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Three-dimensional (3D) Visualization Educational Modeling for Ophthalmology Residents' Training: Viewpoints

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Abstract

Background: Three-dimensional models are used to guide residents and physicians in accessing specific anatomical areas and types of fractures and better diagnosis of anomalies. These models are useful for illuminating complex anatomical areas, such as orbit, especially limited space with sensitive access. The aim of this study was to design a three-dimensional visualization educational modeling for ophthalmology residents' training.

Methods: This study is a product-oriented application that uses radiological images of anatomy, anomalies, and orbital fractures based on actual CT scans of patients. These CT scans were carefully selected from the Picture Archiving and Communication System of Ghaem Hospital of Mashhad University of Medical Sciences.

Results: To produce twelve 3D models, the CT scan files were converted to 3D printer output. Then, the models were presented to residents at a training session by an ophthalmologist. These models created all major fractures associated with the orbit area and most disorders, anomalies of this area and several normal anatomical. The features of 3D models were mentioned. The strengths and weaknesses of the educational modeling, the level of satisfaction with the use of three-dimensional models, suggestions and criticisms were assessed qualitatively by the residents. Satisfaction was reported 100% by residents. Suggestions for future 3D models were presented, and the only criticism was fear of exams and grades.

Conclusion: Real-size 3D modeling help to understand the spatial and mental imagery of anatomy and orbital pathology and to touch different anatomical areas creates a clear image in the minds of residents, especially in the orbit.

Keywords: Modeling, Printing, Visualization, Three-Dimensional, Training, Ophthalmic

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Introduction

Education is of particular importance in achieving organizational goals. It increases the effi ciency of staff in the system. Therefore, education is an investment in achieving efficiency and maintaining people through long-term progress and satisfaction (1). Training is one of the most basic needs of human beings; without education, no society can survive. Education cannot be formed by effort and error,

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↑ ***What is "already known" in this topic:***
Educational intervention is valuable through 3D-models, the necessity of using effective novel teaching methods is very important. It is possible to understand spatial and deep relationships using those.

→***What this article adds:***
This study is the first attempt in Iran to determine the quantity of the effect of learning 3D-printed-models on orbit. These models allow for clear visualization. 3D educational models are able to motivate, understand, and visualize the mind. Given residents have never encountered such technology before, it can be said 3D-models have a satisfactory and surprising effect on the learning process.

and it requires planning (2). The educational model provides the space for a particular subject at a given time, consisting of all the elements of instruction (3).

Educational technology plays an important role in facilitating learning and is one of the most effective tools for improving the education system. To have a more effective, deeper and long-term learning, the teaching-learning process is designed, implemented, and evaluated using specific goals, new ways of psychology and communication sciences, as well as human and non-human resources (4). One of the technologies used in the educational environment is Three-dimensional (3D) printing. The 3D training provides a powerful visual structure (5).

There are many different types of visualization, such as sensory sender that apply ears, eyes, and hands to avails the phenomenon. The cognitive sender is the second form of visualization that creates intellectual data and knowledge structures. Visualization is a task or exercise of showing content through the visual and verbal method to increase content visibility and retention of information. Thus, educational organizations can benefit from better accessibility for future performance and learning in educational technology. The use of visual and educational systems in the teaching-learning process using images, multimedia technologies has provided good potential in strengthening students' high-level thinking skills. Therefore, there are two important aspects of multimedia, including the first is the combination of hypermedia to create knowledge by learners and designers, and the second is the use of visualization and virtual communities to create an artificial world (6). A step farther from the mere 2D visualization of 3D data is the creation of a double physical 3D model from imaging data. The way to facilitate this sender is now readily available in the form of 3D printing. This technology has expanded rapidly over the preceding decades and is now both ubiquitous and accessible to laypeople and clinicians (7).

Within ophthalmology, studies have shown the use of 3D printing models as a tool for repairing eye fracture surgeries by creating 3D absorbable implant templates (8). Dave et al. (2018), showed that a new approach to post-surgery orbit implant treatment, surgeons enable cost-effective and low-risk, to determine the exact shape of custom implants (9). To achieve 3D training, Meyer et al. (2018) showed the popularity of virtual 3D anatomical models in teaching undergraduate and graduate students in anatomy and physiology courses (10).

In recent years, the fidelity of models has greatly improved. These high-tech models can reflect educational planning (5). It is difficult to use two-dimensional photography techniques to learn, and it is more difficult to understand its disorders. 3D models can help improve understanding of anatomy and anomalies without the need for mastery of two-dimensional images (11).

Due to the anatomical complexity and some of the pathologies and diseases of the orbit and its spatial understanding problems, the need for three-dimensional tactile education for strabismus and echoplasty focal points was felt by the ophthalmology's residents. The physical use of 3D orbit models helps physicians understand common diseases, especially with the display of dynamic physical models of 3D Orbit anatomy, fractures, and anomalies. The purpose of this study was to design a 3D Visualization Educational modeling for Ophthalmology residents' Training.

Methods

Designing Educational Modeling

In this study, radiological images were used, including CT scans with fractures and congenital anomalies of orbit. The selection of normal anatomies was produced based on more than 400 files so we were able to make thinner slices.

Using 3D printing technology, the relevant and training models were prepared in the actual size of the skull in the following order.

- Orbit Anatomical 3D Models: Normal Orbit channels and foramen were identified in Normal Anatomical models.
- 3D models of orbit fractures (Tripod Quadri Pod, Lefort II, and III, inner wall, middle wall, roof, and floor of the orbit fractures)
- 3D models of orbit anomalies (craniosynostosis, plagiocephaly, Anophthalmos)

The procedure was to search through the Picture Archiving and Communication System (PACS) of Ghaem Hospital affiliated to Mashhad University of Medical Sciences for CT scans of the brain and sinuses, including CT scans of the eye area.

Also, the number of slices was noticed, better to convert to a 3D printing file. In the case of paranasal sinuses, the clearer the orbit, the better reconstruction. No age restrictions were applied to the search, and thicknesses of slices were considered less than 1 mm. CT scans without dental artifacts were selected.

Image defects in the initial models of all CT scans were corrected in software by the cooperation of a radiologist and an ophthalmologist. The suture of bones became clear.

Finally, to convert CT scans to the standard 3D printing file format (STL: Stereolithography), the following software, which is a free product of Autodesk, was used for output:

- 3D Slicer software that sends various commands, commands, and settings to the printer to get the best results (12). Different tissues were separated based on their densities (i.e., bone, fat, and soft tissue). The software separated the different tissues, and the bone tissue that is considered in this study was converted by the software into a three-dimensional file with the output of the STL extension.

- Mesh Mixer software that is professionally offered for triangular meshing and working on meshes. Using this software, you can clean complex shapes and 3D files and remove additions. You can also prepare 3D models for 3D printing (12).

- There are several editing software that use Mesh Mixer for editing. The STL output file was given to this software to be edited, and in addition to editing, it was added columns as support, because 3D printing is done layer by layer.

If the lower layers are large and the upper layers are smaller, like a pyramid, there is no problem, but if this order is reversed (i.e. a reversed pyramid), then we design a series

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of bases or supports under it in the software that are temporary. It should be made with the body and after that, it can be separated. Some places have a negative slope or are hanging. It has a small connection point that can be easily removed from the body after printing.

The placement of the bases was done in Mesh Mixer software, and as a result, the output obtained from it was an STL file, which, in addition to being edited, also had its bases laid.

- Repetier software is the basic theme needed to import a digital model in this software. This software supports STL and OBJ file formats (13).

At this stage, the STL file was ready for 3D printing. In this software, the 3D file was translated into the print language according to the instructions related to the printer because the printer does not understand the STL file and wants its commands, which are based on the x, y, and z-axis commands (14). The output of this software was prepared under the title of G.Code, which gave this file to the 3D printer.

Participants

All first- and second-year ophthalmology residents (15) participated in the study who were studying in the academic year 2019-2020.

Inclusion criteria were all ophthalmic assistants in the first and second academic years (2019 and 2020 admissions).

The exclusion criterion was an unwillingness to continue participating and answering research questions.

The project team includes three specialists of medical education, two ophthalmologists, one radiologist and one specialist of Community medicine.

The strengths, weaknesses, suggestions, and criticisms items

Strengths and weaknesses: The analysis was done based on a qualitative and quantitative assessment by the residents . Strengths and weaknesses of the educational modeling oriented-print 3D, the level of satisfaction with the use of three-dimensional models, suggestions and criticisms were recorded. These were reported by resident's mention, frequency, and percentage.

1. The strengths and weaknesses of the 3D printing-based educational model were measured by two qualitative questions (an open-ended question).

The level of satisfaction of the target group in the use of three-dimensional models was measured through an MCQ that it was possible to choose more than one option.

The purpose of using MCQ was more concentrated on the items of 3D models. In fact, what items of 3D models were the most satisfying.

2. Suggestions and criticisms about the use of three-dimensional models were measured through two open-ended questions.

Results

The tactile visualization educational modeling was very helpful in terms of understanding, especially in parts of the body that have specific complexities, such as orbit bones and midfacial areas.

3D models were performed CT scans on normal orbit anatomy, fractures (Tripod Quadri Pod, Lefort II and III, inner wall, middle wall, roof, and floor of the orbit fractures) and orbit anomalies (craniosynostosis, plagiocephaly, anophthalmos).

A special feature of this sample of three-dimensional models, which is unique, is the following;

- Models are made of bright colors and visible.
- The size of three-dimensional models is varied and based on the size of real CT scans.
- The material of the models is of the Plastic filament type (PolyLactic Acid: PLA), which has sufficient strength and is tangible.
- In terms of weight, the models are light and easily portable.

Participant demographics reported

Results are presented in Table 1 that shows the gender, age, and year of academic variables.

Suggestions and criticisms: The residens' suggestions and criticisms were measured by an open-ended question, which is as follows:

The idea for staining different bones was suggested by 45% of participants. Also, the ability to separate components and bones to teach fractures and the ability to move parts and fit like a puzzle was suggested by 36% of participants. Nine percent of individuals Suggested naming bones and increasing visual and three-dimensional training in various fields of ophthalmology and accompanying three-dimensional film training. Finally, the only criticism was presented by 9%, which was the fear of the exam.

Satisfaction results: Residents Satisfaction was 100% of the use of 3D models (Fig. 1).

The residents' opinions

Residents' opinions on the use of 3D modeling strengths and weaknesses. The items listed below:

Strengths: 1. Visualization and mental stabilization, 2. A clear understanding of bones, 3. Spatial visualization with real dimensions, 4. Bones position, 5. Tangible models, 6. Sustainability and a better understanding of content, 7. Better training and Easier to learn and memorize

Weaknesses: 1. Lack of staining of orbital bones, 2. Lack of separation of skull bones, 3. Uncertain suture of bones, 4. Inadequate models of all disorders

Comparison of categorized images of 3D models and their CT scans by fracture, anomaly, and normal is shown in Figures 2 to 12 (Fractures (2, 3, 4, 5), Normal orbit (6) and Anomaly orbit (7, 8, 9).

Table 1. Participant demographics information

Variable		Quantity
Gender	Male	4 (27.3)[1]
	Female	7 (63.6)
Age		31.2 ± 3.9[2]
Year of academic	First-year	6
	Second-year	5

[1] Data reported as Frequency (Percentage)
[2] mean ± standard deviation

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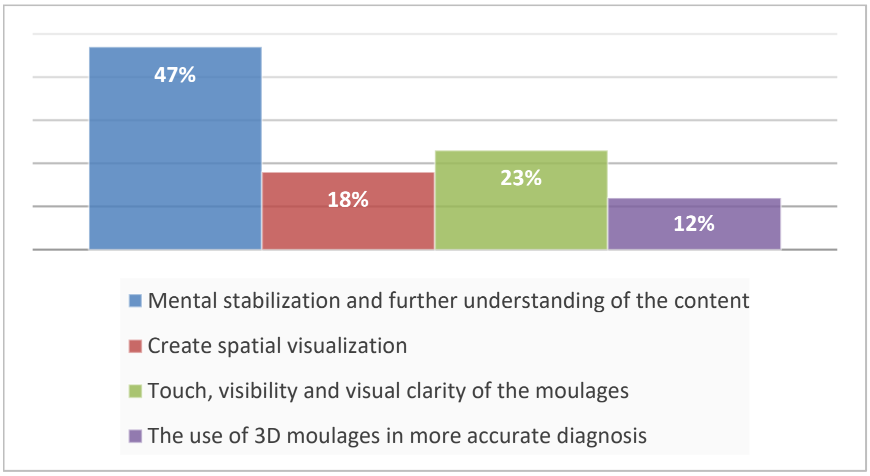

Fig. 1. Residents' satisfaction with the use of 3D models

The training was done by 3D models, such as a classroom, by an ophthalmology teacher to residents. The educational implementation of the 3D printing-based model is shown in Figures 10-12; (A written consent has been gotten from the residents to publish their photo).

Discussion

This study represented the feasibility of three-dimensional manufacturing models using printing technology, from CT scan images, to be used as a contributory in ophthalmology planning, as well as being an educational tool for residents. In fact, a 3D visualization educational modeling for ophthalmic residents' training.

Natural size and the same size as the real structures, 3D models can enhance spatial perception and facilitate the prediction of techniques and fractures and anomalies. On the other hand, a real physical model offers the adequate ophthalmic visualization of the periphery structures and clear identification of ophthalmic disorders.

The field research in the literature has shown that 3D printing technologies have been utilized in various fields such as engineering, medicine, arts, and education. Advocators of 3D printing assume that it is a newfound revolutionary technology and provides modern opportunities that have never been possible for creative generation and prototypes before. 3D printing is used in almost nearly all areas of daily routine life.

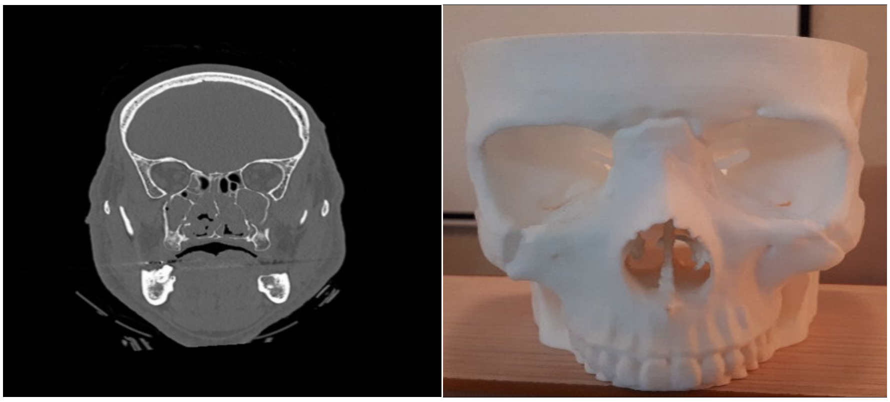

Fig. 2. CT scan and 3D model of Le Fort II fracture

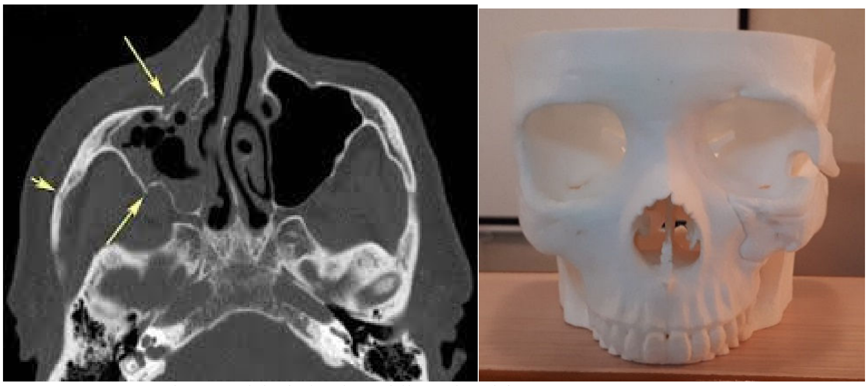

Fig. 3. CT scan and 3D model of tripod quadrilateral pod fracture

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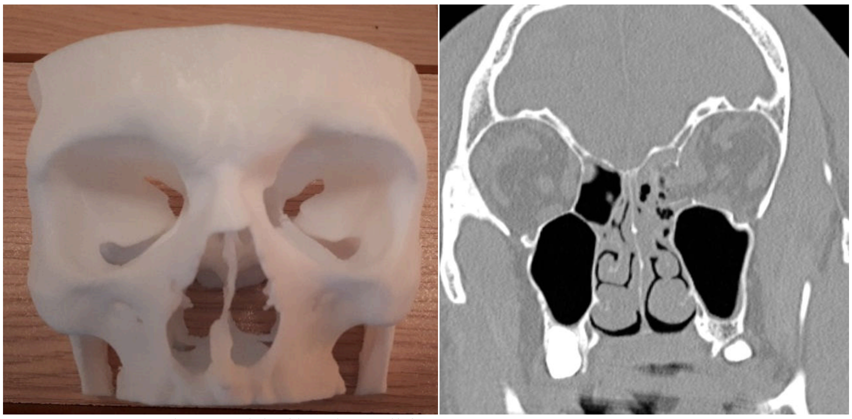

Fig. 4. CT scan and 3D model of interior wall fracture

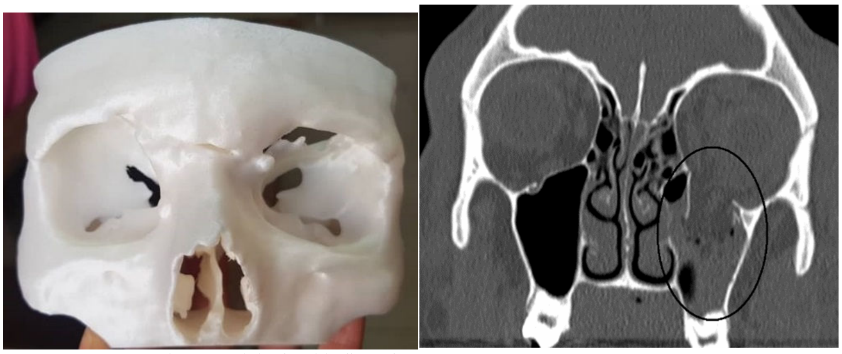

Fig. 5. CT scan and 3D model of Orbit floor fracture

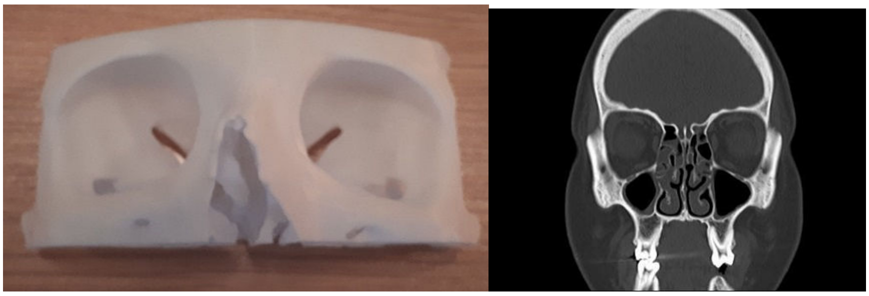

Fig. 6. CT scan and 3D model of normal anatomy

3D printing in the field of architecture attracts users, which is used depending on the needs of the individuals (16). In the same way, Kostakis et al. stated that visual instructional materials in the visual arts and design using 3D printers are among the technologies that can offer the advantage of 3D printers (17).

One of the advantages of 3D printing is the ability to customize new 3D objects. So 3D printing can be powerful instrumentation for generating tangible educational modeling. One of the important findings of this study is to create a clear understanding of the 3D spatial relationship in ophthalmology with the help of three-dimensional printing models. Some researchers highlighted the benefits of using rapid prototyping, digitalization and customization of 3D printing in medical education programs with recent advances in medical treatment needs (18, 19).

The utility of 3D models for planning and simulating medical procedures, recognizing anatomic landmarks, various orbital fractures types with relevant complications carry a high degree of benefit to many surgical specialties like ophthalmology. Similarly, a considerable number of researchers referred to 3D printing technology as being widely available for clinical use, allowing physicians and surgeons to perform more accurate reconstructions of the orbit (20-24).

Based on the survey results, 3D models as a teaching method achieved the highest score in all the survey questions concerning their overall satisfying. The participants gave great scores on the ability of 3D models to mental stabilization and further understanding content. When asked to touch, visibility and visual clarify of the models real was also rated highly by residents. The question of whether the 3D models would help them in creating spatial visualization, the scores were moderate. Because they stated that soft tissues should also be present.

In this study, we created 12 three-dimensional models that have several advantages;

First: Three-dimensional models from all major fractures associated with the orbit area (Triad Quadri Pod, Lefort II

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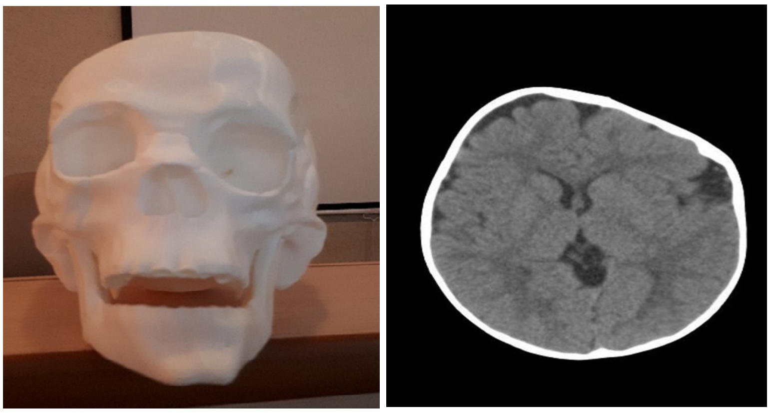

Fig. 7. CT scan and 3D model of orbital anomaly, plagiocephaly

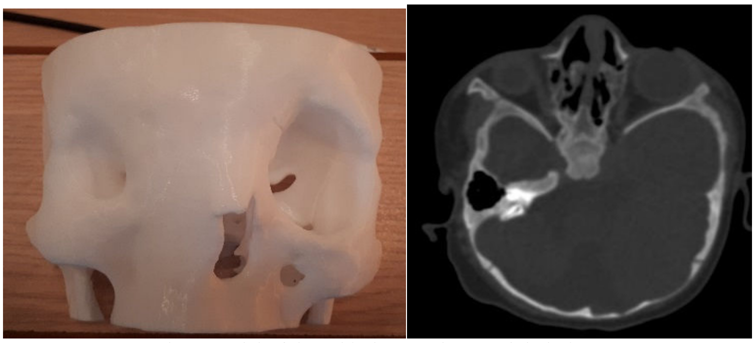

Fig. 8. CT scan and 3D model of the orbital anomaly, anophthalmic

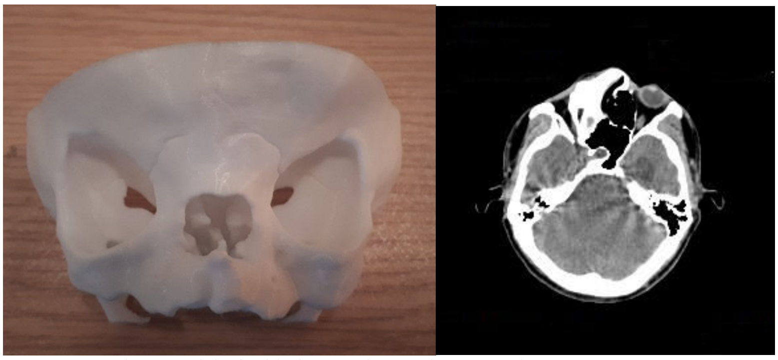

Fig. 9. CT and 3D model of orbital anomaly, craniosynostosis

and III, inner wall, orbital floor, and middle wall) and common disorders and anomalies of this area (craniosynostosis, plagiocephaly, anophthalmos) and some examples of normal anatomy are formed. The study of Kang et al. who produced 11 custom three-dimensional printed orbit implants to initially repair orbit wall fractures. In this regard, 3D printing models in which the orbital fracture site was modeled and then repaired through software. They created two three-dimensional printed modelings, one on each side of the fracture site, and placed the implant between them (20). Besides, Park stated that using three-dimensional printing techniques, other fractures around the eyes were successfully treated using various forms of titanium implants to maintain their structural and aesthetic appearance (21).

In our study, 3D models were physically prepared, which is inconsistent with Chen et al., 2017 study; Anatomical MRI images including the skull, face, nasal cavity, septum, paranasal sinuses, optic nerve, pituitary gland, carotid artery, cervical vertebrae, Atlantic axial joint, using soft tissue Computer software was provided in 3D to provide clinical anatomical models. These models made it possible to visualize, manipulate, and interact with the computer, and could be presented in a three-dimensional stereoscopic virtual environment, making users feel like they were inside the model (25).

In a study by Dongmei Cui et al., CT, images were reconstructed in 3D models using polar 3D glasses, which enabled students to observe vascular structures with clinical anatomical changes in the head and neck and their relationship. The location between the blood vessels, the skull, and the skin was also highlighted (26). Also, Ayala Alvarez's study shows that digital 3D objects are displayed on the system using computer programming (27). In this regard, digital design tools, with modeling, scanning, and prototyping, and 3D printing, have also become common in handicrafts and design, and editing digital images and preparing digital 3D maps, in addition to providing relevant concepts,

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Fig. 10. The teacher explains the details very well.

Fig. 11. The residents discuss about 3D model

Fig. 12. The residents record the voice of the teacher and take a photo

with them. Material concepts link visualization, creativity, judgment, and reflection and provide creative and facilitative opportunities for design and craftsmanship (28).

Second: The components of three-dimensional models are made of PLA (polylactic acid) flammable acids, a type of plastic, which is the most available material for making three-dimensional samples. This is consistent with the study of Gurer et al. 2019 (29). Polylactic acid is the most widely used 3D printer flamenco. In Saorin's study, the replicas are printed with a 3D printer with white PLA components (30). Also, Andreas stated that a string of thermoplastic materials such as PLA in a spool is continuously fed into an extruder that heats the material to its melting point (31). This is incongruent with the work of Kang et al., in which the filaments used to produce 3D models were made of titanium metal (20).

Thirdly: Among the three companies that produce 3D models, the best samples were prepared with the utmost care for the micron. This is consistent with the study of Ehler et al. 2018 (30). Depending on the specific application, different 3D printers with different accuracy (10-300 microns) were used. In this regard, In this regard, in Otton's study, it is noted that the most common types of printers are available with different accuracy (7). It is also recommended to simulate soft tissue three-dimensional models (skin, periosteum, dura, brain, blood vessels, blood, and tissues around the eyes).

The fear of the test was expressed as an important criticism by residents. because of that, we have created and used 3D models to decrease stress and tension.

Conclusion

The three-Dimensional understanding of these areas of the body using models that are fully CT scan Creates, from different angles, creates a more realistic spatial visualization and touches different anatomical areas, especially in the orbital area. These models allow for easy manipulation and clear visualization of such structures in a suitable and functional interactive environment. Therefore, three-dimensional visual and tactile training was effective in mental stabilization and permanence of content in the minds of assistants.

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Conflict of Interests

The authors declare that they have no competing interests.

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