Discussion on the Application of 3D-Printed Crania in Teaching Cranial Base Anatomy

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Abstract: The complex anatomical structure of the skull base makes it difficult to fully demonstrate the specific spatial relationships of anatomical structures in traditional teaching, often leading to suboptimal teaching outcomes. 3D-printed skulls can transform skull base data into tangible teaching models, offering a new approach to reduce the difficulty of skull base anatomy teaching. This paper systematically analyzes and elaborates on the advantages of 3D-printed skull base models in teaching and their production process, explores the specific applications of 3D-printed skulls in skull base anatomy education, and provides references for improving the quality of skull base anatomy teaching.
***Keywords*:** 3D-printed skull; teaching of skull base anatomy; application exploration

1. Introduction

With the high-quality development of medical technology, 3D printing has gradually been integrated into the field of medical education. This technology involves creating three-dimensional models from imaging data such as CT scans and MRI, which are then printed layer by layer to produce physical models with high simulation accuracy, tactile accessibility, and reusability. Applying 3D printing to cranial anatomy teaching can effectively address the shortcomings of traditional methods, enabling students to more intuitively observe detailed intracranial structures and tissue pathways. It enhances students' understanding of anatomical spatial relationships and provides new approaches for teaching cranial base anatomy.

2. Advantages of 3D-printed skull models in teaching skull base anatomy

(1) Achieve the materialization of cranial base anatomy.

The application of 3D printing technology in craniotomy teaching can transform abstract two-dimensional anatomy into three-dimensional physical models, intuitively aiding students in building a three-dimensional cognitive framework and reducing learning difficulty to some extent. Relevant studies indicate that using 3D-printed skull models to assist in craniotomy teaching enhances students' accuracy in identifying cranial base structures and improves their understanding of spatial relationships. The practical application of this teaching method significantly outperforms traditional teaching approaches.

(2) Reduce costs and enhance teaching adaptability.

In medical anatomy teaching, human specimens are scarce and costly to preserve, making it difficult to apply hands-on dissection to practical instruction. In contrast, 3D-printed models can be digitally mass-produced at lower costs and reused in anatomical teaching. Additionally, 3D-printed skulls allow for personalized instructional design tailored to the learning needs of students from different majors and proficiency levels, thereby enhancing the adaptability of skull base anatomy teaching [1].

(3) Improve teaching safety and interactivity.

In practical teaching, applying 3D printed skull bones to teaching can provide students with safe and risk-free practical tools. Students can repeatedly undergo practical training to improve their hands-on ability; Traditional specimen handling carries certain risks, such as specimen damage, formalin contact, and limited opportunities for operation. At the same time, the application of 3D technology in anatomy teaching can visualize flat knowledge, improve the interactivity of anatomy teaching, and to some extent stimulate students' learning enthusiasm.

3. The production process of 3D printed skull model

The production of 3D printed skull models uses mimetics software. Firstly, data collection is required to obtain high-quality anatomical data of the skull base. The commonly used acquisition path is CT scan of the head of clinical patients. Generally, to ensure the clarity of fine structures, the scan layer thickness needs to be controlled within 0.5-1mm, and the scanned data should be saved in DICOM format. Secondly, in the stage of model reconstruction, Mimics modeling software needs to be used to preliminarily process the collected data, extract the three-dimensional contours of skull base bones, blood vessels, nerves and other structures from the data, and remove or repair excess tissue, artifacts and defects to better ensure the integrity and accuracy of the model structure. At the same time, in combination with the teaching needs of skull base anatomy, targeted optimization of skull models is carried out, such as highlighting skull base fissures, labeling important structural names, etc., to facilitate students' learning and observation [2].

After completion, suitable printing materials and parameters should be selected according to the actual teaching needs. In clinical application teaching, the printing material is generally polylactic acid, which has become a commonly used material for making anatomical models due to its non-toxic, environmentally friendly, and hardness close to human bones; To ensure clearer display of the structure, the printing accuracy needs to be set to 0.1-0.2mm. At the same time, the printing speed and supporting structure should be finely adjusted according to the size and complexity of the model to avoid deformation or damage to the model. Finally, polish and polish the printed model to improve its smoothness and tactile feel; For models that need to display the course of blood vessels and nerves, different colored materials can be used for printing, or post staining labeling can be used to enhance the differentiation of the structure.

4. The specific application of 3D printed skull in teaching skull base anatomy

(1) Assisting theoretical teaching and strengthening three-dimensional cognition.

In the theoretical teaching of skull base anatomy, 3D printed skull models can serve as a teaching supplement to flat materials, assisting students in establishing three-dimensional anatomical thinking. The skull model has the characteristics of being touchable and rotatable. Teachers can use the model to provide a more intuitive explanation of the bone structure, vascular and neural pathways related to the skull base. For example, when explaining the relationship between the foramen ovale and the mandibular branch of the trigeminal nerve, students can feel the position , shape of the foramen ovale by touching the model, further deepening their understanding of the knowledge and establishing three-dimensional knowledge. For example, students can make a better image about branches routes and the neural innervation areaof the trigeminal nerve. Especially the pathway of the inferior alveolar nerve of the trigeminal nerve and its branches in the pterygopalatine fossa will be more Visualized on three-dimensional model. In instructional design, teachers can also combine 3D printed models with multimedia teaching, using animation demonstrations and other methods to break down and combine the models, presenting the spatial relationship of the skull base structure in a three-dimensional and dynamic manner, and assisting students in forming a systematic knowledge system of skull base anatomy.

(2) Support practical operations and improve operational skills.

Practical operation is an important component of clinical anatomy teaching, and 3D printed skull models can provide students with a safe and repeatable practical platform for practical operation. In practical teaching, teachers can guide students to identify, locate, and simulate anatomical structures using 3D printed skull models. For example, in the process of practical learning of skull base fissures, students can accurately locate important fissures such as foramen ovale and spinous foramen through touch and observation, and mark the corresponding blood vessels and nerves that pass through based on what they have learned; When simulating surgical approach training, teachers can combine common skull base surgical approaches in neurosurgery, allowing students to simulate incisions, bone window making, and other operations on the model, familiarize themselves with the anatomical structures involved in the surgical path, and improve students' understanding and mastery of surgical approaches. In addition, due to the low cost of 3D printing, personalized 3D printing models can be developed according to the actual teaching needs of different majors. For example, creating models for otolaryngology students that include structures adjacent to the skull base, nasal cavity, and sinuses can make practical teaching more targeted and enhance students' professional practical abilities[3].

(3) Optimize assessment and evaluation to test students' practical abilities.

Assessment and evaluation are key links in testing students' learning outcomes and teaching effectiveness. The application of 3D printed skull models can further optimize the assessment method of skull base anatomy teaching, achieving a combination of theory and practice in assessment. In traditional teaching assessments, written tests are mostly used to focus on testing students' memory of anatomical theoretical knowledge, but there is no systematic and comprehensive evaluation of students' practical operation ability and three-dimensional cognitive ability. After applying 3D printed skull bones to skull base anatomy teaching, practical assessment can be added, such as allowing students to identify corresponding skull base structures on the model, describe their adjacent relationships, or simulate simple anatomical operations. Scores will be given based on students' recognition accuracy and operational standardization, effectively testing their practical and cognitive abilities.

5. Conclusion

In summary, teaching skull base anatomy is a key and difficult point in medical education, and the emergence of 3D printing technology can provide new ways to optimize traditional teaching. The application of 3D printed skull models in skull base anatomy teaching can enhance students' three-dimensional cognition, improve their practical operation ability, and effectively promote the improvement of the quality of skull base anatomy teaching by virtue of its accuracy, touchability, and personalized advantages.

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