Application of computer-aided design combined with 3D printing technology in the treatment of infantile congenital maxillomandibular fusion

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Abstract: Objective: The objective of the present investigation was to explore computer-aided design in combination with 3D printing technology in the infantile congenital maxillomandibular fusion. Methods: A maxillary model was established by using a computer-aided design combined with 3D printing technology to surgically treat congenital maxillomandibular fusion of an infant. Surgical efficiencies were compared. Results: The surgical efficacy was nearly equivalent to that of the computer-aided design surgery with a difference of 11%. No recurrence of maxillomandibular fusion was observed. Conclusion: The maxillary model established by computer-aided design and 3D printing technology is precise and minimally invasive, so it is worth to promote its application.

Keywords: Congenital maxillomandibular fusion, syngnathia, computer-aided design, 3D printing technology

Introduction

Congenital maxillomandibular fusion is a rare congenital malformation involving bony fusion [1]. Infants diagnosed with maxillary deformities suffer from maxillomandibular fusion and restriction of mouth opening after birth, which severely affects feeding and respiration.

Early surgical intervention can resolve the aforementioned symptoms, decrease the effect of maxillomandibular fusion upon maxillary development, and reduce the risk of mandibular joint ankylosis. Early separation of the maxillomandibular fusion may also reduce the gastroesophageal reflux-induced apnea in the affected children [2]. Therefore, how to perform surgery with minimal injury and shorten the operative time is a challenge faced by the physicians.

The emergence of computer-aided design and 3D printing technology significantly enhance the surgical accuracy.

In the current study, computer-aided design and 3D printing technology was employed to design the surgery, perform simulated model surgery, and surgically separate maxillomandibular fusion. The surgical outcomes were compared to evaluate the feasibility of the surgical design.

Patient and methods

Patient

1-month old male infant was admitted to Guangzhou Women and Children’s Medical Center. The infant was diagnosed as the maxillomandibular fusion.

He was required to do surgical treatment of maxillomandibular fusion on the right side and an inability to open his mouth. The present study was approved by the Ethics Committee of the Guangzhou Women and Children’s Medical Center.

Computer-aided design 3D

Before the surgery, computer-aided design 3D and printing technology was utilized to establish a surgical model and perform surgery. The surgical efficacies were compared.

Mimics software was utilized to determine the osteotomy line. The osteotomy line was
designed as a straight line according to the location of the right maxillomandibular fusion and topical anatomic structure, which fully separated the bony fusion, avoided the condyle, inferior alveolar nerve, and maxillomandibular fusion.
3D in infantile congenital maxillomandibular fusion

dental germ injury, and averted the risk of accidental fracture.

**3D printing technology and simulated model surgery**

3D printing technology was adopted to establish a maxillary model.

Implementation of the simulated model surgery was based on the computer-aided design.

**Surgical approach**

Surgical procedures were performed according to the simulated model surgery. General anesthesia was administered via a nasotracheal tube under a bronchofiberscope.

**Comparison between the surgical outcomes**

Geometric studio (V 12) software was adopted to compare the surgical outcomes and calculate the differences.

**Results**

**Diagnosis results of the patient**

The clinical examination revealed right maxillomandibular fusion and a mandibular deformity. The degree of mouth opening was 0 cm on the right side and 0.2 cm on the left side. The height of the mandibular ramus on the right side was lower than that of the left.

A CT scan revealed a mandibular bone, coronoid process, and condyle on the right side were smaller than the left; there was no evidence of bone destruction. Fusions of the maxilla, mandible, and zygoma were observed (Figure 1). The child failed to receive oral feeding due to the restriction of the mouth opening. He was admitted with a nasogastric feeding tube in place, as illustrated in Figure 2. To avert gastroesophageal reflux and aspiration, the infant slept on the left side, and he could breathe normally and the oxygen saturation was maintained between 96% and 100%.

**Surgical model and perform surgery results**

As illustrated in Figure 3, the mandible was marked into yellow. The osteotomy line width was approximately 1 mm. After the osteotomy, a partial bone was located in the medial zygomatic arch was removed to avert the risk of recurrent bony fusion.

The bone in the medial zygoma was precisely removed to prevent surrounding tissue injury (Figure 4).
Results of 3D printing technology and simulated model surgery

3D printing technology was adopted to establish a maxillary model with equivalent size (Figure 5).

Implementation of the simulated model surgery was based on the computer-aided design. Initially, an osteotomy was performed and the redundant bone was discarded, as illustrated in Figure 6.

Surgical approach results

Osteotomy procedures were undertaken based upon the computer-aided design, 3D printing technology, and the design protocol of the simulated model surgery. The osteotomy and abundant bone removal was successfully performed (Figure 7).

The periosteum was preserved to cover the maxilla and mandible. Post-operatively, the infant could open his mouth approximately 2 cm (Figure 8).

A post-operative CT scan detected no injuries on the condyle, inferior alveolar nerve, and maxillomandibular dental germ. No accidental fractures occurred (Figure 9).

Surgical efficacy results

The surgical efficacy was nearly equivalent to that of the computer-aided design surgery with a difference of 11%.

No recurrence of maxillomandibular fusion was observed.

Discussion

Congenital maxillomandibular fusion is a rare congenital anomaly. The pathogenesis underlying congenital maxillomandibular fusion remains largely unknown.

It has been suggested that forward and downward contraction of the tongue were blocked during the embryonic period, thereby leading to abnormal fusion of the palate shelf, maxillomandibular fusion, and cleft palate [3]. Others have suggested that residual oropharyngeal mucosa contributed to the incidence of fusion [4]. Dawson et al. [5] retrospectively reviewed the relevant literature regarding maxillomandibular fusion and classified this condition into the following categories.

Type 1 is simple syngnathia with no other anomalies in heads and necks. Type 2 is complex syngnathia, with two subgroups. Type 2a is syngnathia with aglossia. Type 2b is syngnathia with agenesis or hypoplasia of the proximal mandible.

On the basis of these classification criteria, Laster et al. [6] proposed a modified classification for bony syngnathia. Type 1a is simple anterior syngnathia, and is characterized by bony fusion of the alveolar ridge without other congenital deformities in heads and necks. Type 1b is complex anterior syngnathia, and is characterized by bony fusion of the alveolar ridges with other congenital deformities in heads and necks. Type 2a is simple zygomatico-mandibular syngnathia, and is characterized by bony fusion of the mandible to the zygomatic complex, thus causing mandibular micrognathia. Type 2b is complex zygomatico-mandibular syngnathia, and is characterized by bony fusion of the mandible to the zygomatic complex with clefts or TMJ ankylosis.

Due to the rare incidence of the congenital maxillomandibular fusion, no standard therapeutic procedures are currently available [7]. Although a nasogastric feeding tube can overcome feeding difficulties, long-term syngnathia inevitably aggravates the maxillary deformity, induces the incidence of temporomandibular joint ankyloses, and increases the risk of gastroesophageal reflux and aspiration. Consequently, early surgical intervention plays a pivotal role in the clinical outcome [8].

It is relatively difficult to administer anaesthesia via tracheal intubation considering the inability to open the mouth. Intra-operatively, bronchofiberscope-guided tracheal intubation has been frequently adopted. Tracheal intubation via tracheotomy is used in critical conditions [9]. Therefore, the child should sleep in the lateral position to prevent aspiration and the need for emergent intubation during pre-operative nursing.

Due to the young age and relatively small jaws, the surgery should be performed with high precision to avoid injury to the temporomandibular
Joint, dental germ, inferior alveolar nerve, and other vital tissues, and avert the incidence of accidental fractures [10-12]. Individualized surgical procedures should be implemented based on the severity of the deformity and the site of syngnathia [13]. On the basis of the above requirements, CT scanning and 3D reconstruction have been used to establish the surgical procedures and complete the operation [14]; However, surgical precision is rarely been evaluated. Computer-aided design and 3D printing technology were applied to establish the model and implementation of a simulated model operation, which enhanced the precision of the surgical procedure and effectively averted the incidence of surgical complications. The surgical outcomes did not differ significantly, suggesting that the surgical design was rational and feasible.

Conclusion

The findings in this report demonstrate that the maxillary model established by computer-aided design and 3D printing technology is precise and minimally invasive, so it is worth to promote its application.

Disclosure of conflict of interest

None.

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References