Hindawi
Scientific Programming
Volume 2021, Article ID 1169676, 6 pages
https://doi.org/10.1155/2021/1169676

Research Article

Medical Image Three-Dimensional Simulation Technology in Hospital Clinical Practice

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Received 22 July 2021; Revised 17 September 2021; Accepted 14 December 2021; Published 23 December 2021

Academic Editor: Gustavo Ramirez

We performed three-dimensional reconstruction of facial CT scan images of patients with mandibular angle hypertrophy to explore the related factors of mandibular angle hypertrophy. At the same time, the article uses the results of three-dimensional reconstruction to simulate the clinical operation and obtain the final operation method. It was found that all patients were able to obtain the proper surgical plan from the three-dimensional reconstructed images and can get the hypertrophy factor of the mandibular angle. For this reason, we conclude that computer reconstruction simulation technology can obtain the tissue changes before and after osteotomy of mandibular angle hypertrophy and get the cause of hypertrophy. Three-dimensional reconstruction simulation technology is the best auxiliary diagnosis plan for the selection of mandibular angle surgery.

1. Introduction

Mandibular angle osteotomy is a common operation in facial contouring. To improve the accuracy of surgery, plastic surgeons are making continuous efforts. Craniofacial surgery has been a hot topic for maxillofacial surgeons and computer experts. It improves the predictability of surgery and allows patients to understand the degree of deformity, correction methods, and postoperative effects visually and intuitively. This is conducive to strengthening doctor-patient communication [1]. Three-dimensional reconstruction based on DICOM data obtained from three-dimensional spiral CT scanning is a mature method recognized internationally. It has been applied in craniomaxillofacial surgery. To this end, this paper measures the geometric facial features before and after osteotomy of mandibular angle hypertrophy. We hope to explore a feasible way to improve the aesthetic effect and the accuracy of surgery.

2. Materials and Methods

2.1. Object. From March 2016 to August 2018, we treated a total of 16 patients with mandibular angle hypertrophy. The hypertrophic areas of the patient are bilateral. Among them, the number of males is 2 cases and the number of females in 14 cases. The age is (23 ± 6) years old. Inclusion criteria are as follows: (1) all patients required plastic surgery because of the skeletal hypertrophy in the lower mandibular angle area affecting the facial shape; (2) the patient's mental health is free of paranoia, depression, mania, and so on; and (3) the initial laboratory examinations of the patients were normal after admission. Exclusion criteria are as follows: those with other diseases without surgery. All patients gave informed consent to the treatment and trial protocol and were approved by the hospital's ethics committee.

2.2. Method

2.2.1. Data Collection. All patients underwent maxillofacial computer tomography (CT) scan. The equipment is GE 16-slice helical electron beam CT. The patient adopts continuous volume scan mode. The scanning condition is 120 kV, 300 mA. The layer thickness is 0.625 mm. The scan range is from the skull to the neck. The data are saved in DICOM format.

2.2.2. Three-Dimensional Reconstruction. We input the CT image data in DICOM format into Mimics10.0 software. We adjust different thresholds to make the best contour extraction of bone structures and soft tissues and reconstruct the three-dimensional model of the patient's craniomaxillofacial tissue [2].

2.2.3. Design before Osteotomy. We first measured the width between the mandibular angles of the bone tissue, the width between the mandibular angles of the soft tissue, and the angle of the mandibular angle on the reconstructed preoperative three-dimensional graphics. The osteotomy method was designed according to aesthetic principles [3]. We use the simulation function of Mimics software for preoperative simulation. The noisy results can be stored in the format and imported into the geographic information software. In the simulation, irrelevant points and noise points are removed, and the simulated postoperative three-dimensional shape is trimmed. In this way, we complete the preoperative simulated surgery design [4].

2.2.4. Surgical Operation. The operation was performed under general anaesthesia through nasal endotracheal intubation. To strengthen the anaesthesia effect and reduce bleeding, local infiltration anaesthesia is added. An incision is made at the anterior edge of the ascending mandibular branch slightly anterolaterally in the same direction as the outer, oblique line. We cut the mucosa, submucosal tissue, and periosteum and use a periosteal dissector to peel off the periosteum. During the whole process, care should be taken to protect the mental nerve and expose the lateral surface of the ascending branch [5]. According to the design plan determined before the operation, the outer plate was removed by osteotomy. After the bleeding is completely stopped, the wound is washed, the incision is sutured, and the wound is elastically bandaged. Antibiotics and routine care were applied after the operation.

2.2.5. Three-Dimensional Image Reconstruction Method of Mandible Profile Contour. The calculation method of the focal length is shown in Figure 1. We mark II_1 as the plane passing through the centres of all cameras. It intersects the imaging plane of the rear camera at the straight line L and then L passes through the vanishing points E_{V1}, E_{V2}, E_{V212}, and E_{V121}. E_{V1} and E_{V2} are the two vanishing points obtained above. C_R is the centre of the camera. The image centre C_0 is defined as the main point. $C_R C_{II}$ and E_{V1}, E_{V2} are perpendicular to C_{II}. $E_{V1}C_{II}$, $E_{V2}C_{II}$, and $C_R C_{II}$ are denoted as d_1, d_2, and f_{II}, respectively [6].

From the law of cosines,

$$\begin{aligned}(E_{V1}E_{V2})^2 &= (E_{V1}C_R)^2 + (E_{V2}C_R)^2 \\ &\quad - 2 \cdot E_{V1}C_R \cdot E_{V2}C_R \cdot \cos(\angle E_{V1}C_R E_{V2}).\end{aligned} \tag{1}$$

Among them,

$$\begin{aligned}(E_{V1}C_R)^2 &= d_1^2 + f_\pi^2, \\ (E_{V2}C_R)^2 &= d_2^2 + f_\pi^2.\end{aligned} \tag{2}$$

Then,

$$d_1 d_2 = f_\pi^2 - \sqrt{d_1^2 + f_\pi^2}\sqrt{d_2^2 + f_\pi^2}\cos(\angle E_{V1}C_R E_{V2}). \tag{3}$$

We assume that

$$\begin{aligned}f_\pi^2 &= a, \\ \cos(\angle E_{V1}C_R E_{V2}) &= \beta.\end{aligned} \tag{4}$$

Then,

$$(\beta^2 - 1)a^2 + (\beta^2 d_1^2 + \beta^2 d_2^2 + 2d_1 d_2)a + (\beta^2 - 1)d_1 d_2 = 0. \tag{5}$$

We assume that

$$\begin{aligned}A &= \beta^2 - 1, \\ B &= \beta^2 d_1^2 + \beta^2 d_2^2 + 2d_1 d_2, \\ C &= (\beta^2 - 1)d_1 d_2.\end{aligned} \tag{6}$$

The values that do not meet the geometric conditions are dropped; that is, there are

$$f_\pi^2 = \frac{-B + \sqrt{B^2 - 4\mathrm{AC}}}{2A}. \tag{7}$$

From this, the camera focal length f can be calculated as follows:

$$f = \sqrt{f_\pi^2 - C_0 C_{II}^2}. \tag{8}$$

Assume that the camera internal parameter matrix K is as follows:

$$K = \begin{bmatrix} f & 0 & u_0 \\ 0 & f & v_0 \\ 0 & 0 & 1 \end{bmatrix}. \tag{9}$$

Among them, (u_0, v_0) represents the coordinates of the principal point C_0. For a plane mirror whose unit normal vector is $n = [n_x, n_y, n_z]^T$, there is a matrix R of 3×3:

$$R = \begin{bmatrix} -n_x^2 + n_y^2 + n_z^2 & -2n_x n_y & -2n_x n_z \\ -2n_x n_y & n_x^2 - n_y^2 + n_z^2 & -2n_y n_z \\ -2n_x n_z & -2n_y n_z & n_x^2 + n_y^2 - n_z^2 \end{bmatrix}. \tag{10}$$

This matrix represents the rotation transformation between the centre of the rear camera and the centre of the corresponding virtual camera. In this way, the real-to-virtual transformation matrix can be expressed as follows [7]:

$$P = K\begin{bmatrix} R & t \\ 0^T & 1 \end{bmatrix}. \tag{11}$$

Among them, $t = 2(n_x p_x + n_y p_y + n_z p_z)(n_x, n_y, n_z)^T$; $(p_x, p_y, p_z)^T$ is a point on the plane mirror.

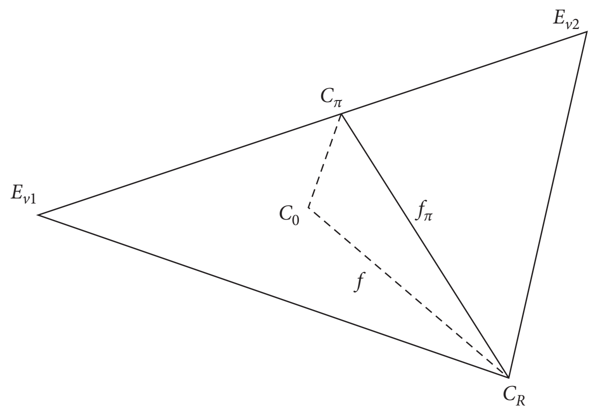


Figure 1: Focal length calculation method.

3. Results

3.1. Analysis of the Number of Participants. A total of 16 patients who met the criteria were included in the study. During the trial period, all patients did not interfere with the treatment or other treatments of this trial. No significant difference was found between the left and right mandibular angles. Therefore, we observe and analyse each mandibular angle as a separate individual [8].

3.2. Typical Cases. The patient Wang came to our hospital for mandibular angle hypertrophy osteotomy due to bilateral hypertrophy of the mandibular angle. Before the osteotomy, the three-dimensional reconstruction simulation was performed by software, and the operation was performed. The three-dimensional reconstruction model of the craniofacial bone before osteotomy is shown in Figure 2.

The three-dimensional reconstruction model of the soft tissue of the skull and jaw before osteotomy is shown in Figure 3.

The three-dimensional reconstruction model of craniomaxillofacial bone tissue half a year after the osteotomy is shown in Figure 4.

The three-dimensional reconstruction model of the craniomaxillofacial soft tissue half a year after the osteotomy is shown in Figure 5.

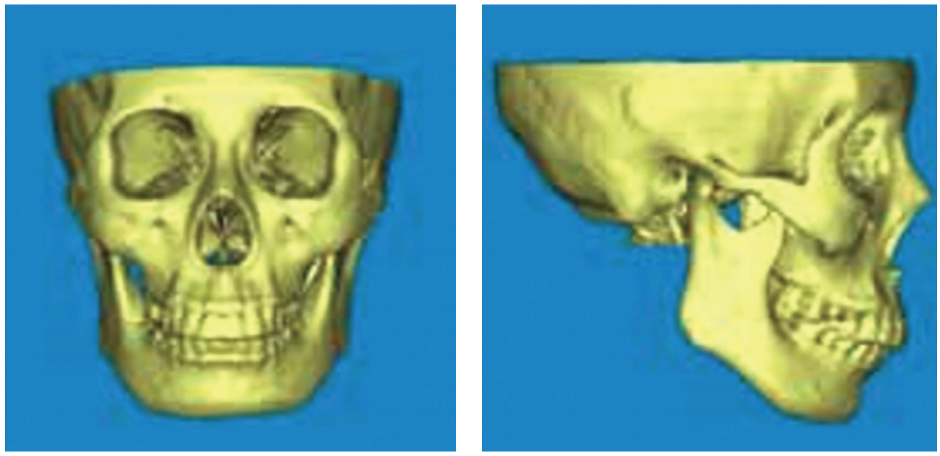
3.3. Measurement of Geometric Facial Features before and Half a Year after Osteotomy. As shown in Table 1, all patients obtained intuitive and accurate three-dimensional reconstruction graphics and simulated surgical plans and accurately calculated the difference of geometric facial features. The width between the bony mandibular angles was reduced by (7.69 ± 0.89) mm. The width between the mandibular angles of the soft tissues was reduced by (5.13 ± 1.19) mm. The mandibular angles on both sides increased by $(5.68 \pm 1.43)^\circ$and $(5.91 \pm 1.66)^\circ$, respectively.

3.4. Typical Cases. The width between the mandibular angles of the soft tissue is 123.69 mm. The angle of the mandibular angle on the left is 124.52°. The right side is 124.91°. Half a year after the osteotomy, a three-dimensional spiral CT scan was performed again. The width of the mandibular angle of the bone tissue was 94.39 mm, which was 9.37 mm less than before the osteotomy. Half a year after osteotomy, the width of the mandibular angle between soft tissues was 119.35 mm, which was 4.34 mm less than before osteotomy. Half a year after osteotomy, the left mandibular angle was 129.94°, 5.42° more than before osteotomy. The right side is 130.38°, which is 5.47° more than before osteotomy. The patient's surgical procedure went smoothly, and he was satisfied with the improvement of facial shape after osteotomy.

4. Discussion

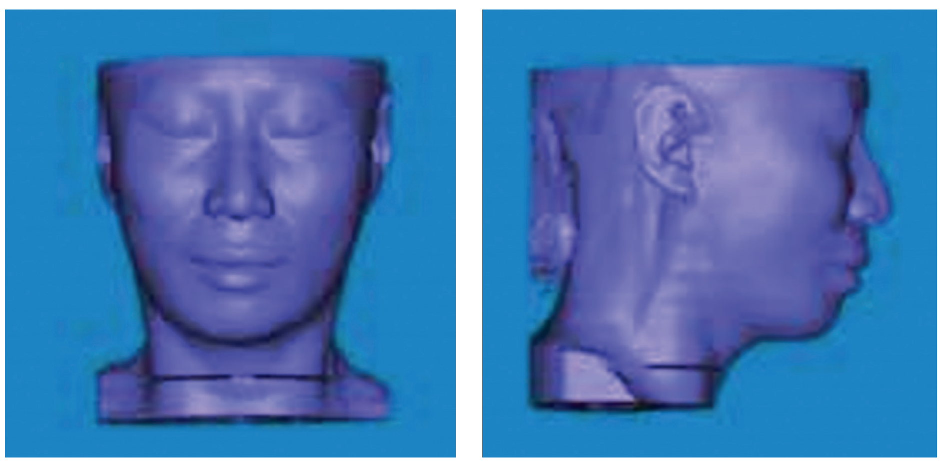
Digital medicine is an emerging discipline formed by the integration of life science and information science. It is not only a branch of information science applied in the field of medicine and health but also an important part of modern medicine. It represents the future direction of medical development. Therefore, it is of great clinical significance to carry out a three-dimensional reconstruction of the face and a simulation and operation prediction system before and after surgery. In the past, the research on the three-dimensional reconstruction and measurement methods of facial soft tissues mostly used 66°, laser scanning, stereophotogrammetry, and so on. 66° cannot be used for angle measurement and morphological observation [9]. Laser scanning takes a long time, and the influence of facial expression changes on the measurement cannot be avoided. Stereo photogrammetry is suitable for three-dimensional reconstruction and measurement of facial soft tissues, and its measurement accuracy depends on the number of pixels of a digital camera.

At present, in addition to routine examinations for patients with mandibular angle hypertrophy, preoperative colour photographs of the front and side of the face are taken, and X-rays of the front and side of the skull and X-rays of the mandibular tome are taken. We need to measure the width of the upper, middle, and lower parts, check the mandibular angle's hypertrophy and valgus degree, and measure the mandibular angle's angle. This will serve as a reference for mandibular classification and osteotomy. The actual operation also mainly depends on the doctor's experience. This has the problem of large data discrepancies. The clinical



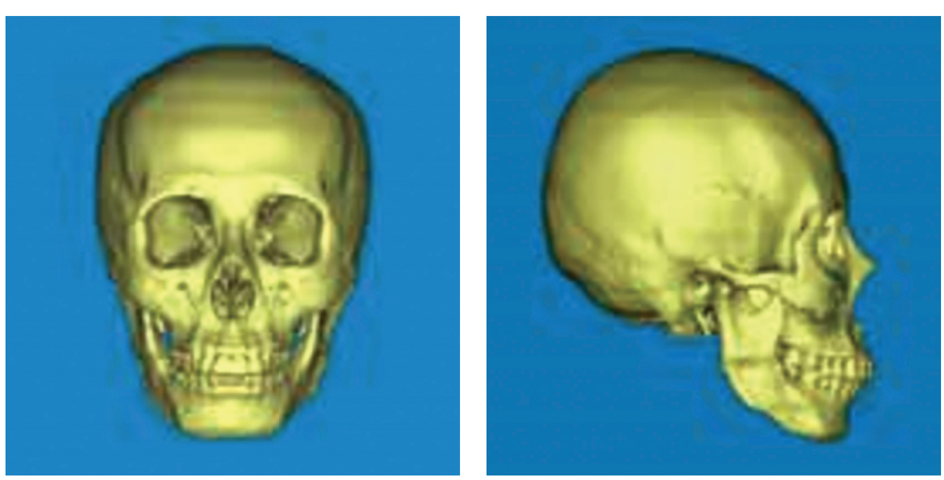
(a) (b)

Figure 2: Three-dimensional reconstruction model of craniofacial bone before osteotomy: (a) anterior view; (b) lateral view.



(a) (b)

Figure 3: Three-dimensional reconstruction model of craniofacial soft tissue before osteotomy: (a) anterior view; (b) lateral view.



(a) (b)

Figure 4: Three-dimensional reconstruction model of craniofacial bone tissue half a year after osteotomy: (a) anterior view; (b) lateral view.

(a)

(b)

Figure 5: Three-dimensional reconstruction model of craniomaxillofacial soft tissue half a year after osteotomy: (a) anterior view; (b) lateral view.

Table 1: Measurements of geometric facial features of patients before and half a year after osteotomy.

Facial geometric feature index	Preosteotomy	Postosteotomy	Difference value
Bone width of mandibular angle (mm)	101.44 ± 7.17	95.06 ± 5.93	-7.69 ± 0.89
Soft tissue width of mandibular angle (mm)	118.65 ± 8.33	114.24 ± 7.95	-5.13 ± 1.19
The angle of left mandibular angle (°)	113.55 ± 15.76	118.83 ± 17.03	$+5.68 \pm 1.43$
The angle of right mandibular angle (°)	113.70 ± 15.15	119.26 ± 17.88	$+5.91 \pm 1.66$

application of multislice spiral CT solves the above problems. The application of spiral CT can provide a three-dimensional image for three-dimensional reconstruction. And we can split the image into any plane and any angle. This provides clinicians with more detailed information on craniomaxillofacial surgery.

The three-dimensional reconstruction and computer simulation surgery system based on CT scan images was first reported by Altobelli in 1993. The 3D reconstruction under the Dicom data obtained by 3D spiral CT scanning is a mature method internationally. It has been successfully used in craniomaxillofacial surgery. Some scholars have confirmed that the difference between the simulation of computer-assisted surgery before surgery and the actual surgery after surgery is between 0.89 mm and 1.784 mm [10]. All patients are satisfied with their postoperative results. Some scholars have used computer-assisted surgical simulation technology to deal with complex craniofacial surgery diseases and found that the difference between the predicted result and the actual result is 0.9 mm, and the angle difference is 1.7°. Some scholars first perform measurement and analysis on 3D graphics and then use a 3D computer virtual surgical accounting system to deal with various maxillofacial surgery deformities. This chooses different surgical methods for the same disease, chooses the appropriate surgical method, and believes that this system shows good potential [11].

5. Conclusion

In this paper, Mimics10.0 software and CT three-dimensional scanning are used to measure the patient's facial geometric features before and after surgery and perform the solid three-dimensional reconstruction. We use computer simulation to select surgical styles and design osteotomy lines to guide intraoperative operations. The width of the mandibular angle between the bony and soft tissues of the patient decreased, and the angle of both mandibular angles increased. The application of three-dimensional reconstruction technology improves the accuracy of the operation, which also reduces the risk of the operation and improves the aesthetic effect.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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