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CHIRURGIE MAXILLO-FACIALE

par

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Autogenous costochondral grafts used for ramus-condyle unit reconstruction: a long-term clinical and radiologic follow-up of 95 grafts

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INTRODUCTION

There are many techniques available for the reconstruction of ramus and condylar unit (RCU) of the mandible (1). Depending on the situation, these procedures aim to restore the moving function of the temporomandibular joint (TMJ) (2,3). This mainly concerns the TMJ ankylosis from traumatic, infectious or from rheumatologic origin (4–7). The other fundamental purpose is to restore the uni- or bilateral posterior vertical dimension of the mandible; this is the case in most of malformative defects of the mandibular growth associated to craniofacial microsmia, congenital condylar hypoplasia but also in juvenile polyarthritis (8,9). The costochondral graft (CCG) can achieve both these functional and architectural objectives. The technique was first described by Sir Harold Gillies in 1920 and physiologically confirmed by Poswillo in 1974 for mandibular reconstruction (10,11).

One of the main advantages of the CCG is its intrinsic growth potential, this makes it the tool of choice for mandibular reconstruction in children(12); nevertheless growth potential remains difficult to predict and can lead to insufficiency or excess of mandibular growth (11,13). In adults, there is currently no consensus on the choice of the technique for the reconstruction of the RCU. If the joint is damaged or ankylosed, replacement of TMJ with bicompartmental prostheses could represent a new alternative for joint reconstruction with the advantage of a reduced operating time, but raises the problem of foreign material (14,15). For the restoration of the posterior vertical insufficiency (PVI), distraction osteogenesis (DO) is an interesting alternative as it allows for a progressive lengthening of both soft tissue and bone structures of the mandible (16,17). Nevertheless, DO often requires several interventions for the insertion and removal of the distractor. Various mandibular lengthening techniques can also be used to correct the PVI in patients with a functional TMJ. This is the case with vertical ramus osteotomy (VRO) with external approach according to the Caldwell-Letterman technique, but also with the Epker-modified-Wolford technique after complete sectioning of the pterygo-masseteric strap, or with mandibular lengthening by endobuccal approach (18–20). CCG is a common choice for reconstruction, as it is easy to harvest, has a low donor site morbidity, and it can provide a large amount of bone, with the ability to regenerate after its harvesting (21). Possible complications include resorption and TMJ ankylosis (22).

Although CCG has been covered many times in the literature particularly regarding the functional results and complications, very few studies have investigated the long-term stability of CCG in a large number of patients (23,24). The purpose of this study was to retrospectively evaluate long-term aesthetic, architectural, and functional results of CCG for RCU reconstruction in a large number of patients managed in a tertiary center.

MATERIALS AND METHODS

Data collection

Patients receiving a CCG in the Maxillofacial Surgery and Stomatology Department of the Nantes University Hospital, France, between 1990 and 2022 were included in the study and analyzed retrospectively. The patients' charts were reviewed, and data regarding the age, the etiology, the main surgical procedure, and additional procedures were compiled. Information regarding TMJ function and potential surgical complications was also collected. In this retrospective study, no change to the current clinical practice or randomization was performed. Approval from an ethics committee was not required in order to use these data in the epidemiologic study, as per French legislation article L. 1121-1 paragraph 1 and R1121-2 of the Public Health Code.

Surgical protocol

The procedure was performed under general anesthesia with nasotracheal intubation. An extra-oral approach was performed by a low submandibular incision. In most of the cases, it was associated with an intraoral incision for muscular detachment and homolateral coronoidectomy. Pre-auricular approach was needed for simultaneous resection of the ankylosis block, using surgical planning and navigation system. To harvest the CCG, the contralateral sixth or seventh rib was retrieved through a sub-mammary incision, and a perichondrium strip was maintained on the costochondral junction. On average, a 5-mm segment of carved cartilage portion was left in place on the graft. The CCG was then placed in physical contact with the skull base and fixed laterally to the mandibular stump using two bicortical screws. For the restoration of posterior vertical deficiencies, a posterior open bite was created on the affected side, and an interocclusal splint was positioned and progressively reduced in length to promote secondary maxillary teeth egression.

In some cases, the CCG was associated with other conventional orthognathic procedures such as a Le Fort I (LFI) osteotomy, a contralateral sagittal split osteotomy (SSO), and/or a genioplasty. The postoperative intermaxillary elastic fixation lasted 6 weeks. Active TMJ physiotherapy based on protrusion and lateral movements was prescribed to promote early recovery of motion (25,26).

Clinical evaluation

Frontal standardized photographs were analyzed preoperatively, postoperatively, and at the end of the follow-up. To assess the chin deviation, the angle α between the facial median line and a line from the glabella to the middle of the chin was measured. The angle β of the tilted lip commissure plane was measured using a parallel to pupillary line as previously described (18,27,28) (figure 1). Because bilateral CCG cases did not show clinical asymmetry of the face, the analysis of the clinical parameters interested only the unilateral cases. An independent evaluation was also conducted in patients who had not undergone genioplasty because it could affect the angle α.

Radiographic evaluation

Cephalometric analysis was performed on frontal and lateral cephalograms or on cone-beam computed tomography preoperatively, immediately postoperatively, at 6-months to 1-year postoperatively, and at the last follow-up. Two reference lines were used for the frontal analysis: the supraorbital line joining the tops of the orbital roofs and a perpendicular line, passing through the crista galli, representing the median facial line. SO was defined as the distance between the supraorbital line and the most prominent cuspid of the second maxillary molar or the occlusal point on the non-affected side. SM was defined as the distance between the supraorbital line and the most prominent cuspid of the second mandibular molar or the occlusal point on the non-affected side. The reference lines in the affected side were designed as SO' and SM'. The SO'/SO ratio was used to assess the maxillary canting of the occlusal plane, while the SM'/SM ratio was used to assess the mandibular occlusal plane tilting in a frontal view.

The chin deviation (CD) was defined as the distance between the projection point of the axis of the lower incisors on symphysis and the median facial line (figure 1). Because bilateral CCG cases normally did not show an asymmetry on the frontal cephalogram, only unilateral cases were included for the cephalometric study. Because the achievement of a concomitant Le Fort I or genioplasty may influence the results of SO'/SO and CD, we performed subgroup analyses in patients without associated Le Fort I and without genioplasty.

For the lateral analysis, the mandibular height (MH) was calculated by measuring the distance between the superior condylar point and the PreGonion point, *i.e.* the lowest point of the mandibular ramus. The FMA angle was calculated between the Frankfurt plane (lower point of the orbit and the upper point of the internal auditory meatus) and the mandibular plane (Me point-PreGo) (29) (figure 1).

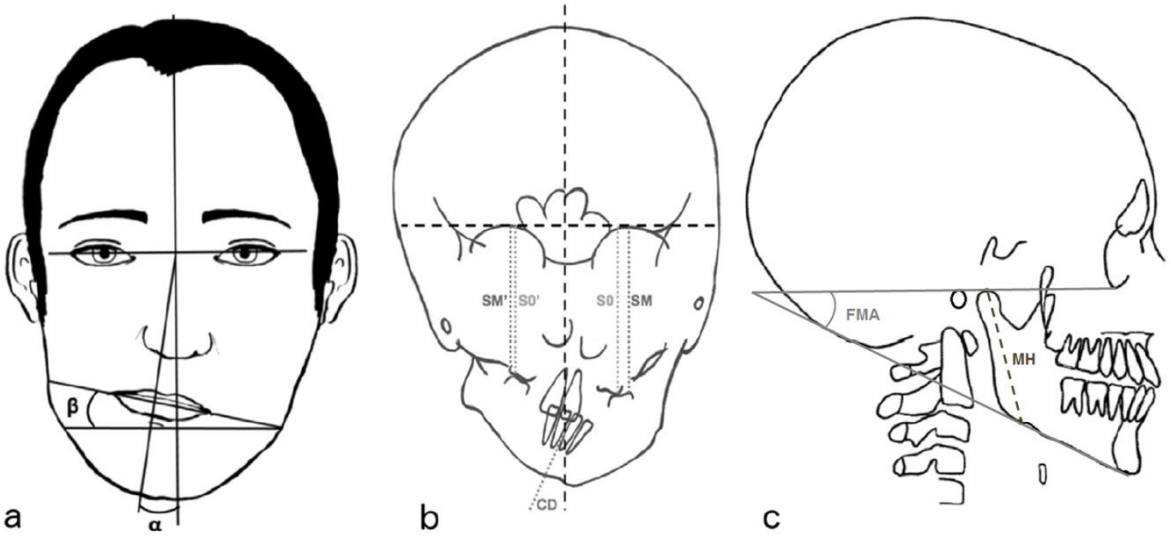

Figure 1. (a) Clinical evaluation of the facial soft tissues. Angle α: Chin deviation. Angle β: Bi-commissural line tilt. Cephalometric analysis on frontal (b) and lateral (c) cephalograms. SO: Distance between the supraorbital line and the maxillary molar occlusal point on the unaffected side. SM: Distance between the supraorbital line and the mandibular molar occlusal point on the unaffected side. SO' and SM': Distance SO and SM on the affected side. CD: Distance between the projection point of the axis of the lower central incisors on symphysis and the medial facial line. MH: distance between the superior condylar point and the PreGonion point. FMA: angle between the Frankfurt plane and the mandibular plane.

Secondary endpoints

The surgical complications were compiled and classified as severe if requiring the procedure to be stopped or requiring a new intervention (e.g., infection, reccurence). Other complications were classified as minor (e.g., temporary lip hypoesthesia, facial nerve paresis). The TMJ function was investigated, when possible, in terms of maximal mouth opening (MMO)

Statistical analysis

The methodical error of the cephalometric and facial measurements was assessed by the Dahlberg's formula (mean square error ($S.E^2$)=$d^2/2n$)), where d is the difference between the first and the second measurements, and n is the number of double measurements (30). To determine the intra-observer error, cephalometric lengths and facial angles were measured twice by the same investigator at 4-week intervals in 10 randomly selected patients. The computerized radiological and photographic data were measured using MB-Ruler (Markus Bader, Iffezheim, Germany). The statistical analysis was performed using GraphPad Prism 9.0 software for Mac (GraphPad Software, La Jolla, CA, USA). Quantitative data were analyzed using a paired t-test when there were more than 30 replicate values and a Wilcoxon test when there were fewer than 30 paired observations. A p-value of less than 0.05 was taken to indicate statistical significance.

RESULTS

Epidemiological data

A total of 76 patients were operated on with a unilateral or bilateral CCG during the inclusion period. Six patients were excluded due to a lack of data in medical records. For the remaining 70 patients, there were 34 females and 36 males. Thirty-nine patients were under 15 years of age, and 31 were adults. The mean age at the time of the CCG was 20.5 ± 14.9 years, and the mean follow-up duration was 7.5 ± 5.9 years. Regarding the etiologies, most of patients presented with a PVI, from congenital origin (craniofacial microsomia in 14 cases, Goldenhar syndrome in 7 patients, 2 patients suffered from a Franseschetti-Zwahlen-Klein syndrome, and one from a Nager syndrome). Other etiologies included rheumatoid polyarthritis, hypocondyly or growth defect due to childhood trauma or neonatal bacteremia. TMJ ankylosis was mostly secondary to infectious or post-traumatic disease. All the epidemiologic data are presented in table 1.

Gender: female/male, n	34 / 36
Adults/Children, n	31 / 39
Mean age at the time of the surgical procedure (years), mean ± S.D. (range)	20.5 ± 14.9 (4 – 66)
Follow-up duration (years), mean ± S.D. (range)	7.5 ± 5.9 (1.1 – 30.0)
Ankylosis: adults/children, n	16 / 13
post-traumatic	*7 / 3*
post-infectious	*4 / 10*
rheumatologic	*5 / -*
Posterior vertical insufficiency: adults/children, n	15 / 26
malformative syndrome	*6 / 19*
post-traumatic	*4 / 2*
rheumatologic	*5 / 3*
post-infectious	*- / 2*

Table 1. Characteristics of the included patients. n, Number of patients; S.D., standard deviation.

Surgical protocol

Ninety-five CCG were performed in 70 patients during the study period: 53 were unilateral and 22 were bilateral grafts. Regarding the bilateral cases, 13 were performed in patients with PVI (juvenile rheumatoid arthritis, bilateral condylar hypoplasia, Franceschetti syndrome, spondylarthropathy, neonatal trauma) and 9 in patients with bilateral TMJ ankylosis; 6 patients receiving a bilateral CCG were under 15 years of age.

In 32 patients a coronoidectomy was associated (21 were bilateral and 11 were unilateral). The mean height of the harvested graft was 70.0 ± 9.9 mm (ranging from 50 mm to 100 mm). The mean height of the cartilaginous portion was 4.6 ± 0.2 mm (2.0 - 5.5 mm).

In more than half of the patients, TMJ surgery was associated with other orthognathic procedures (table 2). A second procedure was necessary for 24 patients: new CCG in case of resorption or recurrence of ankylosis, condylectomy in case of overgrowth, or orthognathic surgery in case of treatment of facial malformation.

Associated osteotomies	
Le Fort I osteotomy, n	10
Genioplasty, n	39
Contralateral SSO, n	13
Contralateral vertical ramus osteotomy, n	6
Coronoidectomy, n	32

Table 2. Associated osteotomies. n, Number of patients; SSO, sagittal split osteotomy.

Aesthetic evaluation

The mean Dahlberg standard errors for the measurement of the angles α and β were 0.27 ± 0.24° and 0.16 ± 0.18°, respectively.

The CCG allowed for immediate and significant improvement in the chin deflection and correction of the lip commissural line tilting in patients (figure 2).

The angle α was corrected after the mandibular procedure, from 5.02 ± 2.82° preoperatively to 1.93 ± 1.56° postoperatively; $p < 0.0001$. A significant 23.7% deterioration rate was observed over time in regard to the chin deviation with a mean angle α of 2.39 ± 3.43° at the last follow-up ($p < 0.0001$) (figure 3). Excluding the patients who underwent an associated genioplasty, the results were substantially comparable: from 4.32 ± 2.86° preoperatively to 1.74 ± 1.24° postoperatively ($p = 0.002$), with a recurrence of the deviation from the postoperative time to the last follow-up, with a mean angle α reaching 2.75 ± 4.99° ($p= 0.50$). There was one case of major overgrowth of the CCG at the last follow-up, with a chin deviation of 20.3° with respect to the median vertical line, which required a secondary condylectomy.

The angle β was corrected from 4.90 ± 3.18° preoperatively to 2.71 ± 2.58° postoperatively ($p < 0.0001$). The surgical results remained stable over time in terms of bicommissural line tilting with angle β measured at last follow-up at 2.33 ± 3.04° ($p=0.91$) (figure 3). Excluding patients receiving a concomitant Le Fort I osteotomy, angle β changed in a similar way with 4.96 ± 3.29° in preoperative time vs 2.63 ± 2.54° in postoperative time ($p < 0.0001$), and 2.25 ± 3.18° at the last follow-up ($p=0.69$).

Figure 2. Aesthetic results. Photographs of a young patient exhibiting a right PVI corresponding to a right craniofacial microsomia, who underwent a right CCG at the age of 11 years (frontal photographs preoperatively, 6 months postoperatively, and 4 years postoperatively). Symmetry of the chin and horizontalization of the bicommisural line were partially restored post-operatively and remained stable during the follow-up.

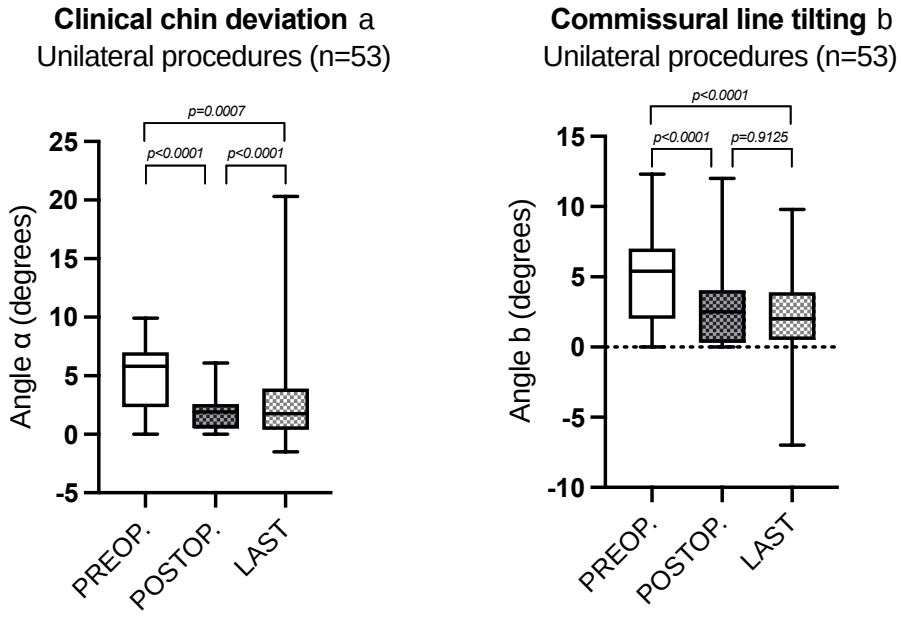

Figure 3. Variation in the chin deflexion and the commissural line tilting preoperatively (PREOP.), postoperatively (POSTOP.), and at the last follow-up (LAST) times for unilateral cases.

Architectural results

The mean Dahlberg standard error for the distance measurements was 0.0010 ± 0.0021 for the SO'/SO ratio, 0.0006 ± 0.001 for the SM'/SM ratio, 0.3205 ± 0.3923 mm for the chin deviation, 2.45 ± 2.94 mm for MH and 3.17 ± 3.41° for the FMA angle.

The maxillary occlusal canting, reflected by the SO'/SO ratio, was significantly improved in patients receiving a unilateral CCG with a progressive horizontalization over time due to spontaneous egression of the maxillary teeth. SO'/SO ranged from 0.95 ± 0.06 in preoperative time to 0.99 ± 0.04 at 6-12-months after the procedure, with stable results at the last follow-up (p=0.0001 between the preoperative and the last follow-up measurements) (figure 4). The results remained similar in the patients who did not receive an associated Le Fort I osteotomy: from 0.95 ± 0.06 preoperatively to 0.98 ± 0.04 in immediate postoperative time (p=0.0236), reaching 0.99 ± 0.05 and 0.98 ± 0.05 at 6-12-months and at the last follow-up respectively (figure 5).

The frontal mandibular occlusal canting reflected by the SM'/SM ratio was also significantly improved from 0.95 ± 0.06 preoperatively vs. 1.00 ± 0.03 postoperatively ($p < 0.0001$). Results remained stable over time with mean ratio of 1.00 ± 0.04 at 6-12-months. A slight trend of recurrence was observed at the last follow-up with a mean SM'/SM ratio of 0.99 ± 0.038 (p=0.682 between 6-12 months and last follow-up) (figure 5).

The chin deviation was substantially corrected after the procedure with a mean cephalometric CD ranged from 9.88 ± 5.80 mm preoperatively to 3.18 ± 3.66 mm postoperatively ($p < 0.0001$). However, the result did not remain stable over time with a progressive recurrence of the deviation at the 6-12 months follow-up and the last follow-up up (4.20 ± 3.70 mm and 4.85 ± 3.90 mm respectively; p_1=0.0296 and p_2=0.0284 respectively). Patients without genioplasty exposed similar results: mean CD of 10.99 ± 5.81 mm preoperatively vs. 4.46 ± 4.55 mm postoperatively (p=0.0007). The CD reached 3.62 ± 2.87 mm at 6-12-months follow-up (p=0.7301 regarding the postoperative period and the 6-12 months postoperatively) and 4.47 ± 2.43 at the last follow-up (p=0.0938 between 6-12 months and last follow-up) (figure 5).

In unilateral cases in children, a horizontalization of the frontal mandibular occlusal plane was found postoperatively, and remained stable during the follow-up.

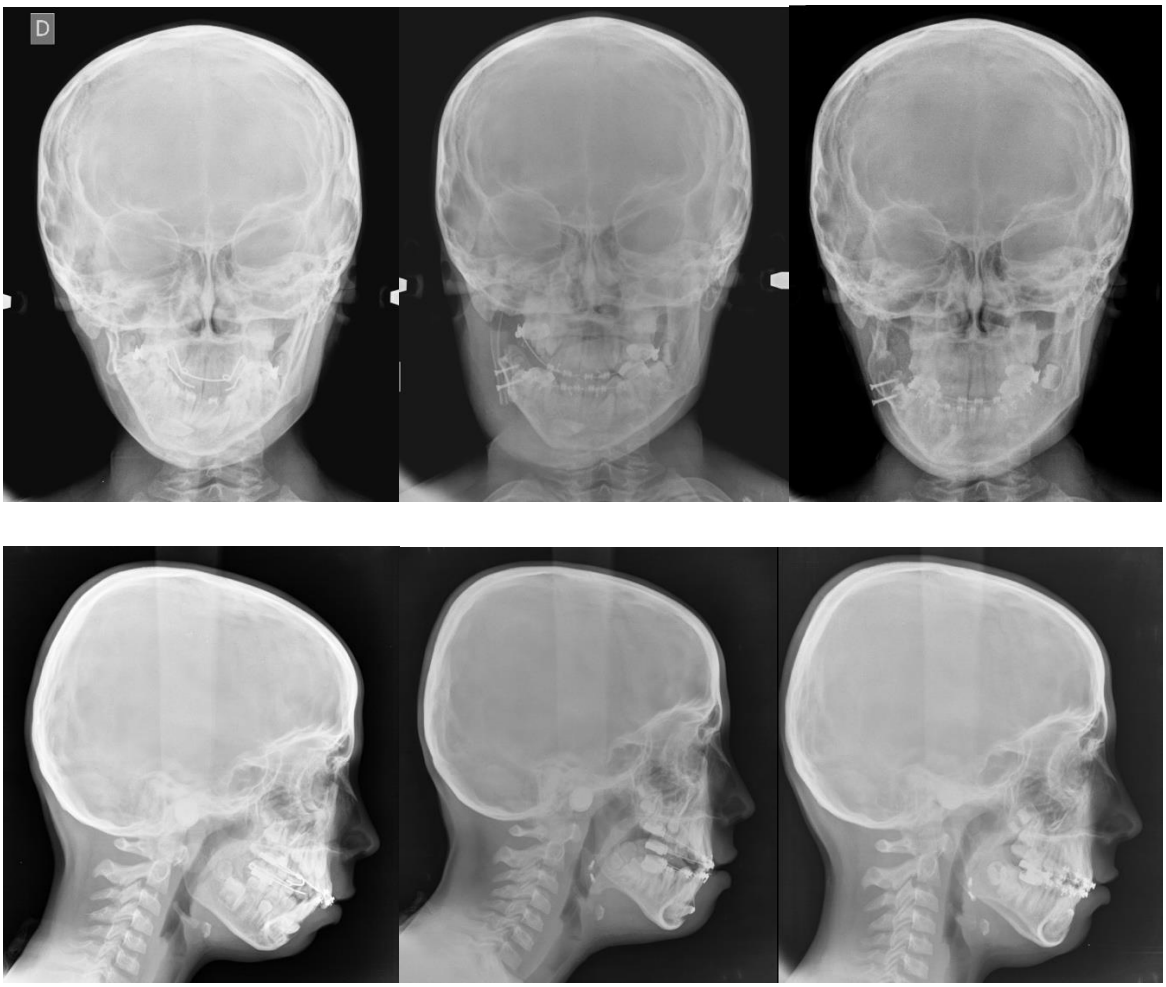

Figure 4. Architectural results of a young patient exhibiting a right PVI corresponding to right craniofacial microsomia, who underwent a right CCG at the age of 11 years, preoperatively, 6 months postoperatively, and 5 years postoperatively. On the frontal teleradiography the mandibular occlusal plane has been horizontalized, a progressive spontaneous egression of the maxillary teeth on the right side allowed for the normalization of the maxillary plane. On the lateral cephalomgrams, the mandibular height was increased postoperatively, and decreased slightly at the last follow-up with a slight reopening of the FMA angle.

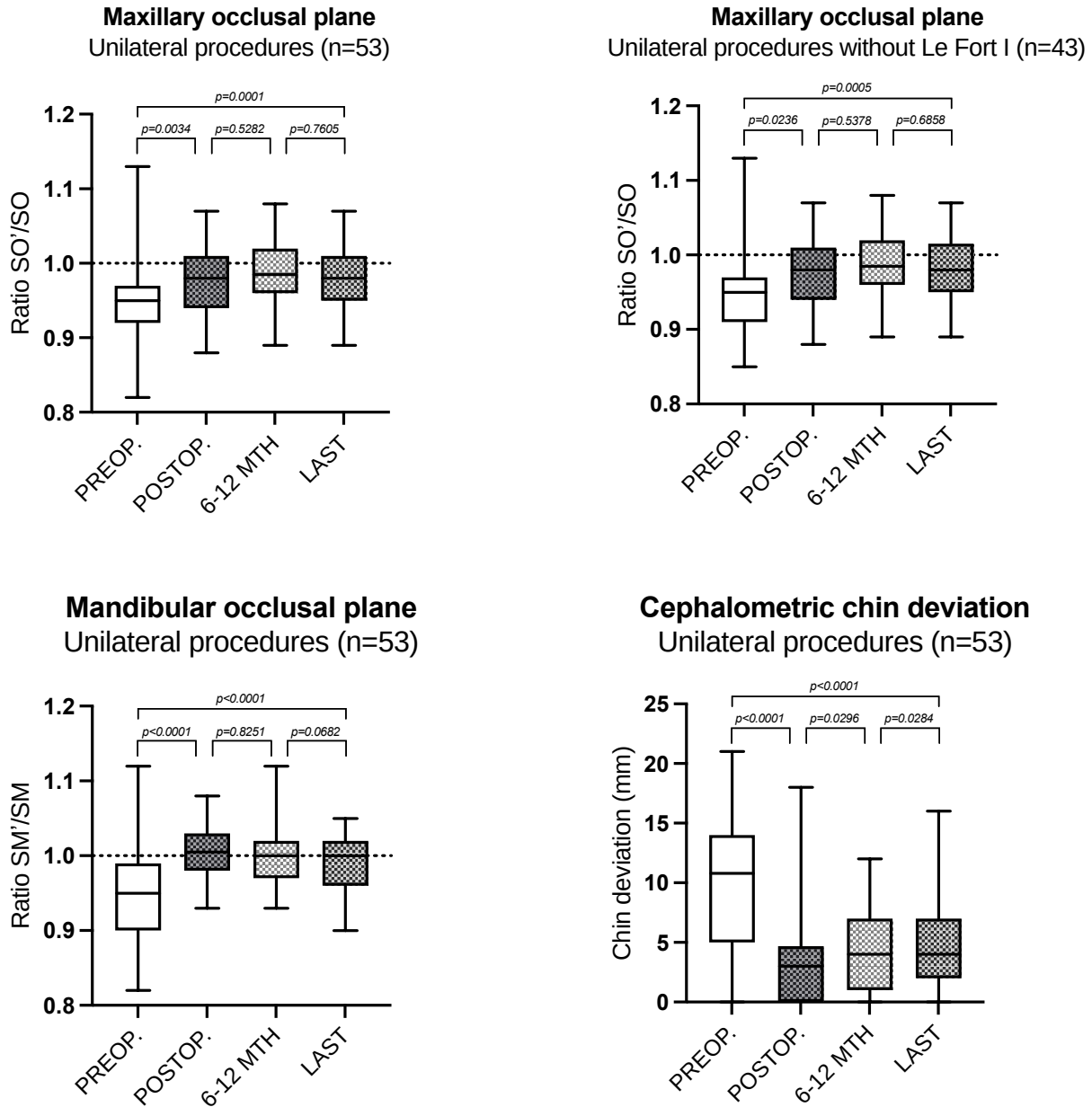

Figure 5. Variation of the cephalometric parameters preoperatively (PREOP.), postoperatively (POSTOP.), at 6-12 months after the surgical procedure and at the last follow-up (LAST).

Mandibular height was increased after the procedure from 49.68 ± 9.10 mm in preoperative time to 62.69 ± 8.46 mm in postoperative period ($p < 0.0001$) in all the procedures including unilateral and bilateral cases (n=95). A slight loss in MH was noted in the first year after surgery (58.81 ± 8.06 mm; $p < 0.0001$), but remained stable at the last follow-up (58.46 ± 1.03 mm; p=0.01). The same results were observed in children <16 years of age with a significant improvement in mandibular height between preoperative and postoperative periods (46.73 ± 7.97 mm and 61.51 ± 7.87 mm respectively, $p < 0.0001$). A loss of MH was noted at 6 months-1 year (57.99 ± 7.53 mm) but with a non-significant increase in mandibular height at last follow-up as a result of growth (58.83 ± 10.26 mm; p=0.38).

Finally, the analysis of FMA angle showed a significant closure of the angle from preoperative to postoperative periods (41.91 ± 11.53 vs 29.54 ± 8.92° respectively, $p<0.0001$). A progressive reopening with a verticalization of the mandibular plane was objectived at 6 months-1 year postoperatively and at the last follow-up (35.05 ± 10.03° and 36.43 ± 11.16° respectively, $p_1<0.0001$ and $p_2=0.0115$ respectively).

Mouth opening

In patients with TMJ ankylosis, a significant improvement of the MMO was observed from 15.07 ± 10.46 mm preoperatively to 27.17 ± 6.46 mm at last follow-up ($p < 0.0001$). No significative difference was reported between the preoperative and the final follow-up in MMO for the patients with PVI (35.80 ± 5.76 vs 33.9 ± 5.95 respectively; p=0.45)

Surgical complications

Two peroperative pleural wounds were reported necessitating a direct suture of a parietal pleura with no pneumothorax objectived in the postoperative chest radiography. Eight cases of CGG overgrowth were observed with a mean delay of 5.1 years (3 – 9 years) after the first procedure. All the patients were children with ranged age from 4 to 14 years at the time of the CCG. All required a secondary condylectomy with stable results over time. Recurrence of ankylosis was observed in six cases (8.6%), with an interval of 1 to 14 years after the CCG; four patients had

already required a post-traumatic or post-infectious ankylosis treatment prior to the CCG. All required an ankylosis block resection, and a new CCG was carried out in three patients. Nine immediate post-surgical infections were reported: three patients required removal of the CCG with a new graft three months later, one patient required surgical drainage, five patients required only oral antibiotic therapy. Anterior displacement of the graft was observed in two cases at one year after the procedure, with no additional procedure and no consequence on aesthetic or occlusal parameters. A temporary hypoesthesia in the inferior alveolar nerve territory was noted in five cases (7.1 %). Five patients (7.1%) exhibited a transitory facial nerve paresis in the lower labial branch territory.

DISCUSSION

The autogenous CCG is one of the relevant tools for the reconstruction of the RCU of the mandible. There are several indications for CCG:

- The restoration of the mouth opening and amplitudes in joint pathologies. Ankylosis of the TMJ is the total or partial fusion of the head of the mandibular condyle with the glenoid cavity, preventing mobilization of the joint and immobilizing the mandible (6). The main etiologies are post-infectious, especially in childhood after-effects of otitis and mastoiditis, post-traumatic, or from inflammatory and rheumatological origins (lupus, spondyloarthritis, psoriasis). The objective of the treatment is in this case to restore the mandibular function.
- The restoration of the posterior vertical dimension of the lower third of the face in patients exposing a PVI from malformative or congenital origins. In these indications the CCG aims to restore the dental occlusion and provide a growth potential for the remaining mandible in children (2,3). Mandibular condyle and ramus hypoplasia is a well-known craniofacial malformation. It can be classified as a congenital or an acquired deformity according to the developmental circumstances (31–34). Among the acquired etiologies, TMJ remodeling after a condyle fracture, TMJ ankylosis, and juvenile idiopathic arthritis are frequently described (35,36). Whereas the congenital causes are dominated by the craniofacial deformations of the structures derived from the first and the second branchial arches, such as with craniofacial microsomia (32). Clinically, unilateral PVI is characterized by an asymmetry of the lower third of the face with elevation of the commissural line, deviation of the chin on the affected side. The maxillary occlusal cant can is often elevated, as well as dental class II malocclusion is observed on the affected side (37).
- The combination of the two (PVI and joint dysfunction) in such as cases of TMJ ankylosis occurring in childhood.

Despite a rich literature on the subject, very few studies report long-term results with CCG, particularly regarding the architectural and aesthetic parameters. In a study of 76 GCCs with a minimum follow-up period of two years, Saeed *et al.* showed an significant improvement in pain

and diet despite a moderate increase of MMO in patients presenting mostly with ankylosed TMJ (24). In a retrospective study of 55 patients with TMJ ankylosis with 7 to 10 years of follow-up, Medra *et al.* showed a MMO superior to 25 mm at a minimum of 1 year after the CCG for 67% patients, satisfactory bone integration and remodeling for 59% of grafts on radiographic studies (38). Another study carried out in 55 patients receiving 74 CCGs with long-term results showed a significant association between the diagnosis of infection-related ankylosis and postoperative complications especially re-ankylosis (23). Despite a trend towards other techniques for RCU repair, we believe that the CCG remains a useful technique for ramus and joint reconstruction in children and adults (39,40). In our study, we aimed to assess the long-term stability of CCG with assessment of objective aesthetic and architectural parameters. We also aimed to better inform our patients and corresponding specialists including orthodontists about the CCG procedure, the expected results and possible complications associated to CCG. For this, we included 103 grafts performed over a period of more than 40 years, which represents to our knowledge one of the most important series in the literature. We chose to include all the CCG, regardless of the initial etiology presented by the patients, explaining the inclusion of both articular and architectural anomalies of the mandible. While bilateral CCGs were studied for epidemiological purposes, they were removed from the aesthetic and architectural analyses to better reflect the correction provided by the CCG. Our results confirmed the incredible effect of CCG in restoring the posterior vertical dimension and a facial symmetrization as shown by the improvement in our aesthetic and architectural results. In a study of 26 patients treated by CCG for ankylosis or PVI with a median follow up of 47.7 month, Perrott *et al.* showed a successful correction of facial asymmetry analyzing clinical chin deviation and RCU length on panoramic radiographs (41). We also reported that mandibular ramus height was increased from 49.68 mm to 62.69 mm with a mean loss of 6.2% in the first year after the procedure. The measurement of MH could be distorted at distance from the surgery by the bony changes that occur in the mandibular region, especially in cases of large facial deformities. Nevertheless, we have systematically observed a deterioration of the result both on the aesthetic and architectural criteria at the last follow-up. Same results were observed by Bertin *et al.* in a long-term study of 24 patients with craniofacial microsomia and reconstructed by CCG after a mean 81.9 months of follow-up (27). Anquetil *et al.* also showed a non-significant deterioration of the result with regard to the aesthetic parameters, and significant deterioration in mandibular occlusal canting in a series of 48 patients

with PVI and treated with a VRO technique (18). There are many factors that can explain the deterioration in results: first is the potential graft resorption inherent to bone grafts but also in this context to the masticatory forces imposed by the elevating muscles of the mandible leading to cartilage remodeling (42). Secondly, a large proportion of our patients suffered from craniofacial microsomia whose soft tissue hypoplasia could lead to recurrence or unfavorable outcomes with elongation procedure of the RCU (19). Therefore, we currently perform a large soft-tissue detachment with sectioning of the pterygomasseteric muscular strap, as well as a superior coronoidectomy to retain the ramus height and to minimize recurrence of the PVI (18). Another solution is to overcorrect the mandibular height with CCG to prevent potential relapse. On profile analysis, the facial hyperdivergence was corrected thanks to the restoration of the posterior mandibular height and the lowering of the mandibular angle. The decrease height had therefore led to a progressive reopening of the FMA angle during the follow-up.

CCG is particularly interesting in children because of its growth potential (13,43,44). As the normal condyle is considered as the main growth center of the mandible, its replacement with CCG allows for the restoration of a satisfactory mandibular height and helps in restoring the dental occlusion (45). Furthermore, the cartilaginous cap is able to adapt to the glenoid cavity by its shape and its hyaline composition which resists to the biomechanical joint stress (46). However, the glenoid fossa can be missing in severe deformities, thereby making it difficult to obtain a cranial support, which might explain the anterior displacement of the grafts observed in two cases (47). In cases of TMJ ankylosis, reconstruction of a glenoid cavity is not easy, and may require interposition of a fascia temporalis to limit the risk of reankylosis (48). Recurrence of TMJ ankylosis could affect 32.7% of patients treated with CCG, our study suggested a lower rate of 6% (49). Early and aggressive physiotherapy is also recommended to limit ankylosis recurrence (50). In patients with PVI, a one-stage correction of the maxillary occlusal canting could be obtained by the execution of a concomitant Le Fort I osteotomy. In other cases, a spontaneous dentoalveolar adaptation of maxillary bone was obtained in response to the generated open-bite, as evidenced by the progressive correction of the SO'/SO ratio in patients. This is usually obtained without any elastic forces, by releasing the maxillary molars from the orthodontic arch and by progressive shortening of the occlusal splint to guide the vertical movement of the maxilla (18,32). Most authors recommend CCG for autogenous mandibular

replacement starting at the age of 5, as it is considered too fragile before this age (21,22). In our current practice in children for the correction of PVI, this procedure is proposed only from the age of 10-12 years. This allows to wait for the eruption of the mandibular canines and the concomitant achievement of a genioplasty, with good aesthetic and social impact for patients. On the other hand, some authors recommend to not perform an associated genioplasty as it increases stress and strain in the muscular functional matrix that could be hypothetically interpreted as requirement of more growth on grafted side leading to CGG overgrowth (51). In TMJ ankylosis, GCC can be performed as early as necessary because of the functional handicap. The growth potential associated to CCG is not predictable and ranges from no growth to overgrowth. In our study, 20% of the children required a condylectomy due to overgrowth, with a maximum growth of 29 mm at 3 years. Various factors may influence the CCG growth such as masticatory movement of the mandible, inherent growth capacity of the cartilage graft, and possible hormonal factors (13,52). To avoid graft overgrowth in children, the height of the cartilage should be limited to a mean 3 mm (53). Our functional results measured in the articular impairment group were satisfactory since 69% patients with TMJ ankylosis had a mean MMO superior to 25 mm. We found a mean MMO of 27.17 mm at the last follow-up, which is consistent with the results observed in a recent meta-analysis reporting a mean MMO of 27.21 to 31.38 mm after a minimum follow-up period of 12 months (54). The use of an external approach can represent a limitation in terms of the scar and the potential for nerve damage in the area of the facial nerve. In our experience, all of the 5 patients recovered from their facial nerve paresis. Harvesting complications are rare with CCG. In our study, only 2 intraoperative pleural leak (2.1%) without pneumothorax were observed and no incision site infection, as observed by Lonergan *et al* (55).

Others procedures have been described for the reconstruction of the RCU. The use of autologous bone graft is possible with various harvesting sites (sternoclavicular bone, fibula, coronoid process, metatarsophalangeal) but it raises the problems of donor site morbidity and the absence of growing potential (54,56). Alloplastic prostheses represent a good alternative for the reconstruction of TMJ in adults as it can be custom-made with CAD/CAM technology, it also requires less operating time, and does not cause donor site morbidity (57,58). Nevertheless, TMJ prostheses raise the problem of high costs, a lifespan limited to 10 to 20 years, and are only indicated for skeletally mature patients (39,59,60). In children, DO represents another alternative

as it allows for a progressive concomitant soft tissue and bone growth, it represents a minimally invasive surgery with intraoral device. Nevertheless, DO has not shown any superiority in terms of MMO and complications compared to the CCG; it also exposes to long term relapse of ankylosis requiring further procedures (17,61–63). For the correction of PVI with functional TMJ, different orthognathic procedures have been described. A VRO according to the Caldwell-Letterman technique, as well as an Epker-modified-Wolford associated with a complete sectioning of the pterygomasseteric sling can lower the mandibular angle and lengthen the ramus with good architectural results (18,19,64). Finally, tooth-supported growth activators, used early in children, can correct growth abnormalities of the RCU, sometimes with impressive results as in condylomandibulodysplasia (65).

To assess the efficacy and stability of CCG, we used standardized photographic and posteroanterior cephalograms for more reliability with the measurement of distances. The mandibular lengthening was evaluated by the variation of the distance between the upper and the lowest point of RCU. Other authors as Perrot *et al.* used the perpendicular distance from a line tangent to the articulating surface to the point of intersection of lines tangent to the posterior and inferior borders of the mandible (41). The SO'/SO and SM'/SM ratios, reflecting the frontal maxillary and mandibular canting respectively, were used to eliminate the variability between radiographs (18,27). A three-dimensional analysis would be more relevant to assess the cephalometric changes and could be part of further studies. Furthermore, a double measurement of the clinical and radiographic parameters by two examiners would have provided our results with a greater degree of reliability. The patients included in this work were heterogeneous regarding the etiologies of articular impairments and PVI, making it difficult to draw conclusions regarding the place of CCG in the therapeutic strategy of these diseases. Nevertheless, our results show the possibility of reconstructing in a single time the RCU of the mandible with a non-negligible recurrence rate of the deformity over time, and a relatively low complication rate.

CONCLUSION

The CCG technique belongs to the therapeutic arsenal for both reconstruction of the ramus-condylar unit of the mandible. It allows for immediate restoration of the symmetry of the lower third of the face in patients with unilateral PVI or TMJ ankylosis, with good functional results in joint impairments. It remains a method of choice in children despite unpredictable growth potential leading to cases of overgrowth. A mean 6.2% of loss in mandibular height is commonly observed in the year following the procedure, as well as partial recurrence of the PVI, which may lead to a secondary orthognathic procedure.

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CONFLICT OF INTEREST

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Titre de These: Autogenous costochondral grafts used for ramus-condyle unit reconstruction: a long-term clinical and radiologic follow-up of 95 grafts

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RESUME

OBJECTIF: La greffe chondro-costale (GCC) est une technique chirurgicale employée dans le traitement de l'ankylose temporo-mandibulaire avec pour but de rétablir la fonction articulaire et dans la correction de l'insuffisance verticale postérieure afin de restaurer la hauteur mandibulaire. L'objectif de cette étude était d'évaluer la stabilité au long terme de critères architecturaux et esthétiques et d'analyser les complications chez des patients ayant bénéficié d'une GCC.

MATERIEL ET METHODES : Les patients ayant bénéficié d'une GCC ont été inclus dans une étude rétrospective. Des paramètres esthétiques et architecturaux ont été évalués en pré-opératoire, post-opératoire, à 6-12 mois et au dernier suivi, sur des photographies de face et des téléradiographies de face pour les cas de GCC unilatérale et sur des téléradiographies de profil pour l'ensemble des GCC.

RESULTATS : 95 GCC ont été étudiées. L'évaluation esthétique a révélé une correction significative de la déviation du menton et de l'inclinaison de la ligne bicommissurale des lèvres après CGG ($p < 0.0001$) avec des résultats stables. L'analyse architecturale a révélé une amélioration significative des plans d'occlusion maxillaire et mandibulaire, ainsi que de la déviation du menton ($p < 0,0001$). Une tendance à la rechute a été notée pour l'inclinaison mandibulaire et la déviation du menton au cours du suivi. Une diminution de 6,2% de la hauteur mandibulaire a été notée à 6-12 mois de suivi. L'ouverture buccale a été significativement améliorée pour les patients traités d'ankylose temporo-mandibulaire, mesurée à 27.17 mm au dernier suivi.

CONCLUSION : La CCG permet de restaurer la symétrie du tiers inférieur du visage avec de bons résultats fonctionnels. Elle reste une méthode de choix chez l'enfant malgré son potentiel de croissance imprévisible.

MOTS-CLES

Temporo-mandibular joint ; Ankylosis ; Posterior vertical insufficiency ; Costochondral graft