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Costochondral graft in growing patients with hemifacial microsomia case series: Long-term results compared with non-treated patients

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Abstract

Objective(s): The aim of this study was to evaluate the long-term effectiveness of costochondral graft in hemifacial microsomia (HFM) type III patients.

Settings and sample population: A sample of 10 patients affected by HFM type III treated during growth in the same Centre with costochondral graft (CCG patients group) is compared with a control group (CG) sample of 10 non-treated patients affected by the same malformation in order to understand whether surgery during growth provides advantages in terms of bony and facial symmetry after an 8-year follow-up.

Materials and Methods: The growth of the CCG was assessed on panoramic X-rays. To assess facial symmetry, a photometric evaluation on the frontal view was carried out.

Results: In CCG patients group the graft grown in mean less than the healthy ramus, a good facial symmetry was achieved after surgery, but was lost in the majority of the cases at the most recent control. In CG, occlusal canting slightly increased and facial asymmetry was relatively stable during the years.

Conclusion: In patients with a congenital deformity, restoring the height of the ramus leads to an immediate restitution of facial symmetry, but in the long term, there is a return to the asymmetrical pattern. In CG, the asymmetry is stable during years with no increase of the facial deformity.

KEYWORDS

chostocondral graft, facial asimmetry, growth, hemifacial microsomia, long term

1 | INTRODUCTION

Costochondral graft (CCG) has been traditionally used in growing patients with severe mandibular hypoplasia, both congenital, such as hemifacial microsomia (HFM), and acquired, after resection in temporomandibular joint (TMJ) ankylosis or tumour resection. The rationale for the use of a CCG is that the cartilaginous portion of the rib graft is considered to have growth potential[1] and adaptive capabilities. Some authors have shown that the growth of a CCG is unpredictable[2] and not linear.[3-7] Attention has been mostly pointed on the action of intrinsic factors of the cartilaginous portion of the CCG, leading to growth. In particular, Peltomaki suggested that rib

growth depends mainly on the action of intrinsic factors acting on the germinative area of the cartilaginous portion.[8] This area is only 4-5 mm away from the osteocartilaginous junction of the rib, and it is alleged to ensure growth of the rib.[9] Kaban and Perrot[2] stated that graft overgrowth may depend on the excessive thickness of the cartilage cuff of the graft. Most authors seem to be more concerned by a potential overgrowth rather than a deficient growth of the graft. In the literature on CCG, little attention has been given to the action of extrinsic factors, such as the aetiology of the mandibular hypoplasia and subsequently the quality of the neuromuscular environment. A review of the literature on CCG has shown that growth of the reconstructed mandibular ramus with costochondral grafts in patients with TMJ ankylosis mostly equals the growth of the unaffected side, while an overgrowth is present in 20%-50% of patients.[2] On the contrary, the sporadic literature on CCG explicitly regarding HFM patients suggests that there is a short-term phenotype recurrence, given the congenital nature of the asymmetry.[10] It is possible, therefore, that the underlying pathology (the extrinsic factors) might play an important role in CCG growth, and that, therefore, prognosis of CCG in HFM might be different from CCG in other types of mandibular hypoplasia. The objective of this study was, therefore, to analyse the long-term growth in a homogeneous sample of children affected by type III HFM subjected to CCG at an early age and compare it with a sample of type III HFM patients who were never subjected to surgical treatment.

2 | MATERIAL AND METHOD

2.1 | Patient sample selection (CCG patients)

In our Centre, between 1995 and 2006, 70 procedures of ramus condyle reconstruction by CCG were performed.

To obtain a homogeneous sample in terms of type of pathology, severity and age at surgery, inclusion criteria were as follows:

- Growing patients affected by HFM type III.[11]
- Costochondral graft for mandibular reconstruction performed during early growth (6-8 years) by the same surgeon.
- Successful CCG, considered as the presence, at the time of the first observation, of a healthy and stable graft which allowed free movement and function of the mandible, as established by clinical and radiological examination.
- A minimum of 8 years of follow-up: no patients younger than 15 years of age at the longest follow-up, were included in the sample.
- No intermediate surgeries (ie lipofilling) performed during the follow-up time.
- No associated macrostomia.
- No associated facial palsy.

Of the 70 CCG procedures, 13 were performed on very young patients affected by HFM type III deformity, according to Pruzansky. Of these patients, 10 had complete pre-surgical and post-surgical records and follow-up records longer than 8 years.

2.2 | Control Group (CG): Non-operated sample selection

A control sample was retrospectively collected. Ten patients were never offered or did not accept treatment during growth.

Selection criteria were as follows:

- HFM type III with records during early growth (6-8 y.o.).
- Never subjected to surgical treatment.
- Records at 15-17 years, prior to any surgical procedures.
- No associated macrostomia.
- No associated facial palsy.

2.3 | Surgical approach in CCG

The patients were all treated by the same senior author according to our protocol: the approach to the articular area was achieved through a pre-auricular curved incision, sometimes extended to the temporal region. A second retromandibular or submandibular approach was used to allow access to the distal stump of the mandibular body. A temporal muscle myofascial flap was rotated to reconstruct the joint. Through a submammary skin incision, the convex surface of the 7th-8th rib was exposed. As stated by several authors,[12] care must be taken to preserve the perichondrium and periosteum at the bone-cartilage junction in order to prevent detaching of the cartilage from the bony segment. The osteocartilaginous segment harvested is moulded to obtain an anatomic adaptation to the recipient site. The thickness of the cartilaginous portion left attached to the bony rib ranged between 4 and 6 mm. The length of the bony portion reflected the distance between the mandibular stump and the deformed glenoid cavity. Intermaxillary rigid fixation was positioned, and then, the CCG is secured to the ramus with wire, bicortical bone screws or plates. Intermaxillary fixation was kept in place for a period of 2-4 weeks depending on the type of graft stabilization (4 weeks for wire stabilization and 2 weeks for screws and plates). The intermaxillary fixation was followed by functional rehabilitation for 6 months. Before discharge, all patients had a panoramic X-ray taken. The average radiographic and photographic long-term follow-up was 8.6 years.

2.4 | Method

2.4.1 | Skeletal evaluation

Occlusal plane inclination was calculated in both samples (CCG Figure 1 and CG Figure 2) as the angle between the Infraorbital (IO) line, the line passing through the lowest points of the orbits and the occlusal plane (OCCL) through to the lowest molar cusps. It was

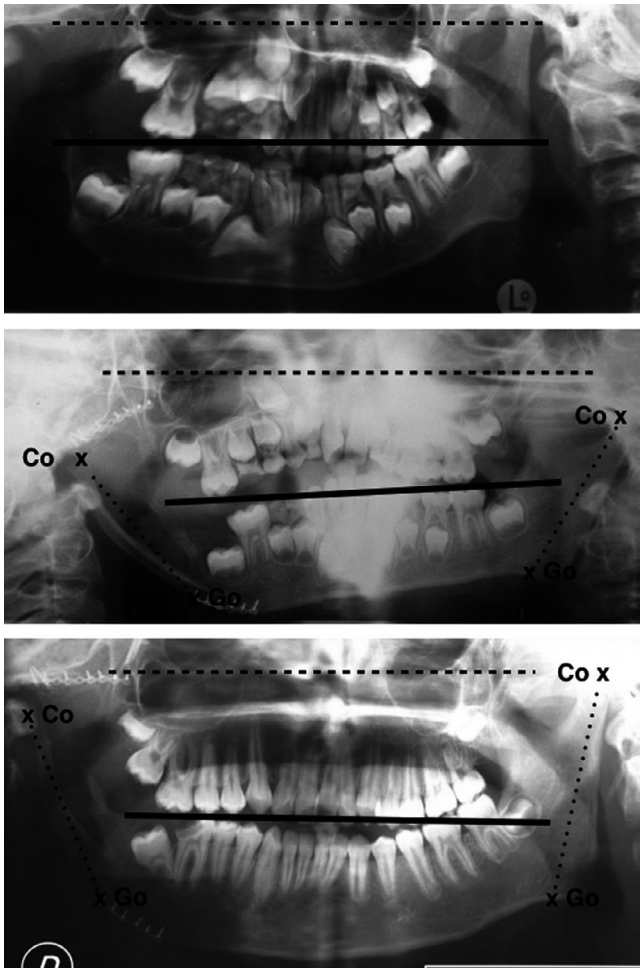

FIGURE 1 Example of measurements on panoramic X-ray in the CCG group 1A: panoramic X-ray at T0, 1B panoramic X-ray at T1, 1C panoramic X-ray at Tlt infraorbital plane (IO) is the line tangent to the most inferior border of the orbits (dotted line with large dots); occlusal plane (OCCL) is the line crossing to the lowest molar cusps (black line) IO^OCCL is calculated. The condylar head point (Co) is the most superior point of the condyle and of the costochondral graft (X). Gonion (Go) is the point of intersection between the line tangent to the mandibular body and the line tangent to the mandibular ramus on the non-affected side. Go on the affected side is a landmark considered stable through the years, as close as possible to the junction between the mandible and the costochondral graft (in many instances a screw or a hole of the plate, in this case the most lateral aspect of the plate) The mandibular height is the distance between Co and Go (fine dotted line)

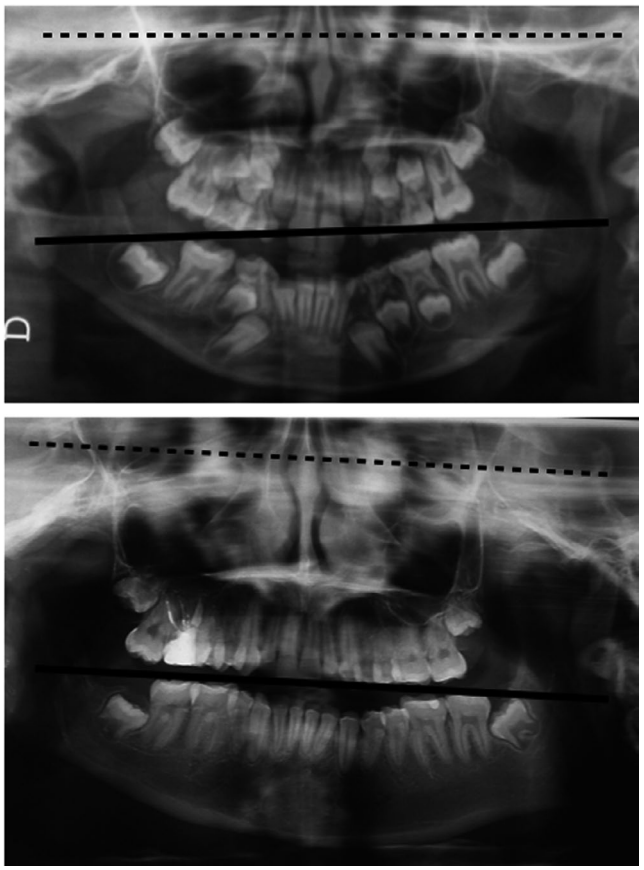

FIGURE 2 Example of measurements on panoramic X-ray in CG 1A: panoramic X-ray at T0, 1B panoramic X-ray at Tlt infraorbital plane (IO) is the line tangent to the most inferior border of the orbits (dotted line); occlusal plane (OCCL) is the line crossing the lowest molar cusps (black line)

calculated in the CCG group on the pre-operative, the immediate post-operative panoramic X-ray and after an average follow-up of 8 years. In the CS group, the occlusal plane was assessed on the panoramic X-ray at an average age of 7 years and after an average follow-up of 8 years. The growth of the reconstructed ramus was calculated in the CCG sample analysing the panoramic X-rays in the immediate post-operative control and at the longest follow-up. The mandibular height was calculated on the non-affected side as the distance between the most superior point of the condylar head (Co) and the point of intersection between the line tangent to the mandibular body and the line tangent to the mandibular ramus (Go).[13,14] On the affected side, height was calculated as the distance between the most superior point of the condylar head and a landmark considered stable through the years, as close as possible to the junction between the mandible and the costochondral graft (Go) (in many instances a screw or a hole of the plate). All of the points mentioned are depicted in Figure 1. Vertical accuracy of panoramic X-ray is well accepted.[15,16] Therefore, as a parameter for investigation, we adopted the ratio between the affected and the non-affected side. Landmark identification was performed by the same trained operator at two different time points to ensure reliability.

2.4.2 | Evaluation of soft tissue morphology: Photometric Study

To assess facial symmetry, a photometric evaluation on the frontal view was carried out by the same trained operator. In the CCG patients, the pre-operative, the post-operative photograph and the photograph after a mean of 8.6 years (from 7.3 to 10 years) were

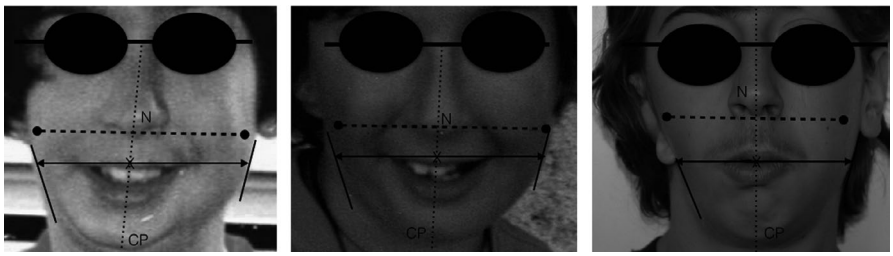

FIGURE 3 Example of photometric evaluation in CCG group Pictures were taken before surgery (T0), in the immediate postoperative period (T1) and after a long-term follow up (Tlt) Facial midline (FM) (fine dotted line) is the line passing through Nasion (N), and the Central chin Point (CP); N is the central point of the glabella; the CP is a point in the central area of the chin. Interpupillary line (IP) is the line crossing left and right pupils (black line). Alar Base Plane (ABP) is the line crossing the most inferior alar aspect on left side and right side (dotted line between back spots). Cheilon-Cheilon line (Ch-Ch) is the line intersecting the labial commissure on both sides (harrows). Two fine black lines underline the external contour of the cheeks

compared in order to assess changes in facial symmetry. In the CG, a photometric evaluation in the frontal view at 7 years ad after a mean long-term follow-up of 8 years was compared. The facial deviation was expressed as the angle between the facial midline (FM), the line passing through Nasion (N) and the central chin point (CP), and the interpupillary line (IP). Another index chosen for the evaluation of facial symmetry and facial growth was the ratio between the hemifacial contour. This was measured by first drawing a line passing through the corners of the lips, with lips at rest: the Cheilon-Cheilon Line (Ch-Ch). This line intersected the facial contour on either side of the face. The distance from the FM to the facial contour of the cheeks intersecting Ch-Ch was measured, and their ratio was calculated to assess the symmetry of face: Hemifacial ratio (HR). The angle between the Alar Base Plane (ABP), the line passing through left and right alar base, and the FM and the angle FM^Ch-Ch were also measured (all points and measurements are described in Figure 3 for CCG group and Figure 4 for CG group). Landmark identification and measurements were performed twice by the same trained operator at 4 months interval, which is suitable to assess test-retest reliability. A Cronbach α intraclass correlation coefficient (ICC) was used to assess intra-examiner reliability. Statistical analysis was carried out with Stata 10 software (StataCorp. 2007. Stata Statistical Software: Release 10. College Station, TX: StataCorp LP).

3 | RESULTS

The intraclass correlation coefficient used to assess consistency of the single rater was 0.91, thus providing an indication of good intrarater reliability.

3.1 | Skeletal evaluation in the CCG group

The IO-OCCL angle remained stable in two patients, decreased in four patients and increase in four patients, the mean angle in the immediate post-operative period was 2.6° and at 8 years, it was still on average 2.6°, although with a standard deviation of 2°. Mandibular ratio in the immediate post-operative period was on average 0.95, and after a mean follow-up of 8 years, it was 0.87, with an average reduction of 8% (Table 1).

3.2 | Skeletal evaluation in CG

The mean IO-OCCL angle was 0.8°(SD: 0.4) in the first panoramic X-ray and increased slightly during the years: 1.4° after 8 years of follow-up (Table 1).

3.3 | Photometric study in CCG

HR increased in all patients post-operatively (average: 26%), but in the long term, an almost total relapse of the original proportion was seen (19%). There was a recurrence of the original facial deviation expressed as the MF^IP angle: it increased on average of 3.4° at T1 and decreased of 3° at Tlt (Table 1).

3.4 | Photometric study in CG

HR increased of 5% in the long term and MF^IP increased on average of 0.4°. Therefore, facial asymmetry was stable during the years (Table 1).

4 | DISCUSSION

To our knowledge, this is the first study in the literature to report long-term skeletal and soft tissue results in a sample of HFM type III treated with CCG at an early age. Peculiar interest to the study is given by the comparison with a non-treated sample. Bertin et al[17] reported results in 10 type III HFM patients. All needed multiple osteotomies at the completion of growth, mainly a Le Fort 1 to correct occlusal canting. Results in terms of architectural changes and stability were reported together with type II A and B; therefore, no specific assessment could be made on type III patients. Recurrence of mandibular asymmetry was

TABLE 1 Skeletal Evaluation and Photometric Study: Mean, Standard Deviation and Range of all of the parameters measured are listed for CCG group at the immediate pre-operative period (T0), 6 mo after surgery (T1), and at the long-term evaluation (Tlt)

	T0				T1		Tlt			
	Mean ± SD		Range		Mean ± SD	Range	Mean ± SD		Range	
	CCG	NS	CCG	NS			CCG	NS	CCG	NS
Age	6.8 ± 0.7	7 ± 0.7	6-8	6-8	7.2 ± 0.8	7-9	16 ± 1	16.4 ± 0.9	15-17	15-17
IO-OCCL angle (°)	-	0.8 ± 0.4	-	0-1	2.6° ± 2.7°	1°-6°	2.6 ± 2	1.4 ± 0.1	1-3	1-3
Mandibular Ratio	-	-	-	-	0.95 ± 0.2	0.8-1.3	0.87 ± 0.1		0.68-1.07	-
MF^IP (°)	83.8 ± 4.8	83.8 ± 4.3	77-90	78-89	87.2 ± 1.8	85-89	85.6 ± 4.7	84.2 ± 4.4	85-90	79-89
ABP^MF	85.4 ± 3.1	86.4 ± 2	82-90	84-89	88.4 ± 2.2	85-91	88.2 ± 3.1	85.6 ± 3.2	85-93	82-90
Ch-Ch^MF	86.8 ± 2.3	85.6+-2.9	83-89	82-89	88.4 ± 0.5	88-89	87 ± 4	88 ± 1.9	87-90	85-90
Hemifacial Ratio	0.72 ± 0.13	0.6 ± 0.12	0.5-0.8	0.44-0.73	0.98 ± 0.06	0.89-1.04	0.79 ± 0.05	0.65 ± 0.08	0.73-0.88	0.57-0.77

Note: F or CG are listed results at a mean age of 6.3 y.o (T0), and at 16 y.o. (Tlt). Parameters are listed are: IO^OCCL expressed in degrees (°), Mandibular Ratio (MR), MF^MP expressed in degrees (°), ABP^MF expressed in degrees, Ch-Ch^MF (°), Hemifacial Ratio (HR).

noted. As no control sample was used, the paper was unable to demonstrate whether CCG reduced the subsequent burden of surgical care.[17] The main limit of the present study is the relatively small number of cases. Notably, though, the same problem is present in most of the other studies in the literature.[2,7,18-20] The second obvious limit of the study is the fact that it is retrospective and not prospectively randomized. On the other hand, the main advantage of this study is the homogeneity of the sample in terms of age, severity of the pathology and the length of follow-up. The problem in most of the literature on CCG is, notably, the wide heterogeneity in the population analysed and their method for evaluation of results. Many well-known studies show procedural bias that limit their value: lack of quantitative data,[2] lack of distinction between underlying pathology of patients requiring mandibular reconstruction mixing ankylosis, the three types of HFM[21-23] and Goldenhar syndrome. Wide disparity in age and follow-up time[13,24,25] lack of indication of technical modifications through the years.[23] Recently, Bin Zhang et al reported a follow-up of 4 children operated at an average age of 3.8 affected by type III, but also type IIb, with a follow-up ranging from 23 to 64 months (final follow-up at 4.5-9 years). No control sample was reported. All new ramuses grew, but no quantitative assessment on facial symmetry was carried out. In terms of method, in the literature there is no consensus regarding the best way of measuring growth of costochondral grafts or assessing their success. Ko et al[20] used linear measurements on lateral cephalometric analysis. Padwa et al[13] evaluated growth measuring the inclination of planes on posteroanterior cephalometric X-rays. Ross measured the inclination of the midline on posteroanterior cephalometric X-rays and Basion-Nasion^Pogonion angle in Lateral cephalometry.[23] In this study, mandibular ratio[7,14,26] calculated on panoramic X-rays was used for two reasons: panoramic X-ray is considered reliable for vertical measurements,[16] and the ratio obviates the error caused by measuring panoramic X-rays with different magnification. Of course, new technologies such as CBCT and 3D software are now more commonly used and would have allowed a more accurate evaluation of growth in the vertical and the lateral planes. Unfortunately, given the length of follow-up, in our sample only the panoramic X-rays were available in the initial records of most of the patients, to be compared with the long-term records. Furthermore, in this study, only patients reconstructed between 6 and 8 years of age were selected. Including older children in the study would have introduced a severe bias.[14] In the CCG sample, no overgrowth was observed. One of the hypotheses that could explain the lack of overgrowth of the reconstructed ramus might not only be related to the thickness of the cartilage cuff, but especially to the fact that patients with HFM have missing or hypoplastic masticatory muscles and, therefore, a different functional matrix compared to acquired mandibular asymmetry. Interestingly, 8 years post-grafting the proportion between grafted side and non-affected side is only mildly reduced from 95% to 87%, with a relapse of 8% of the proportion after lengthening. This amount of relapse is much less than what

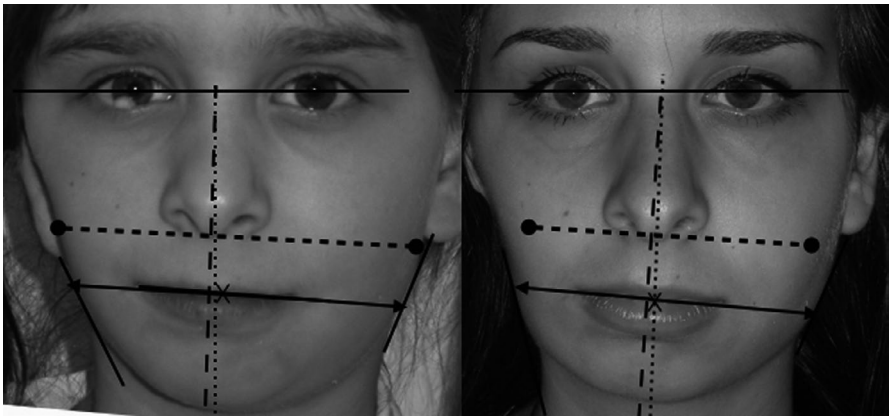

FIGURE 4 Example of photometric evaluation in CG Pictures were taken before surgery (T0), and after a long-term follow up (Tlt) Facial midline (FM) (fine dotted line) is the line passing through Nasion (N), and the Central chin Point (CP); N is the central point of the glabella; the CP is a point in the central area of the chin. Interpupillary line (IP) is the line crossing left and right pupils (black line). Alar Base Plane (ABP) is the line crossing the most inferior alar aspect on left and right side (dotted line between back spots). Cheilon-Cheilon line (Ch-Ch) is the line intersecting the labial commissure on both sides (harrows). Two fine black lines underline the external contour of the cheeks

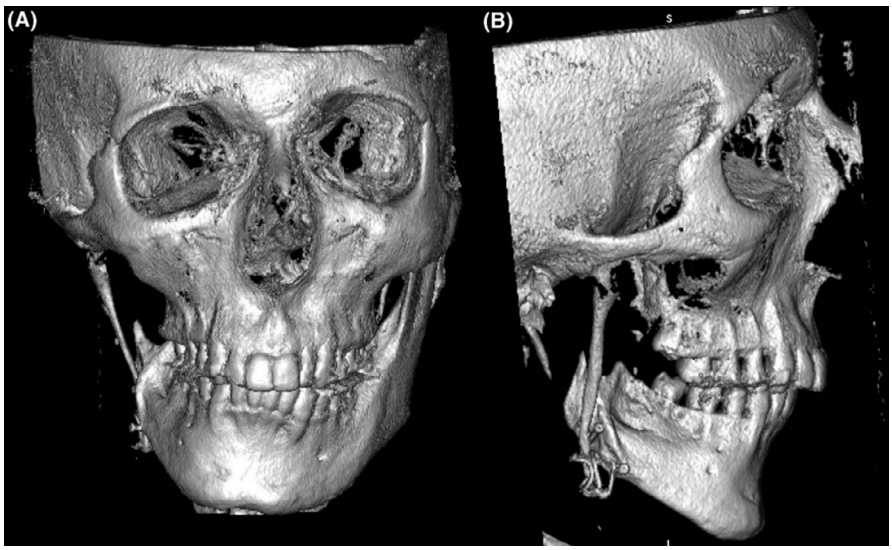

FIGURE 5 3D CT scan view in a treated patient at the competition of the growth. The CCG is grown but as we can appreciate in the lateral and frontal view it is not functional neither useful for the bimaxillary surgery the patient is scheduled for. It is in fact much thin

is seen after distraction osteogenesis (DO) in type I and type II Pruzansky.[26,27] Therefore, in contrast with the long-term results after DO, where the recurrence of the skeletal asymmetry is complete, the actual loss of vertical dimension of the graft is much slower and there is never a complete relapse. Nevertheless, even though the skeletal length of the graft is not completely lost, the presence of the residual CCG does not seem to improve either the dental or the facial symmetry in the long term, compared to non-treated patients. Furthermore, once adulthood is reached, most residual CCGs are not useful for further surgery and are not functional (Figure 5). The occlusal plane in type III Pruzansky, as shown in the literature,[16] is very variable; in seven CCG and in all non-treated patients, it was essentially flat, while only in three of the CCG patients, it was canted of 4°-5°, which is considered a moderate canting.[10] In the long term, the occlusal plane again varied, but, in those CCG patients who had an initial canting, it was not improved in the long term. In the non-treated patients, an occlusal plane worsening of an average of 0.6° was measured, which it is not a clinically significant value. Hemifacial ratio (HR) on the affected side in CCG relapsed almost completely in the long-term follow-up, thus showing a tendency in HFM patients to re-express their congenital facial proportion, as seen after distraction osteogenesis (DO) in type I and type II.[26,27] The average recurrence of asymmetry, measured as HR, was 19% in 8 years. In the non-treated patients, interestingly, from infancy to adulthood, the HR improved 5% with no treatment, although, again, standard deviation was high (Table 1). Clinically, therefore, there seems to be very little difference in the long term, in terms of facial contour of the affected side, compared to the non-affected side, whether a CCG has been placed or not. Both in CG and in CCG patients, growth and symmetry were highly unpredictable, as supported by the high Standard Deviations in all data.

5 | CONCLUSIONS

In patients with type III HFM, restoring the height of the ramus with CCG leads to an immediate correction of facial asymmetry. In the long term, there is a partial return towards asymmetry of the bony ratio and a complete return of the asymmetry of the facial appearance and contour in most of the patients.

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REFERENCES

1. Svensson B, Adell R. Costochondral grafts to replace mandibular condyles in juvenile chronic arthritis patients: long-term effects on facial growth. *J Cranio-Maxillo Surg*. 1998;26(5):275-285.
2. Guyuron B, Lasa Jr CI. Unpredictable growth pattern of costochondral graft. *Plast Reconstr Surg*. 1992;90(5):880-886; discussion 887-9.
3. Ware WH, Brown SL. Growth centre transplantation to replace mandibular condyles. *J Maxillofac Surg*. 1981;9:50-58.
4. Lindqvist C, Pihakari A, Tasanen A, Hampf G. Autogenous costochondral grafts in temporo-mandibular joint arthroplasty. A survey of 66 arthroplasties in 60 patients. *J Maxillofac Surg*. 1986;14(3):143-149.
5. Lindqvist C, Jokinen J, Paukku P, Tasanen A. Adaptation of autogenous costochondral grafts used for temporomandibular joint reconstruction: a long-term clinical and radiologic follow-up. *J Oral Maxillofac Surg*. 1988;46(6):465-470.
6. Tideman H, Doddridge M. Temporomandibular joint ankylosis. *Aust Dent J*. 1987;32(3):171-177.
7. Mulliken JB, Ferraro NF, Vento AR. A retrospective analysis of growth of the constructed condyle-ramus in children with hemifacial microsomia. *Cleft Palate J*. 1989;26(4):312-317.
8. Peltomäki T, Quevedo LA, Jeldes G, Rönning O. Histology of surgically removed overgrown osteochondral rib grafts. *J Craniomaxillofac Surg*. 2002;30(6):355-360.
9. Kaban LB, Moses MH, Mulliken JB. Surgical correction of hemifacial microsomia in the growing child. *Plast Reconstr Surg*. 1988;82(1):9-19.
10. Padwa BL, Kaiser MO, Kaban LB. Occlusal cant in the frontal plane as a reflection of facial asymmetry. *J Oral Maxillofac Surg*. 1997;55(8):811-816.
11. Pruzansky S. Not all dwarfed mandibles are alike. *Birth Defects*. 1969;5(5):120-129.
12. James DR, Irvine GH. Autogenous rib grafts in maxillofacial surgery. *J Maxillofac Surg*. 1983;11(5):201-203.
13. Padwa BL, Mulliken JB, Maghen A, Kaban LB. Midfacial growth after costochondral graft construction of the mandibular ramus in hemifacial microsomia. *J Oral Maxillofac Surg*. 1998;56(2):122–127; discussion 127-8.
14. Meazzini MC, Mazzoleni F, Gabriele C, Bozzetti A. Mandibular distraction osteogenesis in hemifacial microsomia: long-term follow-up. *J Craniomaxillofac Surg*. 2005;33(6):370-376.
15. Larheim TA, Svanaes DB. Reproducibility of rotational panoramic radiography: mandibular linear dimensions and angles. *Am J Orthod Dentofacial Orthop*. 1986;90(1):45-51.
16. Ongkosuwito EM, Dieleman MMJ, Kuijpers-Jagtman AM, Mulder PGH, van Neck JW. Linear mandibular measurements: comparison between orthopantomograms and lateral cephalograms. *Cleft Palate Craniofac J*. 2009;46(2):147–153.
17. Bertin H, Mercier J, Cohen A, et al. Surgical correction of mandibular hypoplasia in hemifacial microsomia: a retrospective study in 39 patients. *J Craniomaxillofac Surg*. 2017;45(6):1031-1038.
18. Figueroa AA, Gans BJ, Pruzansky S. Long-term follow-up of a mandibular costochondral graft. *Oral Surg Oral Med Oral Pathol*. 1984;58(3):257-268.
19. Raustia A, Pernu H, Pyhtinen J, Oikarinen K. Clinical and computed tomographic findings in costochondral grafts replacing the mandibular condyle. *J Oral Maxillofac Surg*. 1996;54(12):1393–1400; discussion 1400–1.
20. Ko EW, Huang CS, Chen YR. Temporomandibular joint reconstruction in children using costochondral grafts. *J Oral Maxillofac Surg*. 1999;57(7):789-798; discussion 799–800.
21. Pluijmers BI, Caron CJJM, Dunaway DJ, Wolvius EB, Koudstaal MJ. Mandibular reconstruction in the growing patient with unilateral craniofacial microsomia: a systematic review. *Int J Oral Maxillofac Surg*. 2014;43(3):286-295.
22. Kumar P, Rattan V, Rai S. Do costochondral grafts have any growth potential in temporomandibular joint surgery? A systematic review. *J Oral Biol Craniofac Res*. 2015;5(3):198-202.
23. Ross RB. Costochondral grafts replacing the mandibular condyle. *Cleft Palate Craniofac J*. 1999;36(4):334-339.
24. Tahiri Y, Chang CS, Tuin J, et al. Costochondral Grafting in Craniofacial Microsomia. *Plast Reconstr Surg*. 2015;135(2):530-541.
25. Goerke D, Sampson DE, Tibesar RJ, Sidman JD. Rib reconstruction of the absent mandibular condyle in children. *Otolaryngol Head Neck Surg*. 2013;149(3):372-376.
26. Meazzini MC, Mazzoleni F, Bozzetti A, Brusati R. Comparison of mandibular vertical growth in hemifacial microsomia patients treated with early distraction or not treated: follow up till the completion of growth. *J Craniomaxillofac Surg*. 2012;40(2):105-111.
27. Nagy K, Kuijpers-Jagtman AM, Mommaerts MY. No evidence for long-term effectiveness of early osteodistraction in hemifacial microsomia "outcomes article". *Plast Reconstr Surg*. 2009;124(6):2061-2071.

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