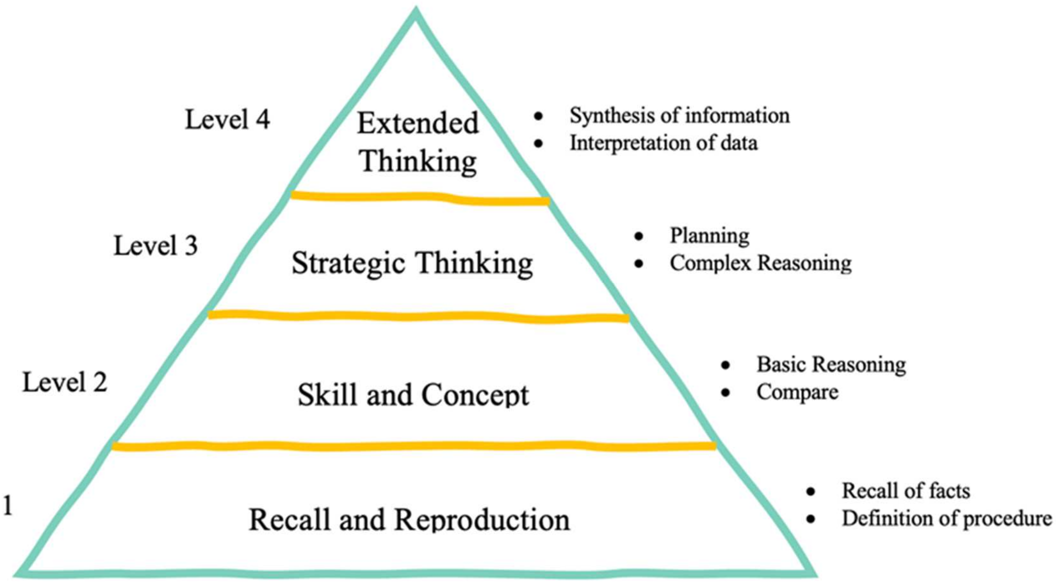

Figure 3: Webb's Depth of knowledge (DOK)

LEVEL 1 — 1 mark per question, Total marks= 3

1. **Buccal space is between**
   a. *Buccinator and skin*
   b. Mandible and buccinator
   c. Tongue and buccinator
   d. Amongst the buccinator muscle fibres
2. **Infra-temporal space is between**
   a. Temporalis and Skull
   b. Temporalis muscle and Temporalis fascia
   c. *Pterygoid plate and coronoid process*
   d. medial pterygoid and lateral pterygoid
3. **Submental space is _____ mylohyoid, and sublingual is _____ the mylohyoid,**
   a. below, below
   b. *below, above*
   c. above, below
   d. above, above

LEVEL 2 — 2 marks per question, Total marks= 6

4. **Which is the correct order – from origin of infection to the route it takes to spread**
   a. *Mandibular molar, submandibular space, submental space*
   b. Mandibular molar, pterygomandibular space, sub-lingual space, buccal space
   c. Maxillary molar, sublingual space, pterygomandibular space
   d. Mandibular incisor, buccal space, superficial temporal space
5. **Correct order of the spaces from anterior to posterior**
   a. Submandibular space, sub-mental space, pterygomandibular space
   b. *Canine space, buccal space, sub-masseteric space, parotid space, retro-pharyngeal space*
   c. Canine space, sub-masseteric space, buccal space, parotid space, retro-pharyngeal space
   d. Buccal space, canine space, sub-masseteric space, parotid space
6. **Correct order of the spaces from superior to inferior**
   a. Temporal space, infra-temporal space, submental space, sub-masseteric space, sublingual
   b. Temporal space, infra-temporal space, sub-masseteric space, submental space, sublingual
   c. *Temporal space, infra-temporal space, sub-masseteric space, sublingual space, submental*
   d. Temporal space, infra-temporal space, sublingual space, sub-masseteric space, submental

LEVEL 3 — 3 marks per question, Total marks= 9

7. **Swelling of cheek; space NOT involved in producing this symptom**
   a. Canine Space
   b. Buccal Space
   c. Sub-masseteric Space
   d. *Pterygomandibular Space*
8. **Swelling in the floor of the mouth is produced by-**
   a. Submental Space
   b. Parotid Space
   c. *Sublingual Space*
   d. Sub-mandibular space
9. **Trismus; space NOT involved in producing this symptom**
   a. Superficial Temporal space
   b. Deep Temporal space
   c. Sub-masseteric space
   d. *Submandibular space*

LEVEL 4 — 4 marks per question, Total marks= 12

10. **Identify**

   a. Canine space infection
   b. *Buccal space infection*
   c. Sub-masseteric space infection
   d. Sub-mandibular space infection

11. **Identify**

   a. Sub-lingual space infection
   b. Sub-mandibular space infection
   c. *Sub-mental space infection*
   d. Pterygomandibular space infection

12. **Identify**

   a. Parotid space infection
   b. *Canine space infection*
   c. Sub-mandibular space infection
   d. Sub-masseteric space infection

Underlined option is the correct answer
Courtesy: Prof Divya Mehrotra: Fundamentals of oral and maxillofacial surgery, Elsevier; 2020[30].

Figure 4: Space infection Depth of Knowledge Questionnaire (Total Marks = 30)

The mean score of level 3 for group 1 was 6.14±2.22 while for group 2 it was 6.86±2.35. No significant difference was found in mean score of the two methods (z=0.91, p=0.363). The mean score of level 4 for group 1 was 3.81±4.47 while for group 2 it was 7.05±4.88. The significant difference was found in mean score of the two methods (z=2.13, p=0.033) and group 2 got more score than group 1. The mean total score for group 1 was 16.52±5.33 while for group 2 it was 20.67±6.12. A significant difference was found in mean score of the two methods (z=2.37, p=0.018) with group 2 scoring higher than group 1. (Figure 5)

In group 1, 28.6% of students received scores between 21- 30, compared to 57.1% of students in group 2. Scores within 11-20 marks were obtained by 66.7 % of students in group 1 and 42.9% of students in group 2. While 4.8% of students in group 1 and none in group 2 received scores between 0-10. (Figure 6)

Student Satisfaction

Question 1 and Question 2 got the maximum strongly agree responses (71.4%) followed by Question 3 (66.7%), Question 8 (57.1%) Questions 4, 6, and 7 (52.4%), and least in Question 5 (47.6 %), Overall, the satisfaction index of respondents was 91.07% and it was maximum for Question 1 and Question 2 (94.29%) and least for Question 5 (87.62%). (Table 1, Figure 7, Figure 8) Where the satisfaction index is calculated by the formula:

Satisfaction Index for single Question *(q)*

$$SI = \frac{1\times(\text{No. Str Disagree})+2\times(\text{No. Disagree})+3\times(\text{No. Neutral})+4\times(\text{No. Agree})+5\times(\text{No. Str Agree})}{5\times N}\times 100$$

Satisfaction Index for all Questions (*q*)

$$SI = \frac{1\times(\text{No. Str Disagree})+2\times(\text{No. Disagree})+3\times(\text{No. Neutral})+4\times(\text{No. Agree})+5\times(\text{No. Str Agree})}{5\times q\times N}\times 100$$

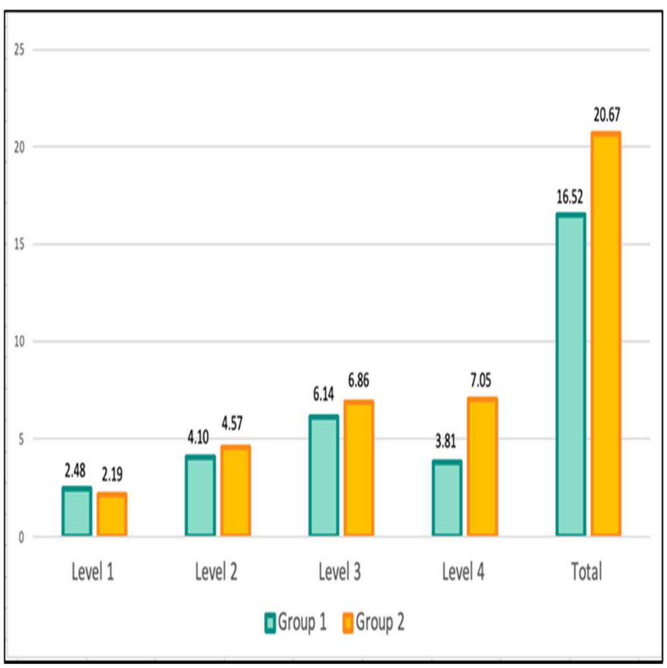

Figure 5: Comparison of Group 1 and Group 2 scores of each level

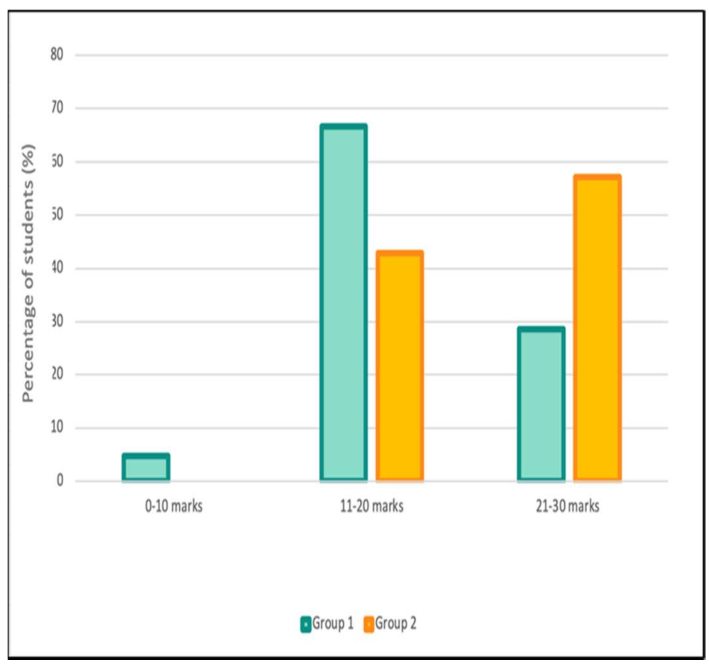

Figure 6: Relationship between score range and percentage of students of both groups

Item	Response	No.	%	Satisfaction Index
Question 1	Agree	6	28.6	94.29
	Strongly Agree	15	71.4	
Question 2	Agree	6	28.6	94.29
	Strongly Agree	15	71.4	
Question 3	Neutral	1	4.8	92.38
	Agree	6	28.6	
	Strongly Agree	14	66.7	
Question 4	Neutral	2	9.5	88.57
	Agree	8	38.1	
	Strongly Agree	11	52.4	
Question 5	Neutral	2	9.5	87.62
	Agree	9	42.9	
	Strongly Agree	10	47.6	
Question 6	Agree	10	47.6	90.48
	Strongly Agree	11	52.4	
Question 7	Neutral	1	4.8	89.52
	Agree	9	42.9	
	Strongly Agree	11	52.4	
Question 8	Agree	9	42.9	91.43
	Strongly Agree	12	57.1	
Overall	Neutral	6	3.6	91.07
	Agree	63	37.5	
	Strongly Agree	99	58.9	

Table 1: Student responses for various satisfaction items

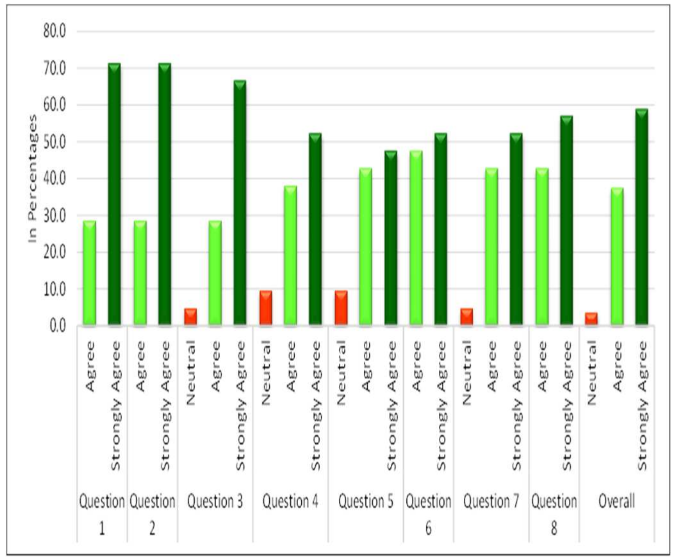

Figure 7: Percentage responses of satisfaction items

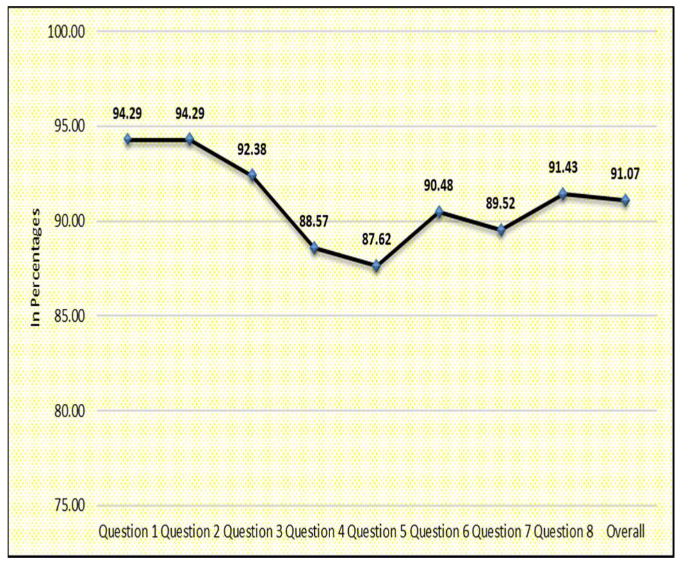

Figure 8: Satisfaction indices of each item and overall

Discussion

Animation is an enchanting way to breathe life and spirit into the illustrative diagrams of anatomy. It has long been employed to demystify the concepts of the hand and wrist [34], ear [35], larynx [31], anterolateral thigh [36], atrial septation [37], neuroanatomy [38], dental morphology [19], cranial nerves [39], pterygopalatine fossa [40] and head and neck anatomy [41]. It has even proved its utility in simplifying topics of maxillofacial surgery like dental implantology [25,42] and orthognathic surgery [43]. 3D animation tool has proven to be a valuable supplementary education tool [31,32]. Sparking excitement [38] and motivation [44], it kindles the road to effective learning with increased engagement and focus [38]. Both students and trainees have expressed satisfaction with this method of learning [45-47]. It is not only enjoyable [31,39,48] but it also demonstrates cognitive efficiency [31,49] with better student knowledge [19,38,39,50]. It improves student scores [35,51], is effective in deep learning [52], aids in understanding spatial information [53], and improves visual understanding of complex structures [8,19, 31,32,49, 54].

But majority of the studies have assessed the effectiveness based on student feedback [10,19,31, 39,55,56] and some through tests [10,35,39,55,56], and to the best of our knowledge, no studies have evaluated the depth of knowledge gained about anatomy through animation.

Our study's objective was to develop a tool that would make complex anatomy easier to visualize and, as a result, enable accurate diagnosis of maxillofacial space infections. The animation videos were triumphant. In group 2 more number of students scored higher as compared to Group 1, with a significantly higher average score in Level 4 and the grand total. The result suggests that animation videos were successful in attaining the deepest level of learning that is related to extended thinking and complex reasoning. Students were able to connect the information from the animation videos and apply them to correctly diagnose the space infection. Though the scores of group 2 were more in level 2 and level 3, the result was not significant. Group 1 achieved more marks in Level 1 questions, though not significant. This may relate that simple memory recall questions do not significantly benefit from animation.

The students of group 2 had an enthusiastic response to the animation video. According to the result from the satisfaction index the students agreed that the module achieved its learning purpose (satisfaction index of 90.48%), increased their understanding of the topic (91.43%), and were happy with the overall quality of the information (94.29%) as well as how it was presented and explained (94.29%). Students acknowledged that the module is relevant (92.38%), and the knowledge gained met their expectations (89.52%). Students also appreciated its usefulness practically (87.62%) and clinically (88.57%). The overall satisfaction score of 91.07% confirms that 3D animations were well-designed and met students' expectations and satisfaction levels.

Altogether, the study indicates that animation is a helpful teaching technique for maxillofacial spaces, and when reinforced with lectures, improves understanding, test scores, and the ability to accurately identify the space infection.

Limitations

The study assessed knowledge retention through the animation video after 2 weeks. Future work could be done to observe the long-term effect of the tool on the depth of knowledge. Even though a period of 2 weeks was kept between implementation of learning resource and testing, it is difficult to say whether the increase in scores is due to animation video itself or because the students were taught the same topic twice; once through lecture and then through animation videos. The study could also not tabulate how much self-study a student had done before giving the test, or compare between both groups variables like students' IQ, spatial ability, and concentration ability that may influence the result. The animation tool provided 3-dimensional visualization on 2-dimensional screen also referred to as pseudo-3D. A better outcome could have been achieved if it could have been viewed in 3-dimensional space, but it was not possible for the study due to technical restraints. In future, the animation series could also be expanded to include the management through incisions for respective space infections.

Conclusion

In this project, animation videos were developed as a supplementary learning tool for students to simplify the complicated spatial relations of maxillofacial spaces, that in the future may aid them to diagnose and manage maxillofacial space infection effectively. The tool met its learning objective as it has a positive impact on deep understanding of the topic and the students were happy with its implementation. Also, the depth of knowledge questionnaire provided insight into exactly what level of animation was helpful. After the study, all nine animation videos were uploaded on YouTube [57].

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Conflict of interest

The authors declare that they have nothing to disclose and there is no conflict of interest.

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