Facial Symmetry Outcomes in Craniofacial Microsomia after Growth Monitoring, Corrective Surgery, and Orthodontic Treatment

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Abstract

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Background: Craniofacial Microsomia (CFM) is a congenital malformation syndrome affecting craniofacial structures derived from the first and second pharyngeal arches. It presents with variable degrees of chin point deviation, mandibular hypoplasia, facial asymmetry, ear anomalies, and soft tissue deficiencies, making classification and treatment challenging. The Kaban classification systems is commonly used to assess severity and guide treatment.

Objective: This study evaluates facial symmetry and occlusal outcomes in patients with CFM following staged growth monitoring, surgical interventions, and orthodontic treatments, using the Phenotypic Assessment Tool – Craniofacial Microsomia (PAT-CFM) tool and conventional orthodontic measures.

Methods: A single-center retrospective cohort study was conducted at Seattle Children's Hospital Craniofacial Center. Data from 130 patients with CFM were reviewed, with 74 subjects meeting inclusion criteria based on imaging at multiple time points. Growth monitoring outcomes, surgical interventions—including costochondral grafting (CCG), orthognathic surgery, and orthodontic treatments were analyzed to determine their impact on facial asymmetry and occlusion.

Results: Forty-five patients with mild CFM (Kaban I and IIa) showed stable or improved chin point deviation, mandibular hypoplasia, and occlusal plane canting over a mean growth period of 4.6–6.0 years. In fifteen moderate to severe subjects (Kaban IIb and III), CCG, orthognathic surgery, and/or orthodontic treatment resulted in improved mandibular morphology and occlusal plane alignment, though outcomes varied. Orthognathic surgery combined with orthodontics significantly enhanced facial symmetry and occlusion in severe cases.

Conclusion: Data indicated that mild CFM remains stable or improves with growth, while surgical and orthodontic interventions play a crucial role in managing moderate to severe cases. Comprehensive treatment strategies, including CCG and orthognathic surgery, result in improved facial symmetry and occlusal outcomes.

Etiology, Incidence and Classification

Craniofacial Microsomia (CFM) is a complex malformation syndrome affecting the ears and jaws, and occasionally the eyes, cheeks, and bones of the neck.[1] Disruption in development during the first six weeks of gestation results in an absence or underdevelopment of structures that arise from the first and second pharyngeal arches (e.g. mandible, maxilla, ear, facial soft tissue, facial and masticatory muscles, facial nerve).[2] CFM is estimated to occur in 1:3,000 to 1:5,000 live births, making it the most common congenital disorder of the face after cleft lip and palate.[2]

Phenotypes of CFM present with variable degrees of orbit dysmorphology, mandibular hypoplasia, facial asymmetry, ear malformations, chin deviation, soft tissue deficiencies, and occlusal abnormalities. The spectrum of phenotypes presents challenges for accurate classification and description of treatment outcomes. The OMENS classification (O – orbital distortion; M – mandibular hypoplasia; E – ear anomaly; N – nerve involvement; S – soft-tissue deficiency) is the most comprehensive and commonly used CFM classification system.[1] The Kaban radiographic classification includes description of the mandible and temporomandibular joint. (Table 1).[3]

Table 1: Kaban classification system for Craniofacial Microsomia	
I	Small mandible
IIA	Short mandibular ramus of abnormal shape; glenoid fossa in satisfactory position
IIB	Temporomandibular joint abnormally placed inferiorly, medially, and anteriorly
III	Absent Temporomandibular joint

Management of CFM

The management of patients with CFM is dictated by the patient's functional needs and esthetic goals; approaches vary due to differences in the number and severity of affected structures. Timing for surgical treatments may be during infancy, childhood, adolescence, or adulthood.[1] Orthodontic treatment is often part of a comprehensive management plan for patients with CFM and is done in the mixed dentition and/or permanent dentition.

In the infancy/early childhood stage (birth to six years), patients often receive surgeries for correction of soft tissue defects (e.g. pre-auricular tags, cleft lip/palate), surgery targeted at hearing (e.g. bone anchored hearing aids, cochlear implants), and osteotomies to correct significant orbital dystopia or plagiocephaly. The preferred early surgical procedure for a deficient mandibular ramus is an autologous costochondral graft (CCG). A CCG provides length to the ramus, creates an articulation with skull base, and functions as a growth center. Complications of CCG include potential overgrowth of the graft, disruption of developing posterior teeth, and postoperative complications (e.g. infection, pain, donor site morbidity).[4] Some centers utilize distraction osteogenesis as the early procedure of choice to treat Kaban type IIa and IIb mandibles. Mandibular distraction osteogenesis (MDO) can be employed following CCG for treatment of Kaban type III mandibles.[5]

Between six to twelve years (mixed dentition stage), middle ear reconstruction, external ear reconstruction, nerve and muscle grafts, costochondral grafts or MDO or a combination of surgeries can be done.[6] Orthodontic functional or fixed appliances are used to coordinate dental arches or manage the erupting permanent dentition.

In the adolescent/adult stage (12 years and older), definitive orthodontic and orthognathic correction are often completed. This later stage of treatment often involves bimaxillary orthognathic surgery to correct the position and cant of the maxilla, combined with mandibular advancement and ramus lengthening and genioplasty. Following bony reconstruction, soft tissues may be augmented to address significant tissue asymmetries. At this stage, further corrections to external ear morphology and position can be made.[6]Fixed orthodontic treatment is used to support orthognathic surgery and create a functional and esthetic occlusion.[7] Key treatment outcomes include improved facial symmetry, functional jaw movements, a stable occlusion with minimal relapse, and patient satisfaction.

Tools to Rate Facial Symmetry in CFM

In 2017, the International Consortium for Health Outcome Measurement (ICHOM) published a Craniofacial Microsomia Data Collection Reference Guide to facilitate implementing a standard set of comparable data for global benchmarking and measure outcomes for patients with CFM.[8] The Phenotypic Assessment Tool – Craniofacial Microsomia (PAT-CFM) was developed to accurately measure facial asymmetry outcomes in CFM patients using both photographs and clinical examinations (Figure 1). A study comparing physical exams of patients with CFM to photographs of patients with CFM found that photographs provide a reliable method for classifying craniofacial features in CFM and supported the use of PAT-CFM as an effective tool for assessing facial symmetry.[9]

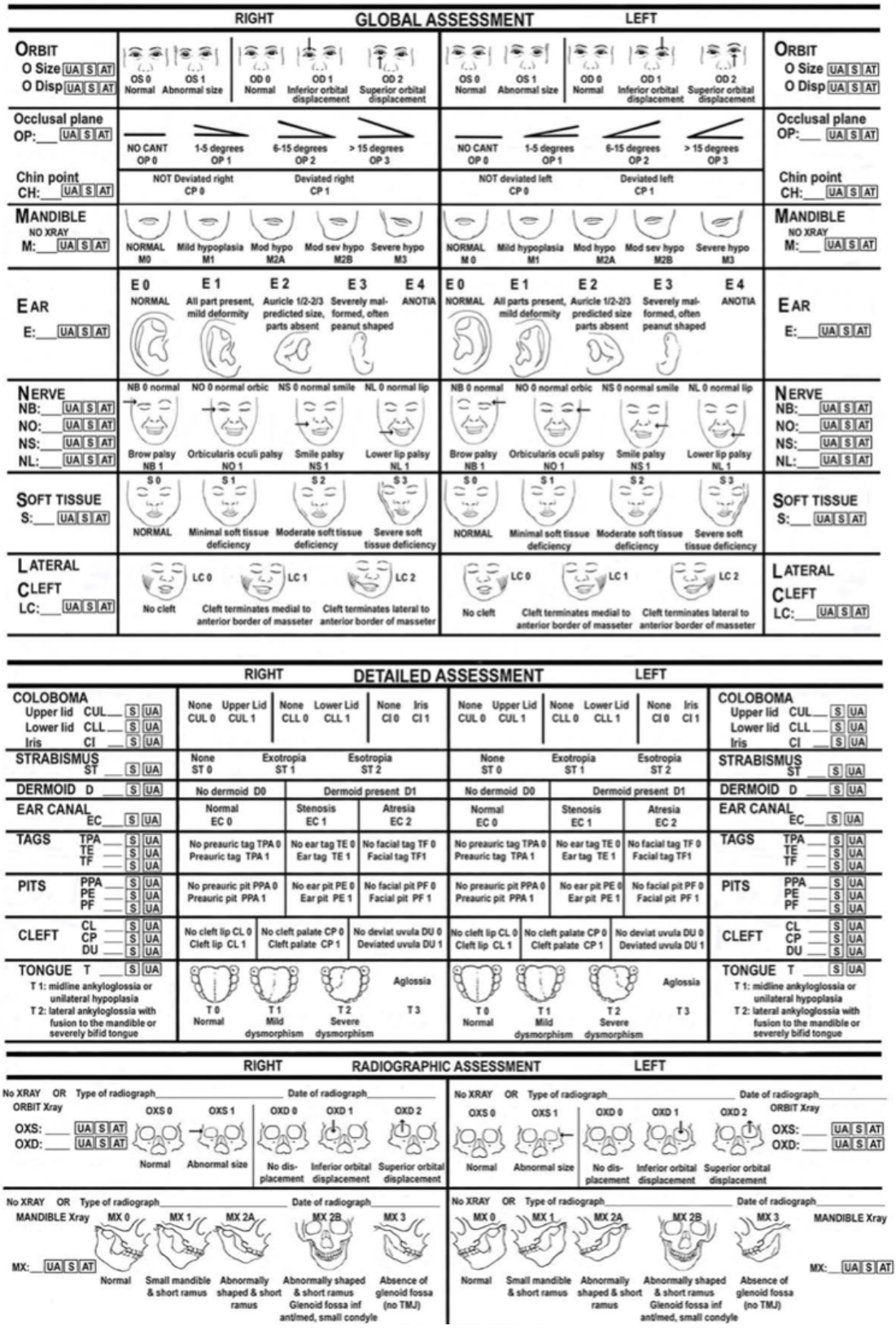

Figure 1: Phenotypic Assessment Tool- Craniofacial Microsomia (PAT-CFM)

Treatment Outcomes for Patients with CFM

Although surgery is frequently performed for CFM, specific patient outcomes after interventions such as growth monitoring, surgeries, and orthodontic treatments are not commonly reported. Pluijmers et al. analyzed 565 patients at three major European craniofacial centers and confirmed the high prevalence of surgical interventions, with 78.4% of patients undergoing procedures ranging from minor corrections to major reconstructions.[10]However, despite extensive documentation on the types and frequencies of surgical procedures, few studies provide detailed outcome assessments regarding occlusal or esthetic outcomes for patients with CFM after growth monitoring, surgeries, and orthodontic treatment(s).

Chen et al. found vertical contour asymmetry was more pronounced in CFM patients post-surgery with no significant differences in midline deviation, lip, or occlusal cant when comparing facial asymmetry after orthognathic surgery in 20 patients with mild CFM.[11] Shibazaki-Yorozuya, et al. used cone beam computed tomography to investigate growth in six patients with unilateral CFM over an 18 month to five-year period. The included subjects were Kaban type I (n=2), IIA (n=2), and IIB (n=2). The affected side of the cranial base, maxilla, and mandible grew differently than the unaffected side. Nasomaxillary length was shorter on the affected side in all subjects, and growth was reduced in five of the six subjects. The mandibular ramus was shorter and grew less on the affected side in most cases, resulting in occlusal plane canting. The growth rate of the mandibular body on the affected side compared to the contralateral side varied in this sample.[12]

Purpose

This study used the PAT-CFM tool to evaluate facial symmetry outcomes in subjects with CFM after staged growth monitoring, corrective surgery(ies), and/or orthodontic treatment(s). Extraoral photographs, intraoral photographs, and intraoral scans were used to rate orthodontic outcomes. The research questions were:

1. For individuals with mild CFM (Kaban I and IIa), does facial asymmetry (chin point, degree of chin deviation, mandible hypoplasia, soft tissue deficiency, occlusal plane) remain stable, improve, or worsen during growth monitoring without surgical or growth modifying orthodontic intervention (e.g. functional appliance, interarch elastics, headgear)?
2. In subjects with moderate to severe CFM (Kaban IIb and III) does facial asymmetry (chin point, degree of chin deviation, soft tissue deficiency, mandible hypoplasia, occlusal plane) remain stable, improve, or worsen following costochondral grafting during the growth period? How does this differ from growth monitoring without CCG?
3. In moderate to severe cases of CFM (Kaban IIb and III) does final facial asymmetry (chin point, degree of chin deviation, soft tissue deficiency, mandible hypoplasia, occlusal plane) remain stable, improve, or worsen following surgical and orthodontic treatment?
4. Which orthodontic treatment(s) +/- in combination with orthognathic surgery result in the best occlusal outcomes (posterior occlusal relationships, ideal overbite, ideal overjet, coincident midlines) for subjects with mild CFM (Kaban I and IIa)?

RESEARCH DESIGN AND METHODS

RESEARCH DESIGN

This project was a single center retrospective cohort study of subjects with CFM treated at the Seattle Children's Hospital Craniofacial Center. Data was sourced from electronic health records, extraoral and intraoral photographs, radiographs, computerized tomography (CT), diagnostic casts, and intraoral scans. Outcomes were assessed using portions of the PAT-CFM and basic orthodontic criteria. The study was approved by the Seattle Children's Hospital Institutional Review Board (CR00008712).

METHODS

Sample

Subjects were identified by Seattle Children's Hospital's Craniofacial Center internal reports.

Inclusion Criteria

Eligible subjects met these criteria:

- Diagnosis of craniofacial microsomia, hemifacial microsomia, Goldenhar or oculo-auriculo-vertebral syndrome
- Completed surgical and orthodontic treatment at Seattle Children's Hospital
- Orthodontic assessment including imaging at two or more timepoints
- All records available at time points of interest
- Treated between January 1, 1995 through December 31, 2024.

Exclusion Criteria

- Nondiagnostic imaging
- Received treatment outside study time frame.

Research Procedures

Electronic health records, radiographs, and photographs for each potential subject were reviewed. Eligible subjects were assigned a study number to de-identify the subject. All data was entered into REDCap hosted at Seattle Children's Hospital. REDCap is an online, secure database that manages and analyzes electronic health record information.[13]

Subject Variables (Appendix Table 1)

- Gender, date of birth, race/ethnicity, side of microsomia, Kaban classification as determined by radiographic images
- Date first seen at the craniofacial center

Initial treatment recommended

- Growth monitoring
- Surgery
- Orthodontic treatment

Surgeries

- History of surgery completed prior to initial visit at SCH Craniofacial Center
- For surgeries at SCH: date, type of surgery
- Symmetry Outcomes from Extraoral Clinical Photographs (PAT-CFM Categories) (Appendix Table 2)
- Occlusal plane angulation
- Chin point deviation, degree of chin point deviation
- Mandible hypoplasia
- Soft tissue deficiency

Occlusion Outcomes from Intraoral Clinical Photographs or Intraoral Scan (Appendix Table 2)

- Phase of dentition
- Angle classification affected and nonaffected side
- Overjet (mm)
- Overbite (%)
- Posterior open bite
- Dental midlines

Reliability measures

Calibration procedures were conducted between the primary investigator (PI) and a craniofacial orthodontist throughout the data collection process to ensure consistency and accuracy. Inter-rater reliability was assessed by comparing assessments of a second craniofacial orthodontist with those made by the PI. Inter-examiner reliability of facial asymmetry (occlusal plane, chin point, chin point, deviation, mandible and soft tissue) was assessed by rescoring ten cases with Kaban I or Kaban IIa (n=2), Kaban IIb (n=6) or Kaban III (n=2) CFM with the PAT-CFM. All measures were categorical, and the agreement and reliability were summarized by the percent agreement and unweighted and weighted Kappa statistic. A Kappa statistic > 0.75 generally indicates excellent agreement, 0.40 to 0.75 is fair to good agreement, and below 0.40 is poor agreement.[14]

Data Analysis

The data analysis was primarily descriptive. Descriptive summaries included mean, standard deviation (SD), median, interquartile range, and minimum and maximum values for continuous variables, and frequency and percentage for categorical variables. Summaries were restricted to subjects with an initial primary or mixed dentition and with an initial and final data

for at least 1 of the 4 measures of facial asymmetry (occlusal plane, chin point deviation, mandible and soft tissue). Summaries were based on all included subjects and by microsomia severity (Kaban classification I, IIa, IIb and III).

Facial asymmetry was described by PAT-CFM categorical measures for occlusal plane, chin point deviation, mandible and soft tissue. The initial, final and change (improved, no change, worsened) in facial asymmetry were summarized by Kaban classification by the frequency and percent. Facial asymmetry change was also reported by treatment received. The change was described for Kaban I and Kaban IIa subjects who received only growth monitoring with or without phase 1 orthodontic treatment, and the change was described for Kaban IIb and Kaban III subjects who received comprehensive orthodontic treatment, combination of phase 1 and phase 2 orthodontic treatment, or surgery. In addition, the length of growth monitoring was described by Kaban classification for subjects only receiving growth monitoring.

Descriptive summaries were also created for angle classification, overjet and overbite for Kaban I and Kaban IIa subjects with a final permanent dentition and who received comprehensive orthodontic treatment or a combination of phase 1 and phase 2 orthodontic treatment without and with surgery.

RESULTS

Sample

One hundred thirty subjects diagnosed with craniofacial microsomia were identified through craniofacial center reports. Of these, 74 subjects had imaging at two or more timepoints and were eligible for inclusion. Most subjects were male (58.1%) and Caucasian (48.6%) and exhibited mild CFM involvement, Kaban I (N=39) and Kaban IIa (N=20). Fewer subjects had

moderate or severe CFM (Kaban IIb: N=7, Kaban III: N =8). At the time of initial assessment, the mean (SD) age was 7.8 years (1.8). A detailed description of the sample can be found in Table 2.

Table 2. Sample Descriptive Statistics

Characteristic	N = 74	Kaban I N = 39	Kaban IIa N = 20	Kaban IIb N = 7	Kaban III N = 8
Sex, n (%)					
Female	31 (41.9%)	18 (46.2%)	3 (15.0%)	4 (57.1%)	6 (75.0%)
Male	43 (58.1%)	21 (53.8%)	17 (85.0%)	3 (42.9%)	2 (25.0%)
Race, n (%)					
American Indian/Alaska Native	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Asian	13 (17.6%)	4 (10.3%)	7 (35.0%)	2 (28.6%)	0 (0.0%)
Native Hawaiian or Other Pacific Islander	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Black or African American	3 (4.1%)	2 (5.1%)	0 (0.0%)	0 (0.0%)	1 (12.5%)
White	36 (48.6%)	16 (41.0%)	12 (60.0%)	2 (28.6%)	6 (75.0%)
More Than One Race	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unknown / Not Reported	1 (1.4%)	0 (0.0%)	1 (5.0%)	0 (0.0%)	0 (0.0%)
Other	21 (28.4%)	17 (43.6%)	0 (0.0%)	3 (42.9%)	1 (12.5%)
Age at initial image (y)					
Mean (SD)	7.8 (1.8)	8.0 (1.9)	7.5 (1.5)	7.8 (1.8)	7.5 (2.1)
Median (IQR)	7.7 (6.5, 8.6)	7.7 (6.6, 9.0)	7.7 (6.5, 8.5)	8.0 (6.4, 9.8)	7.4 (6.4, 8.4)
Min to Max	3.7, 13.3	4.2, 13.3	3.7, 10.0	5.7, 10.3	4.3, 11.3
Skewness	0.4	0.6	-0.6	0.2	0.3
Age at growth monitoring (y)					
Mean (SD)	10.6 (2.3)	10.8 (0.8)	10.4 (1.4)	10.0 (2.4)	11.1 (3.1)
Median (IQR)	10.7 (9.2, 11.4)	10.8 (10.2, 11.4)	11.3 (8.9, 11.5)	10.7 (8.4, 11.7)	10.5 (9.2, 11.1)
Min to Max	6.6, 17.7	10.2, 11.4	8.7, 11.6	6.6, 12.2	8.4, 17.7
Skewness	1.3	0.0	-0.3	-0.5	1.3

Characteristic	N = 74	Kaban I N = 39	Kaban IIa N = 20	Kaban IIb N = 7	Kaban III N = 8
Missing	56	37	15	3	1
Age at final image (y)					
Mean (SD)	14.5 (4.2)	12.7 (3.0)	15.3 (4.6)	17.6 (3.7)	18.5 (3.8)
Median (IQR)	13.7 (11.5, 17.5)	12.5 (11.1, 14.6)	13.9 (11.7, 18.6)	19.1 (15.5, 20.1)	18.7 (15.6, 21.3)
Min to Max	6.6, 23.7	6.6, 18.5	8.9, 22.9	10.0, 20.6	13.1, 23.7
Skewness	0.3	-0.1	0.4	-1.1	0.0
Duration, final – initial (y)					
Mean (SD)	6.7 (3.9)	4.7 (2.5)	7.8 (4.3)	9.7 (2.8)	11.0 (3.0)
Median (IQR)	6.4 (3.8, 9.1)	4.5 (2.8, 6.4)	7.3 (4.2, 10.6)	9.8 (9.1, 12.5)	10.9 (8.9, 12.9)
Min to Max	0.0, 15.9	0.0, 10.9	2.5, 15.6	4.3, 12.5	6.9, 15.9
Skewness	0.6	0.2	0.5	-0.8	0.2
Final dentition phase, n (%)					
Primary	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Mixed Dentition	14 (20.0%)	10 (27.0%)	4 (21.1%)	0 (0.0%)	0 (0.0%)
Permanent Dentition	56 (80.0%)	27 (73.0%)	15 (78.9%)	7 (100.0%)	7 (100.0%)
Missing	4	2	1	0	1

Hispanic/Latino: 16 report race as Other, 3 are unknown (1 White, 1 Other, 1 Unknown). The rest were not Hispanic/Latino.

Reliability Measures for PAT-CFM

The reliability for the occlusal plane, chin point and chin point deviation were excellent with perfect agreement (100%) and Kappa statistic of 1. The reliability for mandible hypoplasia was excellent with 90% agreement and weighted Kappa statistic of 0.89 and unweighted Kappa statistic of 0.81. The reliability for soft tissue was also excellent with 90% agreement and weighted Kappa statistic of 0.85 (and [unweighted] Kappa statistic of 0.87).

Question #1: For individuals with mild CFM (Kaban I and IIA), does facial asymmetry (chin point, degree of chin deviation, mandible hypoplasia, soft tissue deficiency, and occlusal plane) remain stable, improve, or worsen during growth monitoring without surgical or growth modifying orthodontic treatment (e.g. functional appliance, interarch elastics, headgear)?

Growth monitoring for subjects with Kaban I classification

Thirty-two subjects with Kaban I CFM had growth monitoring data. The mean age (SD) at start of growth monitoring was 7.7 years (SD = 1.7) and mean age at end of growth monitoring was 12.2 years (SD = 2.6) The mean time elapsed during growth monitoring was 4.6 years (SD = 2.5).

Subjects with Kaban I CFM, most frequently had mild chin deviations (1-3 mm) towards the affected side at the initial time point (74.2%), fewer had symmetrical chin positions (12.9%). Only one subject had a chin deviation greater than 6 mm. During growth monitoring the large majority of subjects exhibited no change in chin point (71.0%) and 29.0% showed improvement in chin point position. No subject experienced a worsening in chin point deviation with growth (Table 3, Appendix Table 3).

Table 3. Kaban I Chin Point Deviation Change During Growth Monitoring Period

	Initial N (%)	Final N (%)		Change	N (%)
Symmetrical	4 (12.9%)	12 (38.7%)		Improved	9 (29.0%)
Mild 1-3 mm	23 (74.2%)	15 (48.4%)		No change	22 (71.0%)
Moderate 3-6 mm	3 (9.7%)	4 (12.9%)		Worsened	0
Severe >6 mm	1 (3.2%)	0			

The majority of subjects with Kaban I CFM exhibited mild mandibular hypoplasia at the start of the growth monitoring period (N=21, 65.6%), while 28.1% of subjects (N=9) showed normal mandibular morphology. Over the course of the monitoring period, 75.0% of subjects experienced no change in mandible morphology (N=24), while 18.7% demonstrated improvement in mandibular morphology (N=6). Two subjects (6.3%) showed worsening of mandibular morphology during the growth monitoring period (Table 4, Appendix Table 4).

Table 4. Kaban I Mandible Hypoplasia Change During Growth Monitoring Period

	Initial N (%)	Final N (%)		Change	N (%)
Normal	9 (28.1%)	13 (40.6%)		Improved	6 (18.7%)
Mild	21 (65.6%)	17 (53.1%)		No change	24 (75.0%)
Moderate	2 (6.3%)	2 (6.3%)		Worsened	2 (6.3%)
Moderate/severe	0	0			
Severe	0	0			

Half of subjects with Kaban I CFM exhibited minimal soft tissue deficiency at the start of growth monitoring (N=16, 50%), and 43.7% had no soft tissue deficiency (N=14). A large majority of subjects with Kaban I CFM showed no significant soft tissue changes with growth (N=26, 81.3%). Soft tissue appearance did not worsen for any subject during growth monitoring. (Table 5, Appendix Table 5).

Table 5. Kaban I Soft Tissue Change During Growth Monitoring Period

	Initial N (%)	Final N (%)		Change	N (%)
Normal	14 (43.7%)	20 (62.5%)		Improved	6 (18.7%)
Minimal	16 (50.0%)	11 (34.4%)		No change	26 (81.3%)
Moderate	2 (6.3%)	1 (3.1%)		Worsened	0
Severe	0	0			

Among Kaban I subjects, most had mild occlusal plane canting (N=19, 65%) or no cant (N=11, 37.9%) at the start of growth monitoring. About three quarters of Kaban I subjects experienced no appreciable change in occlusal cant during growth monitoring (N=22, 75.9%). Four subjects experienced worsening of the occlusal cant (13.8%) and occlusal cant improved in three subjects (10.3%) during growth monitoring. (Table 6, Appendix Table 6).

Table 6. Kaban I Occlusal Plane Cant Change During Growth Monitoring Period

	Initial N (%)	Final N (%)		Change	N (%)
No cant	11 (37.9%)	10 (34.4%)		Improved	3 (10.3%)
1-5^{o}	19 (65.5%)	16 (55.2%)		No change	22 (75.9%)
6-15^{o}	0 (0%)	3 (10.3%)		Worsened	4 (13.8%)
>15^{o}	1 (3.4%)	0 (0%)			

Growth monitoring for subjects with Kaban IIa Classification

Thirteen subjects with Kaban IIa CFM had growth monitoring data. The mean age at start of growth monitoring was 6.9 years (SD =1.3) and mean age at end of growth monitoring was 12.9 years (SD =3.5). The mean time elapsed during growth monitoring was 6.0 years (SD =3.4).

A majority of subjects with Kaban IIa CFM had mild chin point deviations (N=9) and thirty percent had moderate chin point deviations (N=4) at the initial time point. During growth

monitoring, ten showed no change (76.9%) while three subjects (23.1%) showed improvement in chin position. (Table 7, Appendix Table 7).

Table 7. Kaban IIa Chin Point Deviation Change During Growth Monitoring Period

	Initial N (%)	Final N (%)		Change	N (%)
Symmetrical	0 (0%)	0 (0%)		Improved	3 (23.1%)
Mild 1-3 mm	9 (69.2%)	12 (92.3%)		No change	10 (76.9%)
Moderate 3-6 mm	4 (30.8%)	1 (7.7%)		Worsened	0 (0%)
Severe>6 mm	0 (0%)	0 (0%)			

At the initial timepoint, subjects with Kaban IIa classification predominantly presented with mild mandibular hypoplasia (N=9, 69.2%), fewer had moderate hypoplasia (N=2, 15.4%), one had moderate/severe mandible hypoplasia (7.7%), and one had normal mandibular morphology (N=1, 7.7%). Eight subjects (61.5%) showed no change in mandibular hypoplasia over the growth period. Mandible hypoplasia improved for two subjects (15.4%) and worsened for three subjects (32.1%). (Table 8, Appendix Table 8).

Table 8. Kaban IIa Mandible Hypoplasia Change During Growth Monitoring Period

	Initial N (%)	Final N (%)		Change	N (%)
Normal	1 (7.7%)	0 (7.7%)		Improved	2 (15.4%)
Mild	9 (69.2%)	10 (69.2%)		No change	8 (61.5%)
Moderate	2 (15.4%)	2 (15.4%)		Worsened	3 (32.1%)
Moderate/severe	1 (7.7%)	1 (7.7%)			
Severe	0	0			

The majority of subjects with Kaban IIa CFM exhibited minimal (N=5, 38.5%) or moderate (N=4, 30.7%) soft tissue deficiency at the start of growth monitoring. During growth monitoring, a large majority of subjects with Kaban IIa CFM showed no significant soft tissue

changes (N=10, 76.9%). Soft tissue appearance of three subjects improved (23.1%) (Table 9, Appendix Table 9).

Table 9. Kaban IIa Soft Tissue Change During Growth Monitoring Period

	Initial N (%)	Final N (%)		Change	N (%)
Normal	2 (15.4%)	4 (30.7%)		Improved	3 (23.1%)
Minimal	5 (38.5%)	3 (23.1%)		No change	10 (76.9%)
Moderate	4 (30.7%)	5 (38.5%)		Worsened	0
Severe	2 (15.4%)	1 (7.7%)			

Eleven subjects with Kaban IIa classification had photographs which allowed scoring of occlusal plane cant. Initial occlusal plane canting varied with four subjects presenting with mild cants (36.3%) and evenly distributed between moderate (N=3, 27.3%) and severe cants (N=3, 27.3%). One subject had no cant initially. During growth monitoring, eight subjects experienced no change (72.7%). Occlusal plane cant improved for two subject (18.2%) and worsened for one subject (9.1%). (Table 10, Appendix Table 10).

Table 10. Kaban IIa Occlusal Plane Cant Change During Growth Monitoring Period

	Initial N (%)	Final N (%)		Change	N (%)
No cant	1 (9.1%)	1 (9.1%)		Improved	2 (18.2%)
1-5º	4 (36.3%)	4 (36.3%)		No change	8 (72.7%)
6-15º	3 (27.3%)	4 (36.3%)		Worsened	1 (9.1%)
>15º	3 (27.3%)	2 (18.2%)			

Summary of Facial Changes during Growth Monitoring for Subjects with Kaban I and Kaban IIa CFM

Over a mean growth period of 4.6 years, every subject with Kaban I CFM either showed no change or improvement in chin point position and soft tissue symmetry (100%). Nearly all of these subjects exhibited stable or improved mandible appearance (94%). A large majority showed no change or improvement in occlusal plane canting with growth (86%).

Over a mean growth period of 6.0 years all subjects with Kaban IIa CFM showed no change or improvement in chin point deviation and soft tissue (100%). A large majority of these subjects exhibited stable or improved mandible appearance (76.9%). Nearly all showed no change or improvement in occlusal plane canting with growth (90.9%).

Question #2: In subjects with moderate to severe CFM (Kaban IIb and III) does facial asymmetry (chin point, degree of chin deviation, soft tissue deficiency, mandible hypoplasia, occlusal plane) remain stable, improve, or worsen following costochondral grafting during the growth period? How does this differ from growth monitoring without CCG?

Interim outcomes were assessed for three subjects with Kaban IIb CFM who had growth monitoring with or without phase 1 orthodontics and with or without CCG. Chin point was unchanged in all subjects. Mandible hypoplasia showed no change in two subjects, while the mandible hypoplasia for the subject who had orthodontic treatment and CCG worsened. Soft tissue was unchanged in two subjects and worsened in one individual. Occlusal plane canting was unchanged in two subjects and improved in the subject who received CCG. (Table 11).

Interim outcomes were evaluated for three subjects with Kaban III CFM who completed orthodontic treatment combined with costochondral grafting (CCG) with or without fat grafting and ear reconstructions but did not undergo orthognathic surgery. Chin point improved in two

subjects, while one showed no change after growth monitoring, CCG, and orthodontic treatment. Mandibular hypoplasia improved in all three subjects following treatment interventions. Soft tissue remained unchanged in two subjects but improved in one. The occlusal plane improved in all three subjects after growth monitoring and CCG, with or without orthodontic treatment. (Table 11)

Table 11. Kaban IIb and Kaban III interim facial symmetry outcomes following growth monitoring, +/1 phase 1 orthodontic treatment, and +/- CCG

Classification	Study ID	Type of procedure	Chin point	Mandible hypoplasia	Soft tissue	Occlusal plane
Kaban IIb						
Growth monitoring or phase I orthodontic treatment	101	Growth monitoring only	No change (moderate)	No change (Moderate)	No change (minimal)	No change (Severe
	110	Growth Monitoring, Phase I orthodontic treatment, Skin Tag Removal, Macrostomia Repair	No change (moderate)	No change (moderate)	Worse (minimal to moderate)	No change (moderate)
Phase 1 Orthodontic Treatment and Costochondral Graft	40	Growth monitoring, phase 1 orthodontic treatment, Costochondral graft	No change (severe)	Worse (moderate /severe to severe)	No change (severe)	Improved (severe to moderate)
Classification	Study ID	Type of procedure	Chin point	Mandible Hypoplasia	Soft tissue	Occlusal plane
Kaban III						
Costochondral graft in combination with Orthodontic treatment and/or fat grafting, ear reconstruction **WITHOUT** Orthognathic surgery	4	Growth Monitoring, Phase 1 orthodontic treatment, Costochondral graft, Ear Reconstruction	Improved (severe to moderate)	Improved (moderate to mild)	No change (moderate)	Improved (mild to no cant)
	38	Growth monitoring, Costochondral Graft, Comprehensive orthodontic treatment, Fat Grafting, Ear Reconstruction	Improved (Severe to moderate)	Improved (Severe to mild)	Improved (Severe to minimal)	Improved (Severe to mild)
	117	Growth Monitoring, Costochondral graft, Premolar Extractions	No change (severe)	Improved (Severe to moderate)	No change (Severe)	Improved (severe to mild)

Question #3: In moderate to severe cases of CFM (Kaban IIb and III) does final facial asymmetry (chin point, degree of chin deviation, soft tissue deficiency, mandible hypoplasia, occlusal plane) remain stable, improve, or worsen following surgical and orthodontic treatment?

Final outcomes were evaluated for four subjects with Kaban IIb CFM who completed both orthodontic and surgical treatment, including Le Fort I, bilateral sagittal split osteotomy (BSSO), and genioplasty. When orthodontic treatment was combined with bimaxillary surgery (Le Fort I, BSSO, and genioplasty), chin position improved in three subjects (75%) and worsened for one subject. Three subjects experienced improvement in mandibular hypoplasia (75%) while one subject (25%) showed no significant change. Soft tissues were improved in three subjects (75%), and one subject (25%) showed no change. Occlusal plane improved in three subjects (75%) and worsened for one subject (25%) (Table 12).

Table 12. Kaban IIb final facial symmetry outcomes following surgical and orthodontic treatment

Classification	Study ID	Type of procedure	Chin point	Mandible hypoplasia	Soft tissue	Occlusal plane
Kaban IIb						
Comprehensive or combination Phase 1 + Phase 2 orthodontic treatment in combination with Lefort 1 + BSSO +/- Genioplasty	2	Growth monitoring, Comprehensive Orthodontic Treatment, Lefort 1 + BBSO + Genioplasty	Improved (mild to symmetric)	No change (mild)	No change (minimal)	Improved (moderate to no cant)
	6	Growth Monitoring, Combination of phase 1 and phase 2 orthodontic treatment, Lefort 1 + BSSO + Genioplasty	Worse (mild to moderate)	Improved (moderate to mild)	Improved (severe to minimal)	Worse (mild to moderate)
	79	Growth Monitoring, Combination of phase 1 and phase 2 orthodontic treatment, Lefort 1 + BSSO + Genioplasty	Improved (m to symmetric	Improved (mild to normal)	Improved (severe to moderate)	Improved (moderate to none)
	12	Growth Monitoring, Costochondral graft, Comprehensive Orthodontic Treatment, Lefort 1 + BSSO, Ear Reconstruction, Fat Grafting	Improved (moderate to symmetric)	Improved (Moderate/severe To normal)	Improve (severe to moderate)	Improved (moderate to mild)

Final outcomes were evaluated for five subjects with Kaban III CFM who underwent orthodontic and surgical treatments, including CCG with or without MDO, and Lefort I and BSSO with or without genioplasty. Chin point improved in three subjects, remained unchanged in one,

and worsened in one. Four subjects showed improvement in mandibular hypoplasia following CCG with or without MDO, orthodontic treatment, and orthognathic surgery, while one subject experienced worsening. Three subjects showed no soft tissue change, while two exhibited improvements in soft tissue after orthodontic and surgical interventions. Occlusal plane improved in four subjects, with no change observed in one. (Table 13)

Table 13. Kaban III final facial symmetry outcomes following surgical and orthodontic treatment

Classification	Study ID	Type of procedure	Chin point	Mandible Hypoplasia	Soft tissue	Occlusal plane
Kaban III						
Orthodontic treatment and/or costochondral graft, mandibular distraction, and fat grafting **WITH** Lefort 1 + BSSO +/- Genioplasty	27	Growth Monitoring, Costochondral graft, fat grafting, Comprehensive Orthodontic Treatment, Lefort 1 + BSS0	Improved (mild to normal)	Improved (mild to normal)	No change (severe)	Improved (moderate to mild)
	21	Growth monitoring, Costochondral Graft, Mandibular Distraction, Comprehensive Orthodontic Treatment, Lefort 1 + BSSO	No change (moderate)	Improved (moderate to mild)	No change (minimal)	Improved (severe to mild)
	16	Growth Monitoring, Combination of phase 1 and phase 2 orthodontic treatment, Costochondral Graft, Lefort 1 + BSSO + Genioplasty	Improved (severe to symmetric)	Improved (moderate/severe to normal)	Improved (moderate to minimal)	Improved (mild to no cant)
	87	Growth Monitoring, Combination of phase 1 and phase 2 orthodontic treatment, Costochondral Graft, Fat Grafting, Lefort 1 + BSSO + Genioplasty	Improved (Severe to mild)	Improved (Severe to mild)	Improved (Severe to minimal)	Improved (Severe to mild)
	124	Growth monitoring, combination phase 1 and phase 2 orthodontic treatment, Costochondral graft, Mandibular Distraction, Lefort 1 + BSSO + Genioplasty, Ear Reconstruction	Worse (Symmetric to moderate)	Worse (Normal to mild)	No change (severe)	No change (Mild)

Question #4: Which orthodontic treatment(s) +/- in combination with orthognathic surgery result in the best occlusal outcomes (posterior occlusal relationships, ideal overbite, ideal overjet, coincident midlines) for subjects with mild CFM (Kaban I and IIa)?

Final occlusal outcomes were evaluated for 12 subjects with Kaban 1 CFM: seven who underwent orthodontic treatment without orthognathic surgery and five who completed ortho-

dontic treatment and orthognathic surgery, including LeFort I and BSSO, with or without genioplasty. Sagittal measures of occlusion on the affected side either improved or remained the same in all patients. Occlusion on the non-affected side improved or remained the same in all patients, except for one patient who underwent comprehensive orthodontic treatment but did not have orthognathic surgery, where the occlusion worsened. Overjet improved for all patients who underwent both orthodontic treatment and orthognathic surgery. Overjet worsened in just one patient who had orthodontic treatment without orthognathic surgery.

Most patients started and ended treatment without a posterior crossbite. Two of the 12 patients initially had a posterior crossbite which was corrected with orthodontic treatment/orthognathic surgery. One patient developed a posterior crossbite following orthodontic treatment/no surgery. Dental midlines improved for all patients who had both orthodontic treatment and orthognathic surgery. One patient treated with orthodontics/no surgery had worsened midline position.

One patient initially had a posterior open bite and this improved with orthodontic treatment/orthognathic surgery. Overbite either improved or remained the same for all patients. (Table 14).

Table 14: Kaban I final occlusal outcomes with orthodontic treatment +/- orthognathic surgery

			Sagittal Measures			Transverse		Vertical	
Classification	Study ID	Type of procedure	Occlusion affected Side	Occlusion non affected Side	Overjet	Dental Midline	Posterior crossbite	Posterior open bite	Overbite
Kaban I									=
Phase 1 + Phase 2 or Comprehensive Orthodontic Treatment	47	Growth monitoring, Ear Reconstruction, Comprehensive Orthodontic Treatment	Class I No change	Class I No change	Normal (2-3mm) No change	Coincident	None	None	Normal (10-50%) No change
	54	Growth monitoring, Comprehensive Orthodontic Treatment,	Class II to class I Improved	Class I No change	Minimal (less than 2mm) No change	Coincident	None	None	Open-bite to edge to edge **Improved**

	59	Growth monitoring, Ear Reconstruction, Comprehensive Orthodontic Treatment	Class I No change	Class I to class III Worsened	Normal (2-3mm) to minimal (less than 2mm) Worsened	Dev non-affected side oderate (2-4 mm)	None	None	Normal (10-50%) No change
	104	Growth monitoring, Comprehensive Orthodontic Treatment	Class II to Class I **Improved**	Class II-Class I **Improved**	Excessive (Greater than 3mm) to (2-3mm) **Improved**	Dev affected side mild (1-2mm) No change	None	None	Normal (10-50%) No change
	106	Growth monitoring, Comprehensive Orthodontic Treatment	Class II No change	Class II to Class I **Improved**	Excessive (Greater than 3mm) to Normal (2-3mm) **Improved**	Coincident No change	None	None	Deep (Greater than 50%)-Normal (10-50%) **Improved**
	109	Growth monitoring, Ear Reconstruction, Comprehensive Orthodontic Treatment	Class II to Class III	Class II to Class I **Improved**	Excessive (Greater than 3mm) to normal (2-3mm) **Improved**	Coincident to Dev affected side mild 1-2mm Worsened	None	None	Normal (10-50%) No change
	112	Growth monitoring, Comprehensive Orthodontic Treatment	Class II No change	Class II to Class I **Improved**	Excessive (greater than 3mm) No change	Dev Affected side moderate (2-4 mm) to Dev affected side mild (1-2mm) **Improved**	None to affected Side Worsened	None	Normal (10-50%) No change
Comprehensive Orthodontic Treatment + Lefort I + BSSO +/- Genioplasty	100	Growth monitoring, Comprehensive Orthodontic Treatment, Lefort 1 + BSSO	Class III to Class I **Improved**	Class III to Class I **Improved**	Reverse (negative) to normal ((2-3mm) **Improved**	Coincident No change	Posterior XB Non affected side – None **Improved**	Affected Side to None **Improved**	Edge-to-edge to normal (10-50%) **Improved**
	102	Growth monitoring, Ear Reconstruction, Comprehensive Orthodontic Treatment, Lefort 1 + BSSO	Class II to Class I **Improved**	Class II to Class I **Improved**	Normal (2-3mm) No change	Dev affected side mild (1-2mm) to Coincident **Improved**	None	None	Normal (10-50%) No change
	86	Growth monitoring, Ear Reconstruction, Phase 1 + Phase 2 orthodontic treatment, Lefort 1 + BSSO	Class I No change	Class III to Class I **Improved**	Minimal (less than 2mm) to Normal ((2-3mm) **Improved**	Coincident No change	None	None	Edge-to-edge to Normal (10-50%) **Improved**
	118	Growth monitoring, Comprehensive Orthodontic Treatment, Lefort 1 + BSSO	Class III to Class I **Improved**	Class I No change	Reverse (Negative) to (2-3mm) **Improved**	Dev affected side moderate (2-4 mm) – Coincident **Improved**	Bilateral to None **Improved**	None	Open-bite to Normal (10-50%) **Improved**

	123	Growth monitoring, Comprehensive Orthodontic Treatment, Lefort 1 + BSSO + Genioplasty	Class II to Class I **Improved**	Class III to Class I **Improved**	Minimal (less than 2mm) to Normal (2-3mm) **Improved**	Dev affected side moderate (2-4 mm) -Coincident **Improved**	None	None	Edge-to-edge to Normal (10-50%) **Improved**

For Kaban IIa CFM, two patients did not achieve class I occlusion on the affected side with the remaining having Class I occlusion following comprehensive orthodontic treatment with or without orthognathic surgery. Occlusion on the non-affected side either improved, worsened, or remained unchanged for the three patients who had orthodontic treatment/no orthognathic surgery. For patients all who underwent both orthodontic treatment/orthognathic surgery, sagittal occlusion on the non-affected side did not worsen, with two patients showing no change. Overjet improved for two patients who had orthodontic treatment/orthognathic surgery, had normal overjet at initial and final timepoints.

All three patients who received orthodontic treatment without orthognathic surgery began and ended treatment with no posterior crossbite or open bite. Of the three patients who received both orthodontic treatment and orthognathic surgery, all started with posterior crossbites, which improved to normal occlusion. However, one patient developed a posterior crossbite on the non-affected side. Dental midlines either improved or remained coincident with the facial midline for the majority of patients who underwent orthodontic treatment, with or without orthognathic surgery. One patient's midline worsened during treatment, while two patients' midlines remained unchanged from the initial position.

Of the three patients who received both orthodontic treatment and orthognathic surgery, two patients developed posterior open bites on the non-affected side. Overbite either improved or

remained unchanged from the ideal for all patients, except for one, where the open bite persisted after treatment.

Table 15: Kaban IIa final occlusal outcomes with orthodontic treatment +/- orthognathic surgery

			Sagittal Measures			Transverse Measures		Vertical Measures	
Classification	Study ID	Type of procedure	Occlusion affected Side	Occlusion non affected Side	Overjet	Posterior crossbite	Dental Midline	Posterior open bite	Overbite
Kaban IIa									=
Phase 1 + Phase 2 or Comprehensive Orthodontic Treatment	3	Growth Monitoring, fat grafting, functional appliance therapy, combination Phase 1 and Phase 2 Orthodontic Treatment	Class II to Class I **Improved**	Class I to Class III Worsened	Normal 2-3mm No change	None	Dev affected side severe to coincident **Improved**	None	Normal (10-50%) No change
	14	Growth monitoring, ear reconstruction, comprehensive orthodontic treatment	Class II to Class I **Improved**	Class I	Normal 2-3mm No change	None	Dev affected side mild (1-2mm) to coincident (**improved**)	None	Deep (greater than 50%) No change
	42	Growth monitoring, comprehensive orthodontic treatment	class II to Class III	Class II to Class III	Normal 2-3mm No change	None	Dev affected side mild (1-2mm)	None	Normal (10-50%) No change
Orthodontic Treatment + Lefort I + BSSO +/- Genioplasty	9	Growth monitoring, comprehensive w/ Lefort 1+BSSO+Genioplasty	Class II no change	class I no change	Normal 2-3mm No change	Bilateral to none **Improved**	Coincident No change	Non-affected side to none **Improved**	Open bite to Normal (10-50%) **Improved**
	93	Comprehensive Orthodontic Treatment, Lefort 1 + BSSO + Genioplasty	Class II to class I **Improved**	Class II to class I **Improved**	Excessive (Greater than 3mm) to normal **improved**	None	Coincident with facial ML to Dev non-Affected Side Moderate (2-4 mm) Worsened	None	Open-bite-normal (10-50%) **Improved**
	103	Phase 1 + Phase 2 orthodontic treatment , Lefort 1 + BSSO + Genioplasty	Class I No change	Class I No change	Normal (2-3mm) No change	Posterior XB Non affected side to none **Improved**	Dev non-affected Side mild (1-2mm) to coincident **Improved**	None to non-affected side Worsened	Normal (10-50%) No change
	1	Growth Monitoring, Combination Phase I and Phase II Orthodontic Treatment, Lefort 1 + BSSO + Genioplasty	Class I No change	Class III to Class I **Improved**	Normal (2-3mm) No change	None No change	Coincident No Change	None No Change	Normal (10-50%) No change

	29	Comprehensive Orthodontic Treatment, Lefort 1 + BSSO + Genioplasty	Class I No change	Class II No change	Normal (2-3mm) No change	None to non-affected side XB- Worsened	Dev non affected side mild to Coincident **Improved**	None to non-affected side Worsened	Open bite No change
	53	Growth Monitoring, Comprehensive Orthodontic Treatment, Lefort 1 + BSSO	Class I	Class II No change	Normal 2-3mm No change	None	Dev non-Affected Side Mild (1-2mm) No change	None	Normal (10-50%)
	65	Growth Monitoring, Comprehensive Orthodontic Treatment, Lefort 1 + BSSO	Class I No change	Class II to Class I **Improved**	Reverse (negative) to Normal (2-3mm) **Improved**	Bilateral to None **Improved**		None	Normal (10-50%) No change

DISCUSSION

Facial appearance and the impact of facial asymmetry are significant concerns for patients with Craniofacial Microsomia (CFM), influencing both their self-esteem and social interactions. Studies have highlighted the importance of achieving facial symmetry to improve both functional and psychological outcomes. The present study utilized the Phenotypic Assessment Tool for Craniofacial Microsomia (PAT-CFM) to assess facial symmetry outcomes in individuals with CFM following growth monitoring, corrective surgery, and orthodontic treatment.

Our findings suggest that in mild cases, natural growth does not significantly exacerbate facial asymmetry. In subjects with mild CFM (Kaban I and IIa), facial asymmetry remained largely stable during growth, with some improvements observed in chin point deviation, mandibular hypoplasia, and occlusal plane cant. This supports the philosophy that early surgical intervention may not be necessary unless functional concerns arise. This differs from the study of six patients over a period of one to four years by Shibazaki-Yorozuya et al., who found that growth in the affected cranial base, maxilla, and mandible differed from the unaffected side, contributing to persistent asymmetry.[12]

Some have questioned the effectiveness of CCG as a long-term procedure. Padwa et al., in a study of 33 children who underwent CCG for Type IIb and III CFM, found that vertical mid-facial growth following CCG was primarily driven by alveolar growth rather than true skeletal advancement. This finding supports the need for additional interventions, such as mandibular distraction, or orthognathic surgery, to achieve optimal facial symmetry. Our results align with this study, indicating that subjects with moderate to severe CFM (Kaban IIb and III) who underwent CCG experienced mixed outcomes. While some showed improvements in occlusal plane alignment and mandibular hypoplasia, soft tissue deficiencies persisted, and overall facial symmetry remained inconsistent.

Final outcomes for subjects with moderate to severe CFM who underwent both orthodontic treatment and surgical interventions, including Le Fort I osteotomy, BSSO, and genioplasty, revealed significant improvements in mandibular hypoplasia, chin position, and occlusal plane cant. Orthodontic treatment, with or without orthognathic surgery, resulted in stable or improved occlusal relationships for most subjects, particularly those with mild to moderate CFM. This aligns with the findings of a study on surgical correction in 565 CFM patients, which reported that orthodontic treatment is crucial for maintaining occlusal stability and optimizing functional outcomes post-surgery.[10] Some subjects developed posterior crossbites or open bites post-treatment, underscoring the need for long-term orthodontic follow-up. The patients who underwent both orthodontic treatment and orthognathic surgery demonstrated more favorable occlusal outcomes, reinforcing the notion that a combined treatment approach is often necessary to achieve functional and esthetic outcomes in patients with CFM.

In addition to physical appearance, the psychosocial impact of CFM is significant. A 2016-2017 online survey of 42 caregivers and 9 adults with CFM found that self-awareness of

facial differences began as early as three years of age, with teasing starting at a mean age of six. Teasing, including name-calling, peaked in elementary school around the age of nine, affecting 43% of individuals aged four years or older.[15] These social experiences highlight the psychosocial challenges faced by individuals with CFM and highlight the importance of early intervention, counseling, and patient education.

The timing of treatment is critical when balancing optimal facial symmetry outcomes with psychosocial considerations. Our findings suggest that for mild CFM cases, growth monitoring during early childhood may be sufficient, with surgery deferred unless functional concerns arise. In contrast, for more severe cases, a combined orthodontic and orthognathic surgical approach yields the best facial symmetry results, although this typically occurs later in adolescence or adulthood. This delay in treatment may prolong psychosocial challenges, such as teasing, and can be emotionally difficult for patients. Survey participants ranked "understanding diagnosis and treatment" as a top research priority, emphasizing the need for transparency and clear guidance on the timing of interventions.[15] This tension between achieving the best functional and esthetic outcomes while addressing the psychosocial impact of facial differences calls for a careful, individualized treatment plan that accounts for both the clinical and emotional needs of CFM patients.

This study has limitations. As a retrospective cohort study, it is subject to inherent biases and variability in data collection. The heterogeneity in patient phenotypes and the variety of treatments received make direct comparisons challenging. While the PAT-CFM scoring system was utilized, the orbital, ear, nerve, and lateral cleft components were not analyzed, potentially omitting relevant craniofacial asymmetry details. However, this study did incorporate occlusal

analysis to assess functional outcomes. These limitations highlight the need for larger, prospective studies with standardized assessment methods to further validate these findings.

CONCLUSION

This study highlights the complexity of treating CFM and the need for a multidisciplinary, individualized approach. In mild subjects (Kaban I and IIa), facial asymmetry remains stable, supporting a conservative approach unless functional concerns arise. In moderate to severe subjects (Kaban IIb and III), CCG alone yields mixed results, often requiring additional interventions for optimal symmetry. Orthodontic treatment, with or without orthognathic surgery, plays a key role in improving occlusal stability and facial esthetics.

Long-term follow-up and individualized treatment planning is necessary for these patients. Additionally, the significant psychosocial impact of CFM underscores the importance of early counseling and patient education. While advancements in surgical and orthodontic interventions continue to improve facial symmetry and function, further prospective studies with standardized assessments are needed to evaluate outcomes, refine treatment protocols, and enhance patient care.

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APPENDIX

Table 1. Data Collected from Medical Records

Patient Information	
Gender	Male vs. Female
Date of Birth	*Used to calculate Age*
Race	
Ethnicity	
Date First Seen at Craniofacial Center	*Used to calculate age*
Information related to the Microtia	
Side of Microsomia	Unilateral Left Unilateral Right Bilateral
Kaban Classification	I - Small Mandible IIA- Short mandibular ramus of abnormal shape; glenoid fossa in satisfactory position IIB - TMJ abnormally placed inferiorly, medially, and anteriorly III- Absent TMJ
Initial Treatment Recommended	Growth Monitoring Costochondral Graft Fat Grafting 2 jaw surgery Fixed orthodontics functional appliance therapy MDO Ear reconstruction Fixed Orthodontics
Surgical Factors	
Was surgery completed prior to initial Seattle Children's visit	Yes/No
Date of Surgery	
Surgery Complications	No-complications Over-growth Paresthesia hardware failure Infection other

Table 2: Photographic and Scan Data

PAT-CFM	
Date of Image	*Used to calculate age*
Type of Procedure Prior to Image	Growth Monitoring Costochondral Graft fat grafting 2 jaw surgery Fixed orthodontics functional appliance therapy MDO ear reconstruction 3rd molar extractions Premolar Extractions Maxillary Expansion
Occlusal Plane	No cant 1-5 degrees right 6-15 degrees right >15 degrees right 1-5 degrees left 6-15 degrees left > 15 degrees left unable to assess
Chin Point Deviation	Towards affected side Towards non-affected side Symmetrical (non)
Degree of Chin Point Deviation	1-3 mm 3-6 mm > 6 mm
Mandible Hypoplasia	Normal Mild hypoplasia right moderate hypoplasia right moderate/severe hypoplasia right severe hypoplasia right Mild hypoplasia left moderate hypoplasia left moderate/severe hypoplasia left severe hypoplasia left
Soft Tissue Deficiency	Normal Minimal Soft Tissue Deficiency Right Moderate Soft Tissue Deficiency Right Severe Soft Tissue Deficiency Right Minimal Soft Tissue Deficiency Left Moderate Soft Tissue Deficiency Left

	Severe Soft Tissue Deficiency Left
Occlusion	
Date of image	*Used to calculate age*
Type of Orthodontic Treatment Recommended after Assessment	Growth Monitoring Phase 1 Orthodontics Comprehensive Orthodontic Treatment (phase 2) Combination Phase 1 and Phase 2 Orthodontic Treatment Surgery (MDO/ Costochondral Graft) First Distraction
Phase of Dentition	Primary Mixed Dentition Permanent Dentition
Angles Classification Affected Side	Class I Class II Class III
Angles Classification Non-Affected Side	Class I Class II Class III
Overjet	Normal (2-3mm) Minimal (less than 2mm) Excessive (Greater than 3mm) Reverse (Negative) UTO (missing incisors)
Overbite	Normal (10-50%) Deep (Greater than 50%) Edge-To-Edge Open-bite UTO (missing incisors)
Posterior Openbite	None Affected Side Non-affected side Both sides
Dental Midline	N/a Coincident with Facial ML Dev Affected Side Mild (1-2mm) Dev Affected Side Moderate (2-4 mm) Dev Affected Side Severe (>4mm) Dev non-Affected Side Mild (1-2mm) Dev non-Affected Side Moderate (2-4 mm)

	Dev non-Affected Side Severe (>4mm)
Dental Anomalies	None Agenesis Premolars Agenesis Max Laterals Ectopic Eruption Max 1st molars Abnormality of Mand Molars Affected side Impacted Mesiodens impacted maxillary canines impacted mandibular canines ectopic premolar(s) ectopic maxillary lateral(s) agenesis lower incisor

Table 3: Kaban I Chin Point Deviation Initial vs. Final During Growth Monitoring Period

	Final Chin Point Deviation						
Initial Chin Point Deviation	>6 mm unaffected side	3-6 mm unaffected side	1-3 mm unaffected side	Symmetrical	1-3 mm affected side	3-6 mm affected side	>6 mm affected side
>6 mm unaffected side							
3-6 mm unaffected side							
1-3 mm unaffected side			1	5	1		
Symmetrical				4			
1-3 mm affected side				3	13		
3-6 mm affected side						3	
>6 mm affected side						1	

Table 4: Kaban I Mandible Hypoplasia Initial vs. Final During Growth Monitoring Period

	Final Mandible Hypoplasia								
Initial Mandible Hypoplasia	Severe unaffected side	Moderate/severe unaffected side	Moderate unaffected side	Mild unaffected side	Normal	Mild affected side	Moderate affected side	Moderate/severe affected side	Severe affected side
Severe unaffected side									
Moderate/severe unaffected side									
Moderate unaffected side									
Mild unaffected side				2	2				
Normal					8	1			
Mild affected side					3	13	1		
Moderate affected side						1	1		
Moderate/severe affected side									
Severe affected side									

Table 5. Kaban I Soft Tissue Change Initial vs. Final During Growth Monitoring Period

	Final Soft Tissue						
Initial Soft Tissue	Severe unaffected side	Moderate unaffected side	Mild unaffected side	Normal	Mild affected side	Moderate affected side	Severe affected side
Severe unaffected side							
Moderate unaffected side							
Minimal unaffected side							
Normal				14			
Mild affected side				5	11		
Moderate affected side				1		1	
Severe affected side							

Table 6. Kaban I Occlusal Plane Cant Initial vs. Final During Growth Monitoring Period

	Final Occlusal Plane						
Initial Occlusal Plane	>15º unaffected side	6-15º unaffected side	1-5º unaffected side	No cant	1-5º affected side	6-15º affected side	>15º affected side
>15º unaffected side							
6-15º unaffected side							
1-5º unaffected side			3				
No cant			1	7	1		
1-5º affected side				3	11	2	
6-15º affected side							
>15º affected side						1	

Table 7. Kaban IIa Chin Point Deviation Initial vs. Final During Growth Monitoring Period

	Final Chin Point Deviation						
Initial Chin Point Deviation	>6 mm unaffected side	3-6 mm unaffected side	1-3 mm unaffected side	Symmetrical	1-3 mm affected side	3-6 mm affected side	>6 mm affected side
>6 mm unaffected side							
3-6 mm unaffected side							
1-3 mm unaffected side							
Symmetrical							
1-3 mm affected side					9		
3-6 mm affected side					3	1	
>6 mm affected side							

Table 8. Kaban IIa Mandible Hypoplasia Initial vs. Final During Growth Monitoring Period

	Final Mandible Hypoplasia								
Initial Mandible	Severe unaffected side	Moderate/ severe unaffected side	Moderate unaffected side	Mild unaffected side	Normal	Mild affected side	Moderate affected side	Moderate/ severe affected side	Severe affected side
Severe unaffected side									

Moderate/severe unaffected side									
Moderate unaffected side									
Mild unaffected side				1					
Normal						1			
Mild affected side						6	2		
Moderate affected side						2			
Moderate/severe affected side								1	
Severe affected side									

Table 9. Kaban IIa Soft Tissue Change Initial vs. Final During Growth Monitoring Period

	Final Soft Tissue						
Initial Soft Tissue	Severe unaffected side	Moderate unaffected side	Mild unaffected side	Normal	Mild affected side	Moderate affected side	Severe affected side
Severe unaffected side							
Moderate unaffected side							
Minimal unaffected side				1			
Normal				2			
Mild affected side				1	3		
Moderate affected side						4	
Severe affected side						1	1

Table 10. Kaban IIa Occlusal Plane Cant Initial vs. Final During Growth Monitoring Period

	Final Occlusal Plane						
Initial Occlusal Plane	>15º unaffected side	6-15º unaffected side	1-5º unaffected side	No cant	1-5º affected side	6-15º affected side	>15º affected side
>15º unaffected side	1						
6-15º unaffected side							
1-5º unaffected side				1			
No cant					1		
1-5º affected side					3		
6-15º affected side						3	
>15º affected side						1	1