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Clinical Analysis of the Effects of Cranial Suture Reconstruction and Frontal Frame Band Transfer in the Operation of Premature Closure of Coronal Suture in Infants

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ABSTRACT

AIM: To compare and analyze the effects of fronto-orbital band anterior displacement in the operation of premature closure of coronal suture in infants.

MATERIAL and METHODS: A total of 31 infants with premature closure of coronary suture were randomly divided into two groups; experimental group (n=16) and control group (n=15). In the experimental group, the skull model was reconstructed by an imaging examination and three-dimensional (3D) printing technique before the operation, and the fronto-orbital band was anteriorly displaced during the operation to guide the surgical treatment of cranial stenosis. In the control group, the skull model was reconstructed by an imaging examination and 3D printing technique before the operation, and the fronto-orbital band was not anteriorly displaced during the operation by the same operator. The surgical effects of the two groups were compared.

RESULTS: During the 12-month follow up after the operation, the cephalic index of short head deformity in the experimental group was 80.7 ± 1.1, while that in the control group was 89.3 ± 4.5. There was a significant difference between the two groups.

CONCLUSION: Fronto-orbital band anterior displacement may guide the operation of cranial stenosis and significantly improve the effectiveness of surgical treatment of children with premature closure of coronal suture, which is worth popularizing in the clinical management of cases.

KEYWORDS: Infant, Cranial stenosis, Surgery, Cranial suture, 3D printing technique

ABBREVIATIONS: CI: Cephalic index, **CVAI:** Cranial vault asymmetry index

INTRODUCTION

Premature closure of coronal sutures is a common disease of congenital craniofacial malformations in infants and young children. Due to poor surgical tolerance, increased surgical trauma, and increasing rate of postoperative complications, surgery for cranial stenosis remains challenging (3,9,14). Three-dimensional (3D) printing technology is a manufacturing method to form 3D complex structural parts by adding materials point-by-point, line-by-line, and side-by-side. It is widely used in the biomedical field because of its rapidity and accuracy (6,7,10). Presently, the application of 3D printing technology in the field of neurosurgery mainly includes clipping cerebral aneurysms and making individual implants. There are few clinical applications and related reports in the operation of infantile cranial stenosis. To investigate the clinical effect of the 3D printing technique assisting the anterior displacement of the fronto-orbital band in the operation of premature closure of coronal suture in infants, the authors used the 3D printing technique to assist the anterior displacement of the fronto-orbital band to guide the surgical treatment of 16 cases of infantile cranial stenosis. In addition, compared to 15 cases of cranial suture

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reconstruction assisted by 3D printing technique as a control, this research aimed to explore the comparative analysis of the effect of fronto-orbital band anterior displacement in the operation of premature closure of coronal suture in infants and young children.

MATERIAL and METHODS

General Data

A total of 31 infants with coronary suture premature closure treated in our department from July 2012 to November 2020 were included.

Inclusion Criteria

1) short head deformity was the main symptom; 2) cranial computed tomography (CT) suggested that there was simple closure of coronal suture without closure of other cranial sutures; 3) there was no previous surgical history of cranial stenosis; and 4) the clinical data were complete.

Exclusion Criteria

1) short head malformation was not the main symptom; 2) cranial CT suggested the closure of other cranial sutures; 3) microcephaly; 4) previous surgical history of narrow skull; 5) absence or incompleteness of clinical data. In the control group, children with cranial stenosis were treated with preoperative 3D printing voluntarily, followed by cranial suture reconstruction. In the experimental group, we introduced a new surgical method called frontal frame retraction, and 16 patients who were treated with 3D printing auxiliary frontal frame retraction were included in the experimental group. This study was approved by the hospital ethics committee, and the families of patients signed the informed consent form (Date: 11.01.2021; No: 2021-011-01).

Experimental Group

1) 3D reconstruction and model printing: patients were routinely examined by CT and magnetic resonance imaging (MRI) before the operation, and the data were saved and exported to a computer in Digital Imaging and Communications in Medicine (DICOM) format after thin-layer scanning. The DICOM format data were imported into the Canadian Object Research Systems software for accurate processing, and the tissue representing the gray level of the skull was extracted. The tissue with a certain range of two-dimensional gray value was transformed into the general 3D printing format of STereoLithography (STL) through the software operation. The STL file was imported into the Connex3 350 3D printer produced by Stratasys Company in the United States, and the skull model was printed according to 1:1. Different parts of the skull were distinguished by materials of different colors, and the solid anatomical model of the skull was made, which was consistent with the actual size. 2) Formulation of the operation plan: according to the preoperative imaging data, the values of the cephalic index (CI) and cranial vault asymmetry index (CVAI) were measured. In addition, compared with the normal value range, combined with the 3D printing model, the best surgical movement range of frontal and orbital band forward was calculated. 3) Operation: the 3D printing technique was used to assist the fronto-orbital band anterior displacement, which was suitable for deformities of the short head, tip, and tower head caused by early ossification of the bilateral coronal suture. Concerning the operation method, we peeled off the scalp and exposed the frontal and orbital parts through the coronal incision of the scalp. Followed by the osteotomy design, we cut open the zygomatic bone, and the osteotomy line was equivalent to the coronal suture. The anterior osteotomy line was located approximately 1.5-2.0 cm above the supraorbital margin. After the frontal bone was amputated, the fronto-orbital band was cut off horizontally. Moreover, the superior orbital wall, zygomatic frontal suture, and temporal bone were cut horizontally, and the lower frontal band of the temporal bone was moved forward to form a wedge. We took off the fronto-orbital band and moved the bilateral temporal bone wedge closer to the medial side, which needed to be amputated and then fixed. The shaped fronto-orbital band was anteriorly displaced to a proper distance according to the calculated data and fixed to the nasal root, lateral orbit, and temporal part. Then the frontal bone flap was synchronously moved forward and fixed on the fronto-orbital band to improve the traditional cranial suture reconstruction and perform the operation.

The operation plan of the control group: 3D printing was performed to accurately determine the location of the premature closure of cranial suture according to the routine imaging examination data before operation. Subsequently, we reconstructed the cranial suture, opened the closed cranial suture, and removed the hyperplastic bone fibers, but the fronto-orbital band was not anteriorly displaced during the operation by the same operator.

Observation Indicators

The observation indicators were CI, maximum transverse diameter of the head/maximum anterior and posterior diameter of the head * 100, cranial vault asymmetry index (CVAI), and the percentage of the difference between the length of the two oblique paths at an angle of 30° to the anterior and posterior poles of the head to the shorter oblique diameter. The duration of operation and the amount of intraoperative blood loss were recorded. The head circumference, CI, and CVAI of infants with cranial stenosis were recorded before and 12 months after the operation.

SPSS 26.0 statistical software was used to process the data. The measurement data were expressed by $X \pm S$, and the counting data were expressed by examples and percentages. The head circumference, CVAI, and CI were compared by paired t-test before and 12 months after the operation. $P<0.05$ indicated that the difference was statistically significant.

RESULTS

Comparison of head circumference, CI, and CVAI in the same group 12 months before and after the operation: in the experimental group, the preoperative CI of the short head deformity was 91.6 ± 5.9, and the CI 12 months after the operation was 80.7 ± 1.1. There was a significant difference between the two groups ($p<0.05$). In the control group, there was no significant difference in CI before and 12 months after the operation ($p>0.05$). See Table I for details.

Comparison of the head circumference, CI, and CVAI 12 months after operation between the two groups: there was no significant difference in preoperative head circumference, CI, and CVAI between the two groups. During the follow-up 12 months after the operation, the CI of short head deformity in the experimental group was 80.7 ± 1.1 and that in the control group was 89.3 ± 4.5. The difference between the two groups was statistically significant. See Table II for details.

Comparison of intraoperative blood loss and operation time between the two groups: the average operation time was (3.1 ± 0.52) h in the experimental group and (3.0 ± 0.53) h in the control group. There was no significant difference between the two groups. The average intraoperative blood loss was (115.2 ± 37.9) mL in the experimental group and (120.6 ± 39.1) mL in the control group. There was no significant difference between the two groups. The details are presented in Figure 1A-H.

DISCUSSION

3D printing assisting fronto-orbital band anterior displacement technique to guide the operation of cranial stenosis may improve the surgical treatment effect of children with premature closure of sagittal suture, and the effect is better than that of traditional cranial suture reconstruction according to the case analysis of this paper.

This study was the first to carry out the clinical application of the 3D printing-assisted fronto-orbital band anterior displacement technique in the operation of children with premature closure of coronary suture and actively explored its clinical value in these children. As a common disease in pediatric neurosurgery, premature closure of coronal suture often occurs in infants. Short head deformities are the main clinical manifestations, which are often complicated by increased intracranial pressure, visual field impairment, mental retardation, and other neurological disorders. Evidently, they seriously endanger the health of infants and young children. The main treatment is surgical treatment; however, traditional surgery cannot effectively correct the head deformities, as it is accompanied by more complications, difficulties, and high risk (1,8,11). 3D printing technology is presently widely used in many subprofessional fields of neurosurgery. However, there is little clinical application of 3D printing technology in infantile cranial stenosis surgery (2,12,15). In addition, to the best of our knowledge, there is no control study in China through the novelty search report (4,5,13). This study was the first to use 3D printing technology to assist the fronto-orbital band anterior displacement to guide the surgical treatment of 16 infants with coronal suture premature closure. Compared to 15 cases of 3D print-assisted cranial suture reconstruction as control, it aimed to explore the effect of cranial suture reconstruction and frontal frame belt forward transfer in the operation of premature closure of sagittal suture in infants.

3D printing assisted fronto-orbital band anterior displacement technique significantly improved the effect of surgical treatment of premature closure of coronal suture in infants. There was a significant difference in the CI between the children with short head deformity before and after operation in the experimental group ($p<0.05$) from the comparison of head circumference, CI, and CVAI 3 months before and after operation in the same group. In the control group, there was no significant difference in CI and CVAI before and after the operation ($p>0.05$). It indicated that the surgical effect of the experimental group was ideal. It was confirmed that the 3D printing assisted fronto-orbital band forward-moving technique could significantly improve the effectiveness of surgical treatment of infantile cranial stenosis. The 3D printing assisted fronto-orbital band anterior displacement technique uses CT scanned data of deformed skull to reconstruct the

Table I: Comparison of Head Circumference, CI and CVAI 12 Months Before and After Operation in the Same Group

	Preoperative head circumference (cm)	Head circumference 12 months after operation (cm)	p	Preoperative CI	CI 12 months after operation	p	Preoperative CVAI (%)	CVAI 12 months after operation (%)	p
Test group	36.1 ± 2.4	38.8 ± 2.1	0.06	91.6 ± 5.9	80.7 ± 1.1	**0.01**	0.6 ± 0.6	0.5 ± 0.5	0.75
Control group	36.8 ± 1.6	39.2 ± 1.4	0.06	91.6 ± 4.6	89.3 ± 4.5	0.48	0.7 ± 0.5	0.6 ± 0.5	0.84

Table II: Comparison of Head Circumference, CI and CVAI 12 Months After Operation Between the Two Groups

	Head circumference 12 months after operation (cm)	CI 12 months after operation	CVAI 12 months after operation (%)
Test group short head	38.8 ± 2.1	80.7 ± 1.1	0.5 ± 0.5
Control group short head	39.2 ± 1.5	89.3 ± 4.5	0.6 ± 0.5
p	0.75	**0.01**	0.79

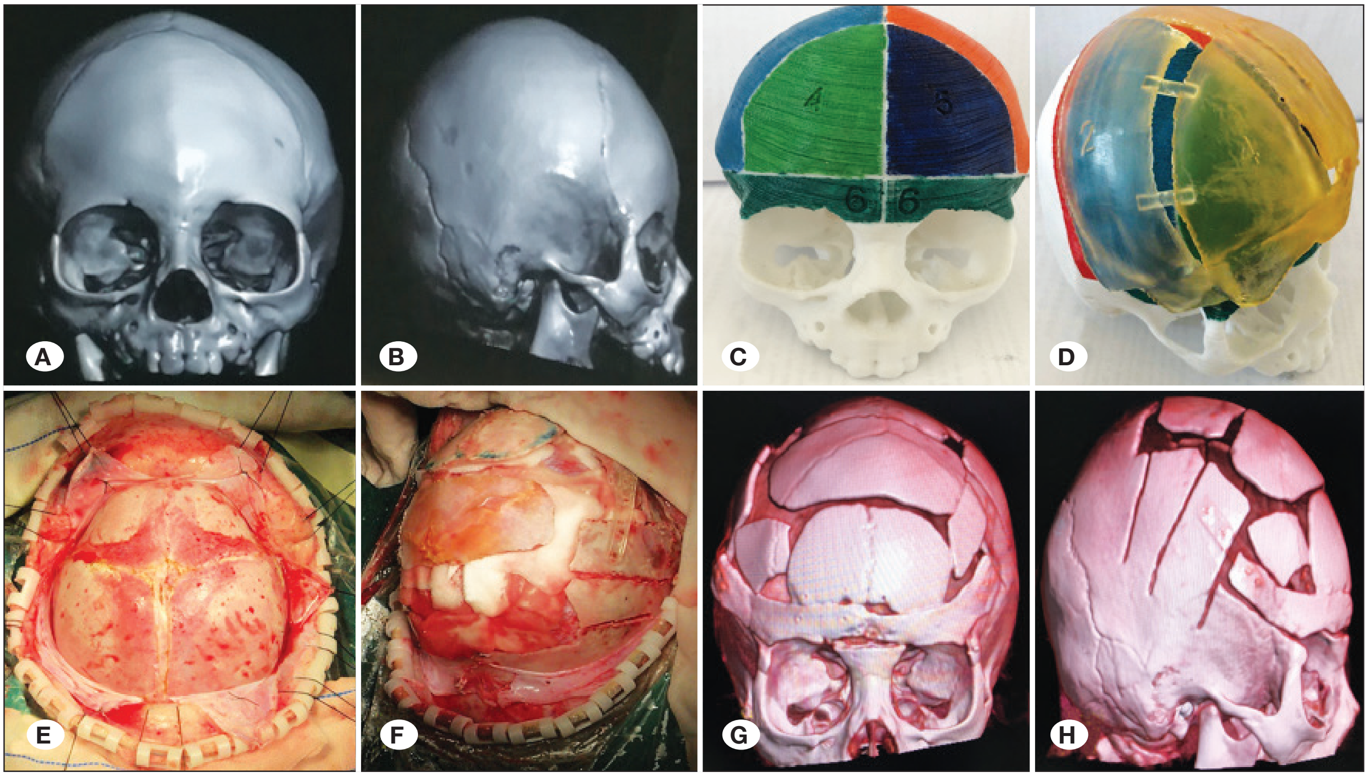

Figure 1: 3D printing technique assisted surgical treatment of infantile cranial stenosis. **A, B)** preoperative CT images; **C, D)** preoperative 3D printing model: assist the frontoorbital band to move forward and guide the formulation of the operation plan. **E, F)** 3D printing model during operation to guide the operation of frontoorbital zone forward; **G, H)** The CT images reexamined after operation.

deformed skull model. In addition, it uses the normal range of CI and CVAI to correct the deformed skull before operation and accurately calculates the fronto-orbital zone forward movement distance. In addition, it assists in the operation, which can significantly improve the therapeutic effect of skull orthopedic surgery for narrow skulls.

The use of 3D printing assisted fronto-orbital band anterior displacement technique to guide the operation of narrow skulls produces a better effect than that of traditional surgery. There was no significant difference in preoperative head circumference, CI, and CVAI between the experimental and control groups in this study. There was a significant difference in the CI value 3 months after the operation between the two groups in the children with short head deformities mentioned above. CI and CVAI in the experimental group were closer to normal after the operation. This indicated that the surgical effect of fronto-orbital belt retraction assisted by 3D printing was better than that of traditional cranial suture reconstruction. In addition, the proportion of head shape corrected after the operation was closer to normal, and the effect of the operation was better than that of traditional operation. Using this technique, according to the normal range of CI and CVAI before the operation, when the fronto-orbital zone anterior movement distance is accurately calculated preoperatively, it may achieve a more specific and complete operative plan, a more significant intraoperative orthopedic effect, and make the head closer to normal size after orthopedic surgery.

The fronto-orbital band anterior displacement technique guides the operation of a narrow skull. However, there was no obvious advantage compared with the control group in shortening the operation time and reducing the amount of intraoperative blood loss. However, compared to the operation time and intraoperative blood loss of a similar operation without 3D printing, it was found that the intraoperative bleeding volume and operation duration were significantly reduced or shortened after using the 3D printing technique. In this paper, statistical calculations were not carried out. However, the 3D printing assisted fronto-orbital band anterior displacement technique was used to guide the operation of narrow cranial stenosis. This technique has some advantages: we could simulate the operation before the operation, shorten the operation time, and reduce the amount of bleeding during operation with the accurate formulation of individual operation plan preoperatively. It reduces the risks of general anesthesia, surgical trauma, blood loss and infection, significantly increases the safety of operation, and reduces the difficulty of operation. In addition, it is beneficial to the operation of infantile cranial stenosis.

CONCLUSION

Using the 3D printing assisting fronto-orbital band anterior displacement technique to guide the operation of cranial stenosis may improve the effectiveness of surgical treatment in children with premature closure of the sagittal suture, and the effect is better than that of traditional cranial suture reconstruction according to the case analysis of this paper. Consequently, it is worthy of clinical promotion. However, the number of cases in this paper is small, and the follow-up time was short, which may deviate from the actual theory. The author will continue to follow up and study the patients and summarize the long-term effect of the operation.

AUTHORSHIP CONTRIBUTION

Study conception and design: HD

Data collection: QQ

Analysis and interpretation of results: QQ

Draft manuscript preparation: QQ

Critical revision of the article: HD

Other (study supervision, fundings, materials, etc...): MF, HW

All authors (QQ, MF, HW, HD) reviewed the results and approved the final version of the manuscript.

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