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Reconstructive Operation of Severe Orbital Hypertelorism With Computer-Assisted Precise Virtual Plan

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Abstract: Orbital hypertelorism correction is still a less precise procedure, with a simple preoperative design and surgical results often depending on the operator's experience. In recent years, computer-assisted technology has been fully utilized in craniofacial surgery. This article aims to explore the clinical results of computer-assisted technology in orbital hypertelorism correction and discuss its advantages and effects on treatment. Four patients with orbital hypertelorism underwent intracranial and extracranial combined box osteotomy correction. Preoperative computed tomography scans were performed, and 3-dimensional 3D digital technology was used to measure the orbital spacing, virtually design the 3D cutting scheme, and guide the intraoperative 3D cutting to improve the accuracy of periorbital osteotomy and reduce the surgical risk. Four patients underwent successful surgery, and the average distance of the medial orbital wall was decreased from 43.6 to 23.4 mm. Computer-assisted box osteotomy shortens the operative time and provides better corrective results.

Key Words: box osteotomy, computer-assisted surgery, navigational plate, orbital hypertelorism, osteotomy simulation, virtual surgical planning

(*J Craniofac Surg* 2023;34: 511–514)

Orbital hypertelorism (ORH) is an abnormally wide interorbital bone distance caused by various craniofacial deformities, such as premature closure of the cranial suture, facial cleft, and post-traumatic deformity. It can be classified as mild (30–34 mm), moderate (35–40 mm), and severe ($\geq$40 mm).[1,2] The surgical correction of ORH was pioneered by French plastic surgeon Paul Tessier in 1968 and has been improved with the development of cranial and maxillofacial surgery techniques and the further understanding of the disease.[3,4] Through the efforts of surgeons, significant progress has been made, and better results have been achieved. Still, the complexity of the periorbital anatomy has limited the development of ORH surgery, which lacks reproducibility and precision.[5]

In the early 2000s, 3-dimensional 3D surgical planning, preoperative 3D printing, augmented reality-based surgical navigation, and computer-designed cutting guides were widely used to improve these techniques.[6,7] These modern-day practices are rapidly developing and are expected to refine and standardize the surgical correction of ORH. Patients with severe ORH exhibit not only lateral but also longitudinal asymmetry. We have used computer-assisted box osteotomy in such patients to correct orbital deformity, reduce surgical complications, shorten the operative time, and decrease blood loss.

This article describes computer-assisted techniques in ORH surgery and discusses its advantages and treatment results in detail.

MATERIALS AND METHODS

Patient Selection

Patients with ORH who attended the Plastic Surgery Hospital of the Chinese Academy of Medical Sciences from 2017 to 2021 were included. All patients provided written informed consent before participation. Inclusion criteria: orbital distance ($\geq$40 mm); patients who had serious digestive and respiratory diseases were excluded. A total of 4 patients, 2 males and 2 females, aged 4 to 8 years, with a mean age of 5.2 years, were included. All included patients underwent preoperative computed tomography (CT) scans with multiplanar and 3D reconstruction to assess the severity of ORH by measuring interorbital distance. By using these 3D data, 3D virtual planning was designed. Routine CT estimated bone correction of ORH scans 2 days postoperatively. Demographic information was tabulated (Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/SCS/E585).

3D Surgical Planning

A preoperative craniofacial CT scan (64-row spiral CT; Philips) was performed. The CT data were imported into the digital design software platform ProPlanCMF 3. 0 (Materialise) for the 3D reconstruction of the skull (Fig. 1A–C). Osteotomy and shaping were performed in the 3D model to determine the osteotomy path, movement direction, and distance. In addition to the extent of the deformity of the skull, the osteotomy path

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Received June 21, 2022.

Accepted for publication August 7, 2022.

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This study was supported by the Chinese Academy of Medical Sciences Innovation Found for Medical and Health Science and Technology & Clinical and Translational Medicine Research (NO. 2020-12M-CT-B-078).

L.O. and B.L. are co-first authors.

The authors report no conflicts of interest.

Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website, www.jcraniofacialsurgery.com.

ISSN: 1049-2275

DOI: 10.1097/SCS.0000000000009046

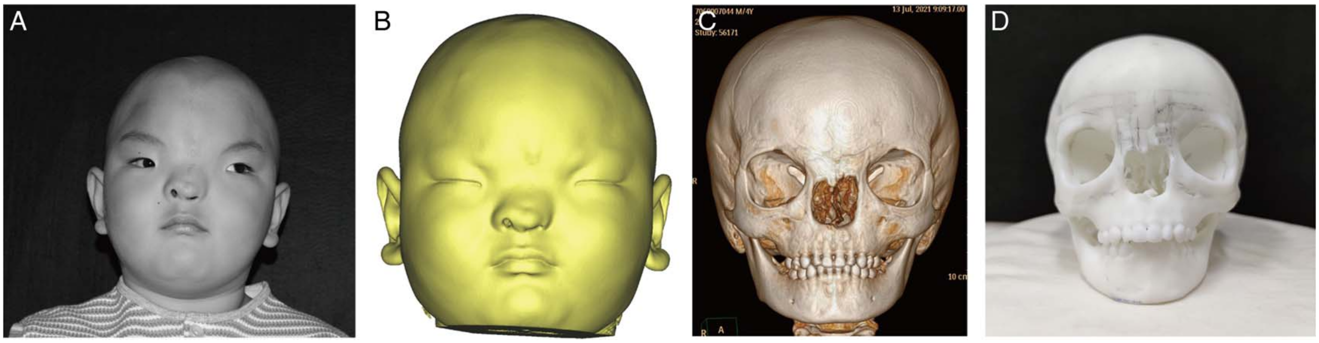

FIGURE 1. The appearance, 3-dimensional computed tomography imaging and a 1:1 plaster model of the skull. A, Preoperative image of the patient. B and C, A preoperative craniofacial computed tomography scan with 3-dimensional reconstruction. D, 1:1 plaster model of the skull with virtual osteotomy line was made by a 3-dimensional printer.

also takes into account the intracranial malformation of the bony crest and the intracranial brain tissue. By trying different planes on the 3D model, the most suitable osteotomy plane can be determined. After that, the final ORH osteotomy guide was printed by a 3D printer (Objet 30; Stratasys) using photosensitive resin. In addition, a 1:1 plaster model of the skull can be printed by a 3D printer (Z Printer 350; 3D System) (Fig. 1D). The osteotomy guide can be placed on the model before surgery to draw the osteotomy line and perform a surgical simulation of osteotomy on the model to verify the suitability of the produced guide.

Surgical Technique

Procedure: The child was anesthetized with general tracheal intubation, and box osteotomy was performed. The coronal incision was incised after a subcapsular injection of renin saline (Fig. 2A). Three-dimensional osteotomy simulation of ORH was showed by virtual surgical planning (Fig. 2B). The subcapsular level was separated downward to 2 cm from the superior orbital rim. The periosteum was incised to expose the skull by rectangular incision upward and split downward to the superior orbital rim (Fig. 2C), taking care to protect the supraorbital neurovascular bundle. The middle part of the flap was separated beneath to expose the inferior edge of the nasal bone, and the infraorbital area was peeled away from the periosteum below the infraorbital neurovascular bundle. A frontal cranial flap was designed and located 1 cm from the superior orbital rim in a semilunar shape. The 3D-printed cutting guide was used and the osteotomy line was marked with methylene blue along with the cutting guide (Fig. 2D). The dura mater was protected under direct vision, and the posterior bone junction of the coronoid was chiseled to the root of the nose, where the bone spine at the coronoid was wrapped in the dura mater. The frontal zygomatic process and the frontal process of the zygomatic bone were sawed on the lateral side of the orbit, the medial side was sawed next to the nose, and the middle nasal bone was reserved for use; the inferior side was transected below the inferior orbital foramen. Above all, the osteotomy line of the low orbital wall is very close to children's deciduous teeth, permanent teeth, and infraorbital nerve, which requires precise osteotomy according to the preoperative 3D design to reduce injury. Breaking the deep bone junction allowed the orbital bone and orbital contents to be free. Our experience showed that the periorbital osteotomy line was safer to be located behind the equator of the eyeball. The cranial flap was designed to be rearranged, and the cranial flap was fixed with steel wire, and the box orbital bones on both sides were brought together medially and fixed with steel wire after the shape was satisfactory (Fig. 3A–C). Two negative pressure drains were placed in the bilateral middle temporal fascia layer, and the periosteum and scalp were sutured, and the negative pressure drains were fixed. Intraoperative transfusion of erythrocyte suspension, plasma, and autologous blood transfusion was performed smoothly.

RESULTS

All 4 patients completed the surgery successfully. The osteotomy time was shortened to 2 to 3 hours, and the total operation time was 7.3 hours. The average blood loss was 610 mL and the average hospital stay was 9 days. There were no postoperative complications such as cerebrospinal fluid leakage, infection, intracranial hematoma, visual or olfactory disturbances. After surgery, the patient's pupil spacing was significantly improved (Fig. 4A–C). After 10 months of follow-up, the appearance was

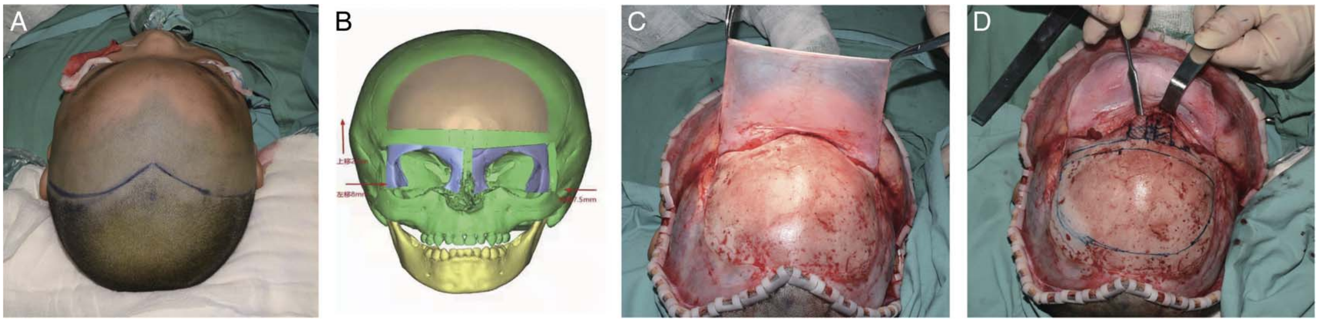

FIGURE 2. Virtual surgery plan. A, The coronal incision was designed. B, Three-dimensional osteotomy simulation of orbital hypertelorism. C, Intraoperative photographs showed the periosteum of the skull is completely separated. D, Osteotomy line was marked on the skull based on the virtual plan.

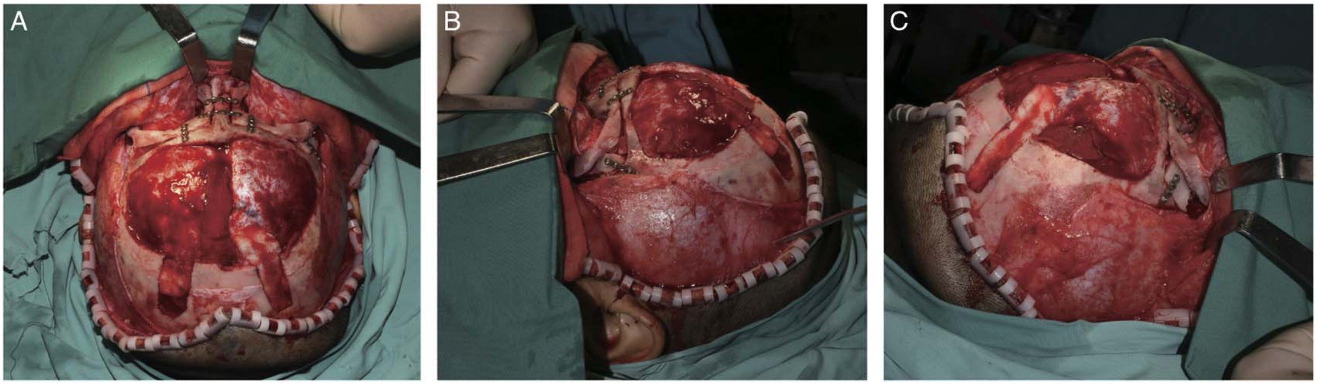

FIGURE 3. Intraoperative osteotomy and remodeling. A, Front view showed the result after orbit remodeling and reposition. B and C, Lateral view showed us that the lateral wall of the orbit was firmly fixed.

significantly improved (Fig. 4D). We also reviewed clinical information, including operative time, blood loss, length of hospital stays, complications, preoperative and postoperative interorbital distance. Clinical information was tabulated (Supplementary Table 2, Supplemental Digital Content 2, http://links.lww.com/SCS/E586).

DISCUSSION

The ORH treatment is a significant challenge in craniofacial surgery. The traditional approach relies on the surgeon's experience and therefore risks damaging the lacrimal apparatus and olfactory nerve. Since the mid-1990s, computer-assisted surgery has continued to develop, particularly in the field of craniofacial surgery.[8–10] On one hand, it enables preoperative planning of the osteotomies and bone resections using a 3D scanner. On the other hand, it allows the simulation of orbital approximation and osteosynthesis outcomes.[3] The choice of surgical approach is based on the severity of the ORH. Treatment of this type of orbital hyperopia involves correcting the hyperopia in the lateral direction and the position of the orbital distance in the longitudinal direction. After the osteotomy, the orbital walls can be moved in any direction as a whole to achieve complete correction. Because the inferior orbital wall of children is close to the permanent teeth, tooth damage can be avoided with 3D surgical design and 3D-printed cutting guide-assisted osteotomy. Based on our experience, the osteotomy line is designed to be safer behind the equator of the eyeball, so that important neurovascular vessels can be preserved. Finally, a precise osteotomy can be performed.

The surgical treatment of ORH is complicated by the long operating time, high bleeding, and high surgical risk in infants and children.[3,11] The use of digital software for preoperative surgical planning allows the surgeon to try multiple surgical options and osteotomy paths to avoid damaging essential tissues and obtain the results of different surgical options in advance to find the best surgical solution. The process performed during the actual surgery would significantly increase the risk of surgery. Once the optimal surgical plan is determined, an intraoperative osteotomy guide can be created based on the schedule, ensuring that the actual surgery will be performed according to the preoperative design and guarantee the postoperative outcome. The preoperative printing of a 1:1 3D solid model of the patient's skull plays a vital role in the surgical procedure, and it is desirable that the cranial vault of the model be lifted to facilitate further observation of the 3D structure of the child's skull base.[6] This allows the operator to be familiar with the dangers and to be able to avoid them during surgery. The operator can further verify the suitability of the guide plate on the solid cranial model, simulate the osteotomy, and simulate the postoperative effect. Through this process, the operator can become well familiar with the surgical technique, reduce the intraoperative surgical thinking time, indirectly reduce the surgical risk, and even prefabricate the titanium plate required for fixation after the intraoperative osteotomy through the solid cranial model so that the operation steps required during the operation can be completed before the operation as much as possible.

Preoperative simulation of the surgical procedure through digital software is also helpful for the child's family to have a

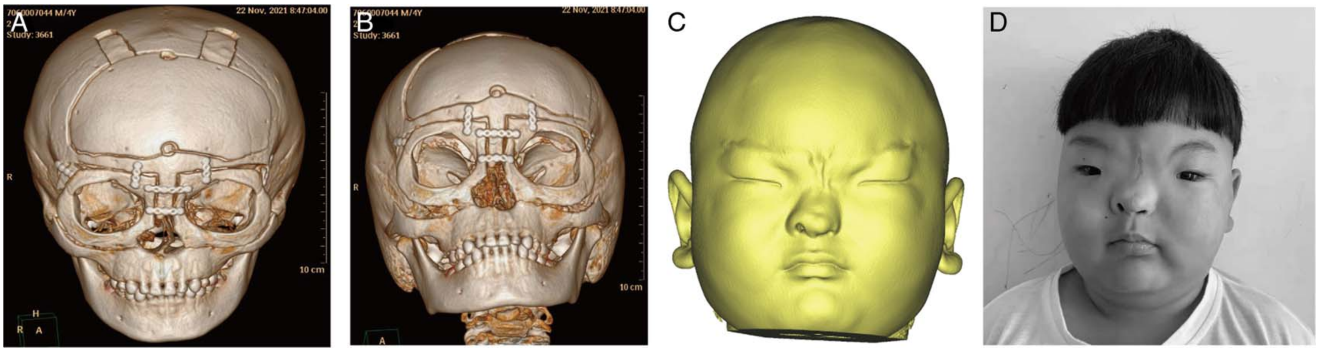

FIGURE 4. Postoperative imaging. A–C, Two-day postoperative computed tomography scans showed the excellent morphology. D, Follow-up photograph 10 months after the operation.

more intuitive understanding of the surgery, to know the risks and prognosis of the surgery, to facilitate doctor-patient communication, to increase the enthusiasm of the child's family to participate in the treatment, to promote the cooperation of the child's family in the postoperative treatment, and to reduce the doctor-patient conflict.[6,12] The positioning of the osteotomy guide is particularly critical because, in the positioning of the osteotomy guide, the operator only needs to follow the osteotomy path of the osteotomy guide to ensure the safety and effectiveness of the operation. This dramatically shortens the time of osteotomy and fixation, reduces intraoperative bleeding, decreases surgical risk, and achieves better surgical results.

The shortcoming of this study was no simultaneous correction of nasal deformity and epicanthus due to the large trauma. After correction of the orbit distance, the epicanthus could block the visual field. If there was no serious obstruction to the vision, the repair surgery of the nasal deformity and epicanthus were often scheduled in preschool. In severe case, it would cause vision loss, which required early correction of nasal deformity. And there is a lack of large samples and long-term follow-up results, including establishing indicators of cranial orbital shape and function, so that they can be quantified and precise and provide feedback for further improvement of the surgical plan to obtain the best overall results. This is the direction we will further investigate. Digital technology and 3D-printed guide plate positioning have improved the diagnosis and treatment of children with congenital ORH. The systematic and standardized application of digital technology and 3D-printed guide plate positioning technology in treating complex congenital widening of the orbital span with simultaneous surgical correction is of tremendous clinical significance and deserves a further promotion.

REFERENCES

1. Winters R. Tessier clefts and hypertelorism. *Facial Plast Surg Clin North Am* 2016;24:545–558
2. Converse JM, McCarthy JG. Orbital hypertelorism. *Scand J Plast Reconstr Surg* 1981;15:265–276
3. Batut C, Joly A, Travers N, et al. Surgical treatment of orbital hypertelorism: historical evolution and development prospects. *J Craniomaxillofac Surg* 2019;47:1712–1719
4. Habal MB. Surgical correction of orbital hypertelorism: a surgical evolution through time. *J Craniofac Surg* 2009;20:715–717
5. Batut C, Paré A, Kolker D, et al. How accurate is computer-assisted orbital hypertelorism surgery? Comparison of the three-dimensional surgical planning with the postoperative outcomes. *Facial Plast Surg Aesthet Med* 2020;22:433–440
6. Engel M, Hoffmann J, Castrillon-Oberndorfer G, et al. The value of three-dimensional printing modelling for surgical correction of orbital hypertelorism. *Oral Maxillofac Surg* 2015;19:91–95
7. Fadda MT, Saverio De Ponte F, Bottini DJ, et al. Study and planning of the surgical procedure for the orbital district in patients affected by craniofacial malformations. *J Craniofac Surg* 1996;7:207–223
8. Lin HH, Lo LJ. Three-dimensional computer-assisted surgical simulation and intraoperative navigation in orthognathic surgery: a literature review. *J Formos Med Assoc* 2015;114:300–307
9. Schlund M, Paré A, Joly A, et al. Computer-assisted surgery in facial bipartition surgery. *J Oral Maxillofac Surg* 2018;76:1094.e1–1094.e7
10. Atanasiu M, Paré A, Joly A, et al. Orbitofrontal bone reconstruction with cutting guides. *Ann Chir Plast Esthet* 2018;63:91–96
11. Laure B, Batut C, Benouhagrem A, et al. Addressing hypertelorism: indications and techniques. *Neurochirurgie* 2019;65:286–294
12. Sailer HF, Haers PE, Zollikofer CP, et al. The value of stereolithographic models for preoperative diagnosis of craniofacial deformities and planning of surgical corrections. *Int J Oral Maxillofac Surg* 1998;27:327–333