Original Article - Retrospective Study

Three-dimensional Planning and Reconstruction of the Mandible in Children with Craniofacial Microsomia Type III Using Costochondral Grafts

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Abstract

Background: In craniofacial microsomia (CFM) Type III patients, autogenous costochondral grafts (CCG) are conventionally used for the reconstruction of the ramus and condyle. The aim of this study was to describe the use of CCG in children with CFM in terms of outcomes, growth patterns, and complications. **Materials and Methods:** This is a retrospective study of nine, aged 4–12 years, patients with CFM Type III, who underwent reconstruction of the mandibular ramus condyle unit by CCG. Seven patients had right-sided CFM and two had left-sided CFM. The rationale for this choice was to utilize the potential growth of the CCG, providing length to the ramus, and the joint by acting as a growth center; to control the repositioning of the chin center; and to improve child compliance by undergoing only one operation. The surgical treatment plan was determined preoperatively, based on measurements of mandibular vertical and horizontal deficiency and analysis of the mandibular posterior and anterior angulation. The mandibular planes and axis were defined by a three-dimensional simulation software program to perform a "mock surgery", by creating a prototype model. Clinical follow-up included measurements of the maximal opening, observation of the facial symmetry, and recording of complications, such as reankylosis. **Results:** There were no serious postoperative complications, infections, or graft rejections. Successful postoperative occlusal cants were noted and measured in five patients and acceptable results were obtained in three patients. In one case, the CCG underwent distraction osteogenesis to improve the facial symmetry. In one patient, the graft continued to grow and the chin started to deviate into the opposite side. Measuring and calculating the ratio of the ramus height on the panoramic X-ray revealed a good relation between the healthy contralateral and the reconstructed ipsilateral ramus. Postoperative mean mouth opening was 34.3 mm, with minimal midline deviation of 2.6 mm in occlusion. Mean follow-up was 51.7 months. The mean postoperative occlusal cant analysis for eight patients was 3.66°. **Conclusion:** CCG is useful in treating CFM Type III. The growth potential of the CCG makes it the ideal choice for children. The advantages of this graft are its biological compatibility, workability, functional adaptability, and minimal additional detriment to the patient. The use of a stereolithographic model preoperatively improved intraoperative precision by clearly displaying detailed anatomy of the patient undergoing craniofacial surgery. The surgeon can plan the length of the CCG before surgery and use the printed template while harvesting without waiting for the exact measurements to be provided by the facial surgical team.

Keywords: Costochondral grafts, hemifacial microsomia, mandibular reconstruction, stereolithographic models

Introduction

Craniofacial microsomia (CFM) is the second most common congenital craniofacial anomaly after cleft lip and palate.[1] CFM is considered as part of the oculo-auriculo-vertebral spectrum (OAVS) of anomalies, also known as the Goldenhar syndrome, with an estimated occurrence rate of 1 in 5600 live births.[2] Genetic and nongenetic factors are involved in the etiology of the Goldenhar syndrome. Autosomal recessive and dominant patterns of inheritance have been reported. Cases identified with an autosomal dominant pattern of inheritance have been noted in about 2%–10% of cases.[3] Most of the investigated cases are sporadic, some with known etiological

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DOI: 10.4103/ams.ams_157_16

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How to cite this article: Emodi O, Israel Y, Almos ME, Aizenbud D, Van Aalst JA, Rachmiel A. Three-dimensional planning and reconstruction of the mandible in children with craniofacial microsomia type iii using costo chondral grafts. Ann Maxillofac Surg 2017;7:64-72.

factors, such as diabetic mothers and the use of teratogens such as thalidomide and retinoic acid.[4] The OAVS of anomalies comprises a very diverse group of abnormalities, thought to be caused by the under-development of the first and second branchial arches, specifically due to an impaired growth of the stapedial artery in early embryogenesis.[5]

CFM's most obvious clinical features are presented as facial asymmetry and unilateral mandibular hypoplasia followed by microtia. Both the musculature and the facial skeleton are involved in CFM, affecting the maxilla, orbit, ear, cranial nerves, and soft tissues.[6] Over the years, there were disagreements regarding the importance of early diagnosis and treatment of CFM since it may be a progressive process, leading to increased asymmetry and disability over time.[7] In 1969, Pruzansky developed the first classification system for CFM and divided it into three subtypes.[8] Kaban *et al*., in 1988, proposed a modification for Pruzansky's classification by stratifying the 2nd subtype. Pruzansky and Kaban's CFM classification is currently the most effective description and grading tool of CFM's osseous deficit:[9] in Type I CFM, the mandibular and the temporomandibular joint (TMJ) components are present, normal in shape, but hypoplastic. The TMJ presents normal function but may be restricted in translation movement. In Type II CFM, the ramus-condyle unit (RCU) is small in size and abnormal in shape. In Type III CFM, the mandibular RCU and the TMJ are completely absent, and the lateral pterygoid muscle and temporalis, if present, are not attached to the mandibular remnant. The designation between Types IIa versus IIb relates to the displacement of the RCU and TMJ. In Type IIa CFM, the RCU and TMJ are located so that they can be used and the RCU reconstruction does not require complete replacement with costochondral grafts (CCG). Type IIb demonstrates enough displacement so that the treatment is the same as for Type III, i.e., absent RCU and TMJ. Distinguishing between Type IIa and IIb is based on X-ray ramifications. During the last years, the three-dimensional (3D) computed tomography (CT), a new diagnostic paradigm, has pointed out the inaccuracy and variability of the traditionally used classification. Studies have questioned the current clinical paradigm, suggesting the need to reexamine the classification of CFM.[10]

The CFM treatment plan has to take two factors into consideration: (1) the degree of osseous elements hypoplasia and deformity and (2) the facial abnormal growth potential of the affected and adjacent skeleton.[11] The treatment protocols are controversial and early intervention is still an issue for argument.[7] The main goals of CFM reconstruction are to reduce the oral functional disability and to correct facial appearance. Furthermore, noteworthy is the fact that most of the CFM patients are early in age, who, together with their families, suffer stress and have to overcome psychological hurdles.

Craniofacial deformities are treated by orthognathic and reconstructive surgeries. CFM reconstruction includes the movement or placement of bony segments into a 3D space. Thus, for satisfactory results, accurate treatment planning is required. Today, virtual surgery can be performed before the operation.[12-14] 3D tomography offers the opportunity to evaluate the craniofacial structures in precise details, thereby avoiding structure superimposition and magnification limitations. Newly developed helical CT scanning with 3D image formation techniques improves image adequacy, reduces radiation, and assists in data collection and measurements before reconstruction.[15] The mandibular complex reconstructive dimensions can be simulated by these new progressive 3D imaging stereolithography techniques, and computer-aided design/computer-aided manufacturing can create numerically controlled printed templates.

Autogenous CCGs are conventionally used for the construction and reconstruction of the ramus and condyle in adults and in children with a severe grade of deformity, especially in case of CFM. The graft contains a "growth center" at the costochondral junction. The advantages of this graft are its biological compatibility, workability, functional adaptability, and minimal additional detriment to the patient. The growth potential of the CCG renders it the ideal choice for children due to the ability of the rib to grow in tandem with the child's growth. Years of experience have supported the accepted approach that it is advantageous to correct malformed mandible with a missing condyle by CCG at an early age.[16] In Type I and II CFM, mandibular distraction osteogenesis (MDO) has also become in recent years an effective method for treating facial asymmetry.[17,18] A constant debate exists among clinicians about the efficacy and timing of MDO. However, CCG is considered the gold standard treatment option for Type III CFM, where there is an absence of the ramus.[19] We emphasize that the severity of the soft tissue deformity has a significant effect on the skeletal growth potential and on the ability to achieve a satisfactory clinical result for patients. This manuscript only deals with the skeletal component.

The aim of this study is to describe the use of CCG in CFM in terms of outcomes, growth patterns, and complications. In addition, we strive to present a new 3D technique for reconstruction of the mandible using 3D software and a 3D printed stereolithographic template.

Materials and Methods

This is a retrospective study of nine patients with CFM Type III who underwent reconstruction of the mandibular RCU by CCG surgery, between the years 2002 and 2014, in the Department of Oral and Maxillofacial Surgery, Rambam Health Care Campus, Haifa, Israel. Institutional review board (IRB) and ethical approval were obtained for the study. The children were introduced to a conventional treatment plan, based on a partial replacement of the mandibular ramus and condyle deficiency by an autologous CCG graft. The rationale for this approach was (1) utilizing the potential growth of the CCG; (2) providing length to the ramus and the joint by

acting as a growth center; (3) controlling the re-positioning of the chin center; and (4) improving child compliance by undergoing only one operation. All the patients' previously recorded data, operative process, and follow-up charts were extracted and gathered into one database. Surgical outcomes were measured by analyzing traditional radiographs and clinical examination, i.e., functional outcomes, such as mouth opening, symmetry changes, complications, graft resorption, or overgrowth and re-ankylosis. Based on Padwa's study of radiograph's analysis (1998),[20] pre- and post-operative occlusal cant was measured by the most current posteroanterior cephalogram. The postoperative analyzing was conducted by drawing a horizontal line from the supraorbital rim left to right (supraorbital line) and another horizontal line between the molars of the upper jaw (occlusal line). A vertical line was drawn from the Crista Galli through the nasal septum and tangent to the supraorbital horizontal line. The angle that the vertical line (crista galli–septum) creates with the occlusal line determines the occlusal cant degree.[21] In addition, we used an established method for measuring condylar and ramus asymmetry on panoramic radiographs (Padwa, 1998). The healthy ramus height was traced and measured as a ratio of the reconstructed CCG ramus using the panoramic radiograph. The ramus heights were measured from the most superior point on the condyle to an intersection point between two tangents, one to the vertical ramus and the other to the body of the mandible.

Three-dimensional planning and printing

The 3D surgical treatment planning was based on measurement of the mandibular vertical and horizontal deficiency and analysis of the mandibular posterior and anterior angulations. To lengthen the affected ramus area, a surgically created open bite was planned on the affected side. The mandibular planes and axis were defined by the 3D simulation software program to perform a "mock surgery" by creating a prototype model. An essential part of the surgical treatment success was the formation of an accurate 3D image of the facial skeleton preoperatively, based on numerically controlled mathematical models. The patient was scanned with a spiral CT scan [Figure 1].

The 3D surgical treatment plan was based on the measurement of the vertical and horizontal mandibular deficiency, as well as on the analysis of the mandible posterior and anterior angulation. The mandibular planes and axis were defined by the 3D simulation software program [Figure 2] to perform "mock up surgery" and surgical guides by creating a stereolithographic prototype model [Figures 3a, b and 4].

The surgical technique

Team I operated on the affected side of the face and prepared the operation site in the usual sterile method. A skin incision was made through the Risdon approach, exposing the angle of the mandible on the affected side. A blunt dissection was performed by preserving the marginal mandibular branch of the facial nerve. A pocket was then created in the direction of the glenoid fossa.

Simultaneously, Team II focused on the graft harvesting. A 4 cm incision was made in the skin overlying the 4th rib, using a 15 blade scalpel; the site was then infiltrated with 1% lidocaine with 1:100,000 epinephrine. Electrocautery was used for dissecting the underlying subcutaneous tissue. The rectus abdominis was identified, running vertically through the surgical field, divided horizontally, and retracted superiorly and inferiorly. The underlying rib was identified and bluntly dissected from the surrounding tissue. Great care was taken to avoid perforating the chest wall and subsequent pneumothorax.

Retention of a rectangle of the periosteum over the costochondral junction is necessary to reduce the risk of the bone becoming separated from the cartilage. The costochondral junction was identified laterally and medially to facilitate full access to the cartilage. The rib cartilage exposed was 3–5 mm thick and a segment was harvested with dimensions based on the 3D printed template which had been sterilized for intraoperative use [Figure 4]. The chest cavity was then filled with saline and a Valsalva maneuver was performed to rule out any pleural perforation. Accurate repair of the periosteum with 3.0 vicryl sutures and repair of the rectus muscle is important. Subcutaneous tissues were then approximated using 4.0 vicryl sutures and intracuticular 4.0 biocin was applied to the skin.

Team I positioned the prefabricated 3D stent intraorally, producing the surgically created open bite on the affected side and closing the mouth in the predicted occlusion by a temporary intermaxillary fixation [Figure 5]. The CCG was positioned according to the preoperative 3D planning [Figure 2]. The graft was secured in place with three miniscrews through the angle of the mandible [Figure 6]. The patients' occlusion was checked periodically throughout the procedure. Before closure, the area was copiously irrigated with normal saline and sutured in routine fashion with 3.0 vicryl and 5.0 nylon sutures. On completion of surgery, the patients were transferred, in stable condition, to the Pediatric Intensive Care Unit for 24 h of observation. The children were put on a soft diet for 2 weeks. A regimen of physiotherapy was used postoperatively to improve mouth opening and lateral movement. Radiographic follow-up was conducted using panoramic radiographs and posteroanterior cephalogram [Figures 7a, b and 8].

This is a retrospective study that was approved by and in accordance with local IRB standards of the Rambam Health Care Campus.

The orthodontic technique

Placing the CCG according the preoperative 3D planning was resulted with lowering of the mandibular occlusal plane on the grafted side while the untreated maxilla still has its upward occlusal cant. The prefabricated 3D planning stent was then inserted for stabilizing the surgically created posterior open bite, thus facilitates a normal and a balanced occlusal plane. In this way, excessive occlusal and mastication muscle force on the newly CCG were prevented. Four weeks postoperatively when bite opening and oral functions were improved, CCG surgically created open bite was managed with gradual

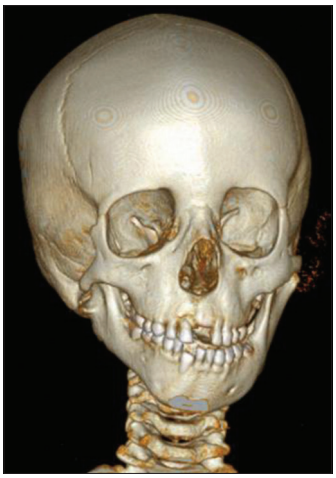

Figure 1: Spiral computerized tomography scan

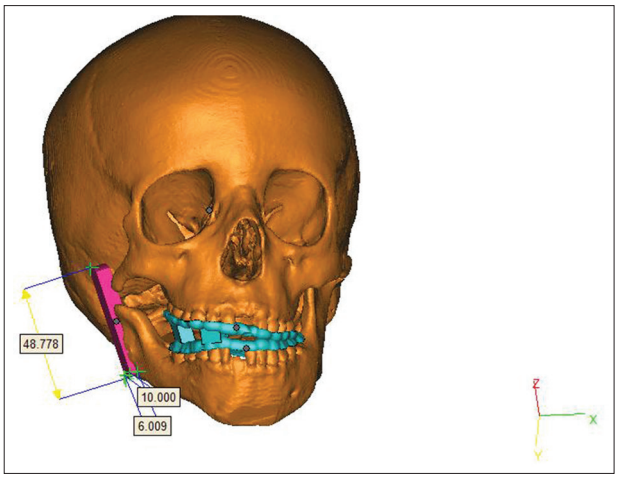

Figure 2: Segmented stereolithographic three-dimensional module

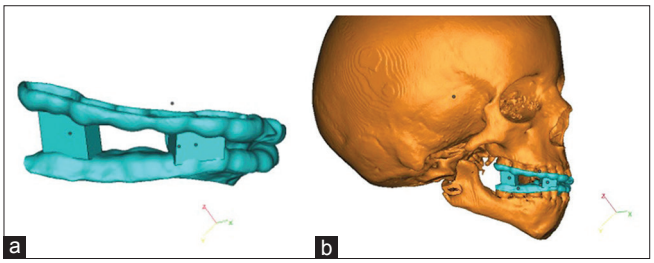

Figure 3: (a) The surgical guide, (b) the virtual "mock up" surgery

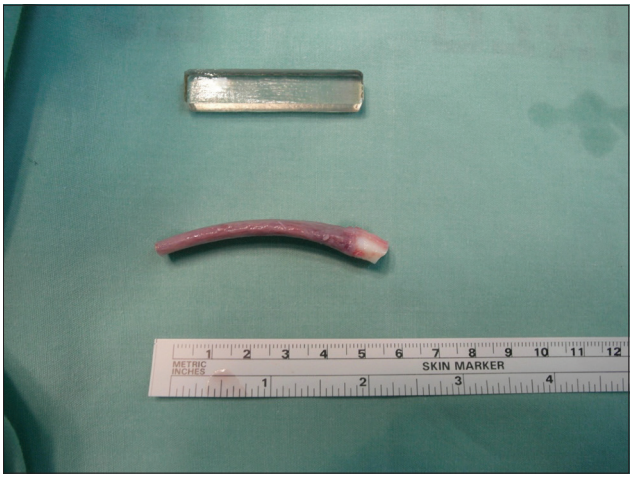

Figure 4: The Harvested costochondral graft according the preplanned three-dimensional printed template

Figure 5: Positioning the intraoral prefabricated computerized creating 6 mm open bite on the affected side and overcorrection of the mandible deviation

adjustment of a bite plate over few months. In this way, maxillary teeth and alveolar process erupted downward to reach the level of the mandibular occlusal plane.

Results

Nine patients (5 males) classified as Type III CFM (right side in 7 out of 9) underwent reconstruction surgery of the mandibular RCU using a CCG procedure. Patients' average age was 8.5 ± 2.65 years (range, 4–12) [Tables 1 and 2]. Follow-up of

Figure 6: Positioning of the CCG according to the pre-planned computerized data

all patients took place at a mean time of 51.7 ± 10.42 months (range: 12–122). Six patients were followed up for over 2 years. Short-term post-CCG surgery complications (Torticollis)

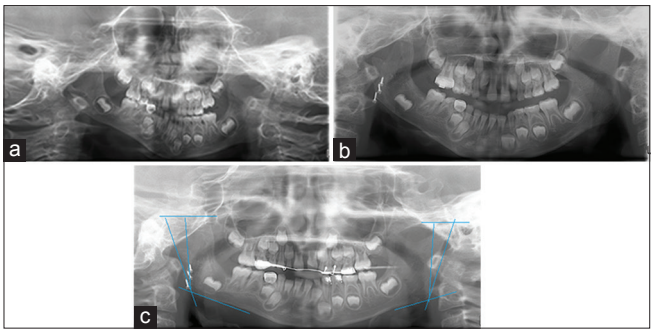

Figure 7: (a) Preoperative panoramic radiograph, (b) 8 months, postoperative panoramic radiograph, (c) The ramus heights were measured from the most superior point on the condyle to an intersection point between two tangents, one to the vertical ramus and the other to the body of the mandible

Figure 9: Preoperative image

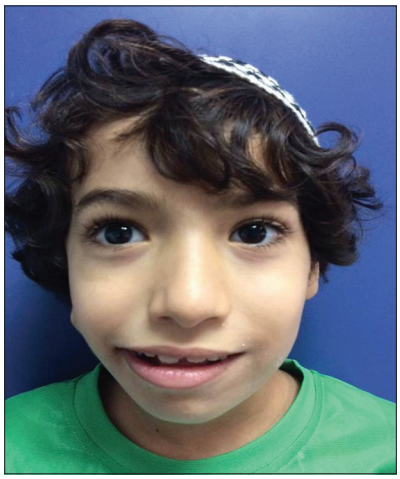

Figure 10: Immediate postoperative child image

were recorded in only 1 patient [Table 3]. CCG surgery was performed by two separate teams; the mean surgery time was 3:07 h.

At the time of admission, two patients suffered from obstructive sleep apnea (OSA), while one patient presented

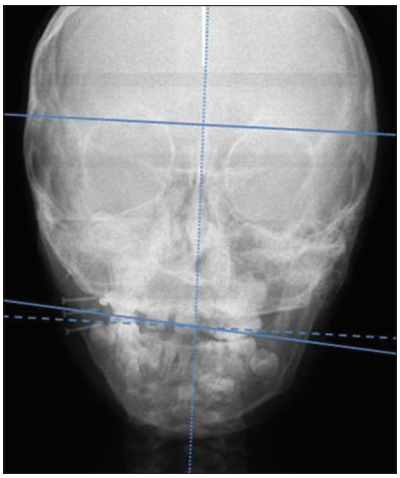

Figure 8: The ramus heights were measured from the most superior point on the condyle to an intersection point between two tangents, one to the vertical ramus and the other to the body of the mandible

Figure 11: 1 year postoperative child image

ipsilateral cleft lip and palate. Dental disorders such as missing impacted teeth and various degrees of malocclusion such as cross bite and Class II open bite were observed in all the children [Tables 4 and 5].

One patient underwent distraction post-CCG. Postoperative mouth opening, recorded at the time of data collection, ranged from 29 to 39 mm (mean 34.4 ± 0.35 mm). Midline deviation to the affected side ranged from 0 to 8 mm (mean 2.6 ± 1.35 mm). Graft resorption was noted in three patients, one patient had overgrowth, and six patients had normal growth. One patient with significant growth resorption underwent DO of the affected side; one patient had demonstrated an absence of growth and went through regraft procedure at the age of 14 [Tables 3 and 6].

The occlusal cant was calculated for eight patients [Figure 8], based on Padwa's analysis (1998):[21] The mean postoperative occlusal cant for 9 patients was 3.66°. Five patients had a postoperative occlusal cant of ≤4°, which indicates successful and symmetrical results. Three patients had

a postoperative occlusal cant of 5° to 8°, indicating an acceptable result [Figure 8]. One patient demonstrated a postoperative occlusal cant of 8°, which points to an unsuccessful result.

The healthy and the reconstructed ramus were measured for nine patients based on panoramic radiographs [Figures 7c and 9-11].

The mean postoperative mandibular ratio was 0.85 ± 0.16 cm. Eight out of nine patients showed a mean postoperative improvement in the mandibular ratio of 0.25 ± 0.14 cm. One patient demonstrated a negative mandibular ratio difference [Table 7]. Two investigators conducted the measurements. Intraexaminer error for reproducibility of the measurements was determined by retracing postoperative cephalogram and panoramic radiographs of nine CFM patients.

Table 1: Summary data: Amount of patients, mean age of surgery, mean follow-up time, and additional surgery

Total number of patients	9
Mean age at CCG surgery	8.5
Mean follow-up time (months)	51.7
Number of patients with follow-up ≥2 years	6
Number of patients undergone additional DO surgery	1

CCG = Costochondral grafts; DO = Distraction osteogenesis

Table 2: Diagnosis of patients

Patient number	Gender	Diagnosis and classification	Side
I	Male	Cl. III CFM	Right
II	Male	Cl. III CFM	Left
III	Female	Cl. III CFM	Right
IV	Male	Cl. III CFM	Right
V	Female	Cl. III CFM	Left
VI	Male	Cl. III CFM	Right
VII	Male	Cl. III CFM	Right
VIII	Female	Cl. III CFM	Right
IX	Female	Cl. III CFM	Right

CFM = Craniofacial microsomia; Cl. = Class

Discussion

CFM Type I and IIa in growing patients, in which there is a hypoplastic mandibular ramus, lengthening of the mandible by DO is the preferred method to ramus reconstruction with CCG. This is due to the possibility of distracting the hypoplastic mandibular ramus and body without the need of an additional bone graft and a donor site.[17,18] However, in growing patients with CFM Type IIb and III, the early reconstruction of the mandibular RCU by CCG is considered the method of choice.[7,11] Our study supports this approach as functional improvement was observed in 90% of the patients. Choosing the timing for surgical reconstruction is the most important consideration in CFM treatment.[21]

Eight out of the nine patients in our series were operated at the early-to-mid stage of mixed dentition when the vertical midfacial growth had not completely achieved its development. However, two patients with OSA symptoms were operated at earlier ages (4–6 years), to improve the airway passages.

Apart from correcting facial asymmetry, one goal of performing surgery at an early stage is to achieve an equal occlusal plane for facilitating controlled permanent teeth eruption, attained by creating and maintaining an adequate open bite for several months.[21] Padwa *et al*. maintain that the ideal time for the construction procedure is the period of mid-mixed dentition when there are active tooth eruption and alveolar growth. The success of the operation depends on the maintenance of the open bite and the regulation of tooth eruption to produce vertical midfacial and dentoalveolar growth.

As the process of additive manufacturing, or 3D printing, has become more practical and affordable, a number of applications to administer this technology in surgical procedures and preoperative planning, in particular, have been considered. While implantation of 3D-printed materials remains rare, the value of 3D design and printing is important for the generation of surgical templates. One example has been

Table 3: Operative data

Patient number	Age at CCG operation	Short-term complications	Follow up post-CCG (months)	Pre-CCG additional surgeries	Post-CCG additional surgeries
I	7	-	24	-	-
II	6 and 14*	-	24	-	Re-graft at age 14 due to no rib growth
III	10	-	12	-	-
IV	12	-	22	Left dentigerous cyst enucleation + iliac crest BG	-
V	9	Left torticulis	26	-	Auricular reconstruction
VI	8	-	122	-	Right mandibular DO Right orbital reconstruction
VII	4	-	110	-	-
VIII	12	-	96	-	-
IX	9	-	30	-	-

*The patient had undergone 2 CCG reconstruction surgeries. DO = Distraction osteogenesis; CCG = Costochondral grafts, BG = Bone graft

Table 4: Clinical findings at time of admission

Patient number	Hearing loss	Auricular malformation	Ocular anomalies	Cleft	Systemic/CNS abnormalities
I	Partial loss	Preauricular skin tag	Lagophthalmos	None	None
II	None	Auricular aplasia	Visual (focal) disorder	None	None
III	Complete deafness	None	None	None	Urogenital sinus, scoliosis, premature birth, right hydronephrosis, iron deficiency
IV	Partial loss	Preauricular skin tag	None	None	None
V	Partial loss	Preauricular skin tag	None	None	OSA, premature birth
VI	Partial loss	Preauricular skin tag	BLT epibulbar dermoid, hypertelorism	Right cleft lip and palate	OSA
VII	Partial loss	Preauricular skin tag	BLT epibulbar dermoid (larger on the right)	None	VSD
VIII	None	Preauricular skin tag	None	None	None
IX	Partial loss	Preauricular skin tag	Right epibulbar dermoid	None	Developmental retardation, OSA, premature birth + pregnancy diabetes, ADHD

CNS = Central nervous system; OSA = Obstructive sleep apnea; VSD = Ventricular septal defect; BLT = Bilateral; ADHD = Attention deficit hyperactivity disorder

Table 5: Dental findings at time of admission

	Patient number								
	I	II	III	IV	V	VI	VII	VIII	IX
Missing teeth	35, 45, 47	36, 37, 38, 45	35	35, 45, 46	35, 36, 37	48	None	None	17, 47
Impacted teeth	None	33, 43	None	None	None	43	None	None	43
Malocclusion	None	Left cross bite	Cl. II malocclusion	None	Anterior open bite	Right open bite	None	None	Right cross bite

Table 6: Clinical and radiographic outcomes

	Patient number									
	I	II	III	IV	V	VI	VII	VIII	IX	Mean
Mouth opening (mm)	36	39	39	33	31	35	29	34	34	34.4
Midline deviation (mm)*	4	8	0	4	0	5	1	0	1	2.6
Follow up (months)	24	24	12	22	26	122	110	96	30	51.7

*Ipsilateral midline deviation

Table 7: Anteroposterior cephalogram occlusal cant analysis: Successful ≤4°; acceptable 5°-8°; unsuccessful ≥8°

Patient number	AP cephalometric radiograph		Panoramic radiograph		
	Preoperative occlusal cant	Postoperative occlusal cant	Preoperative mandibular ratio	Postoperative mandibular ratio	Mandibular ratio differential
I	7°	5°	0.5	0.904	0.4
II	8°	8°	0.61	0.7	0.09
III	5°	1°	0.4	0.81	0.41
IV	20°	5°	0.57	0.90	0.33
V	4°	1°	0.68	0.85	0.17
VI	10°	5°	0.62	0.89	0.28
VII	8°	3°	0.94	1.2	-0.3
VIII	9°	4°	0.64	0.8	0.16
IX	7°	1°	0.20	0.625	0.425
Mean	8.66°	3.66°	0.57	0.85	0.25

Panoramic analysis: The ramus ratio was calculated by dividing the constructed ramus by CCG height by the ramus height on the healthy side. CCG = Costochondral grafts; AP = Anteroposterior; Cl. = Class

the use of 3D modeling for the design of custom intraoperative cutting guides for the osteotomies, necessary in the use of fibular free flap reconstruction of mandibular defects. In the case we present here, preoperative 3D planning and design,

and ultimately 3D printing, were used to generate a physical model of the child's mandible with planned repair of the defect and a customized surgical template that was used intraoperatively for precise reconstruction of the affected mandibular condyle and ramus.

In the present study, a 3D printed prefabricated surgical stent was utilized and served as a crucial stabilizing orthodontic bite plane appliance. The important role of the 3D prefabricated stent was in securing the mandible to the maxilla in its new position, thereby acting as an internal maxillary fixation device. In this way, premature occlusal contacts and interferences, which may have an effect on the occlusion and mastication forces, were eliminated. Thus, the force system vector which involved the newly positioned CCG could be kept physiologically.

Later on, the surgically created open bite of the affected mandibular side was serially reduced by adjusting the stent, thus allowing individual maxillary teeth and the surrounding alveolar process, gradually erupt over several months to the level of the mandibular occlusal plane.

The use of the stereolithographic model preoperatively improved intraoperative precision by clearly displaying the detailed anatomy of the patients undergoing craniofacial surgery. The surgeon can plan the length of the CGG before surgery and use the printed template while harvesting without having to wait for the exact measurements from the facial surgical team, thus decreasing surgical and anesthesia time, as well as wound exposure duration. Moreover, it is more predictable.

During surgical reconstruction of Type III CFM patient, the mandible is elongated and rotated by the CCG. Kaban *et al*. showed that in patients treated at an early age (before age 5), the mandible will usually require a second elongation procedure in the late mixed dentition stage.[9] Vargervik *et al*. reported of the continual growth of the lengthened mandibular ramus in seven out of the ten patients who underwent surgery at an early age.[20] Ware and Brown described four out of ten pediatric patients having had either ankylosis or excision of the condyle, who demonstrated substantial overgrowth.[22] In our study, one patient needed an additional DO surgery, and another patient demonstrated the overgrowth of the grafted mandibular ramus and had to be corrected orthodontically due to CCG overgrowth. Undergrowth and asymmetrical growth are common postoperative concerns, but they are minimized when a minimum amount of cartilage (approximately 2 mm) remains on the articulation surface of the graft.[23]

In our study, we have used Padwa's analysis (1998) method for patient's cephalogram evaluation. This method showed itself useful in evaluating the patient's preoperative asymmetry, surgical outcome and determining whether the use of CCG achieved its goals. Kaban *et al*. demonstrated already in 1981[24] that plane X-rays demonstrate the total anatomic distortion and the abnormal growth vectors in patients with CFM. At present, due to the constant utilizing of the CT in the assessment of maxillo-craniofacial deformities, we can recommend using CT throughout the follow-up period.

Conclusion

Successful treatment in CFM patients requires preoperative planning based on accurate imaging and defect characterization. In Type III CFM growing patients, CCG construction of the ramus and condyle, performed during the early to mid-mixed dentition, alters the deformity to a more symmetrical face and functional occlusion.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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