UNIVERSITE DE NANTES

FACULTE DE MEDECINE

Année 2016 N° 198

THESE

pour le

DIPLOME D'ETAT DE DOCTEUR EN MEDECINE

DES de Chirurgie Générale

Par

Carine KOUDOUGOU
Née le 25 novembre 1985 à La Roche-sur-Yon

Présentée et soutenue publiquement le vendredi 30 septembre 2016

REMODELAGE OSSEUX SAGITTAL ET VERTICAL APRES GENIOPLASTIE FONCTIONNELLE : ETUDE RETROSPECTIVE TRIDIMENSIONNELLE A PROPOS DE 36 CAS.

Président :
Monsieur le Professeur Pierre CORRE

Directeur de thèse :
Monsieur le Docteur Julien GUIOL

Membres du Jury :
Monsieur le Professeur Jacques-Marie MERCIER
Monsieur le Professeur Hervé BENATEAU
Monsieur le Professeur Pascal ROUSSEAU

REMERCIEMENTS

Monsieur le Professeur Pierre Corre,

C'est un honneur pour moi que tu présides ma thèse.
Tes qualités humaines et ton intelligence chirurgicale sont les garants de l'admiration que je te voue depuis mon arrivée dans le service. L'école Nantaise a encore de beaux jours devant elle. Je te souhaite une très belle et grande carrière.

Monsieur le Professeur Jacques-Marie Mercier,

Votre rigueur chirurgicale ainsi que la finesse de votre analyse clinique doivent rester un exemple pour les jeunes chirurgiens que nous sommes.
J'ai appris à vos côtés la chirurgie maxillo-faciale dans les règles de l'art et c'est une immense fierté pour moi d'avoir pu faire partie de votre équipe.
Veuillez trouver dans ce travail un témoignage de mon plus profond respect.

Monsieur le Professeur Hervé Bénateau,

Je vous remercie d'avoir accepté de faire partie de ce jury.
Je vous remercie de m'avoir chaleureusement accueilli en cette fraîche terre normande. Vous m'avez fait partager votre belle expérience, notamment en reconstruction maxillo-faciale. Votre grand investissement dans la cause humanitaire mérite toute notre estime.

Monsieur le Professeur Pascal Rousseau,

Un grand merci pour ta présence aujourd'hui.
Ce semestre angevin, dans ce service qui n'a de petit que sa taille, m'a enseigné bien plus que les principes fondamentaux de la chirurgie des parties molles. Sois assuré de toute ma considération envers cette belle spécialité qu'est la chirurgie plastique.

Monsieur le Docteur Julien Guiol,

Je te remercie tout d'abord d'avoir accepté d'encadrer ce travail avec beaucoup de disponibilité. Tes connaissances pointues en chirurgie préimplantaire, mais pas que, ainsi que ta détermination à mener ta carrière comme tu l'entends font plus d'un envieux. Je te souhaite plein de belles choses pour cette carrière hospitalière qui débute.

Au Docteur Benoit Piot. Je te remercie de m'avoir fait partager ta grande expérience en chirurgie carcinologique et en reconstruction faciale. Merci Patron, merci Patron, merci Patron !!

Au Docteur Jean-Philippe Perrin, avec qui je n'ai malheureusement pas eu la chance de passer un semestre.

Au Docteur Julie Longis. J'ai beaucoup appris, chirurgicalement (discises, discises !!) et cliniquement lors de ce semestre à tes côtés et je t'en remercie. Tu as une belle carrière hospitalière devant toi.

Au Dr Denis Jacquemaire, pour m'avoir appris l'art de la germectomie.

Au Dr Anne Chatellier, pour la qualité de son enseignement et sa rigueur professionnelle et chirurgicale.

Au Dr Michel Girard. Pour son aptitude à tout tenter et le réussir avec modestie et la qualité de son enseignement.

A tous les chefs actuels ou anciens du service (dont d'anciens co-internes) : Francis, Fab, Fanny, Guillaume, Matthieu, Antoine, Raph. A mes chefs caennais Alexis et Aude. Aux chefs angevins Thibault et Fares.

A mes anciens co-internes, pour leur bonne humeur au quotidien et ces semestres « bisounours » : Hélios, Gitan, Fanny-Laure, Anaëlle, Garance, Maria, Mathilde, Pierre-Antoine, Anthony, Anne, Hugo, Adrien, Cheick, Aymeric.

A tout le personnel du service de chirurgie maxillo-faciale de Nantes, pour leur travail quotidien auprès des patients, au moins aussi important que le nôtre. Mention spéciale pour Morgan, Christine P, Christine D, Beatrice, Pierrette, Florence, Valérie, Aurélie, Amandine, Geneviève, Estelle, Isabelle, Lydie, et j'en oublie certainement…

A tous le personnel des services de chirurgie maxillo-faciale de Saint Nazaire (spécialement Maryse et Mireille), de chirurgie maxillo-faciale de Caen, de chirurgie plastique d'Angers, d'ORL de Saint-Nazaire et du Mans pour leur accueil chaleureux et leur professionnalisme.

Aux copains de lycée, et à tous les amis de Nantes et d'ailleurs : Chopi, Lolo B, Matthieu L, Anna, Sami, Anne-So, Emmanuelle, Mélanie, Alex et Greg (et cette fameuse salade de tomates…), Plou-plou, Chachou, Popo, Marie F, Clem ,Delphin, Julien et Charlotte, et j'en oublie, mais ils m'excuseront c'est sûr !

Pour Etienne qui tenait tant à être cité ! Paraît' il que rien n'aurait été possible sans mon très honorable beau bof (c'est pas moi qui l'ait dit… :-D :-D)

A Barbara, pour toutes ces folles années de coloc (mon canap s'en souvient…), mais surtout parce que tu restes à ce jour la meilleure imitatrice des Pussycat Dolls que le monde ait connu !

A Cam-Cam, pour son amitié indéfectible et précieuse.

A mon Di-mé. Pour tous ces moments depuis la fac à aujourd'hui. Yes, we can !

A Marie (Gui-gui !), Julia (shake, shake, shake la marga !) et Elo (chouuuch !). No vies évoluent mais votre amitié reste la plus importante pour moi.

A toute ma famille mais surtout Cathy. Mamie-Jo, j'espère retrouver un jour le gout de tes gaufres-cœur. A Papi, qui aurait été très fier de moi aujourd'hui.

A Matthieu, pour toutes les belles choses qu'il nous reste à vivre…

A Carelle, Princess of Koudougou's Kingdom ! Nous n'avons pas conquit l'Everest, ni le Far-West mais le tube digestif c'est déjà pas mal…

A Maman, pour tout.

TABLE DES MATIERES

LISTE DES ABREVIATIONS 5

INTRODUCTION 6

MATERIEL ET METHODES 8

RESULTATS 13

DISCUSSION 20

REFERENCES 25

LISTE DES ABREVIATIONS

3D	Three-dimensional
CBCT	Cone Beam Computed Tomography
SG	Sliding Genioplasty
JG	Jumping Genioplasty
BSSO	Bilateral sagittal split osteotomy
Pg point	Point pogonion
Me point	Point menton

SAGITTAL AND VERTICAL BONE REMODELING
AFTER FUNCTIONAL GENIOPLASTY :
TRIDIMENSIONNAL RETROSPECTIVE STUDY ABOUT 36 CASES

INTRODUCTION

Chin position in the facial balance is functionally, and morphogically decisive in orthognathic surgery. The height of the lower third of the face, the projection of soft tissues and the lip function is crucial for good results in chin osteotomies.

The bone chin transposition osteotomy, or functional genioplasty, is an usual technique in orthognathic surgery. It is combined or not with maxillomandibular osteotomy. It is usually performed to correct labiomental dysfunctions, especially in vertical or sagittal discrepancies (anterior vertical excess of mandibular symphysis, retrogenia, progenia)[1,2]. Since the first report of sliding genioplasty, published in 1957 by Trauner and Obwegeser [3], several surgical procedures have been described to improve bone stability and also aesthetic profile [4–8].

The post-operative clinical follow-up is usually completed by lateral cephalograms that allow to observe from the first months bone remodeling that can affect the quality of functional, and aesthetic results. Bone remodeling has already been studied [6][9–13], and frequently reported as bone resorption. Sagittally, it was described like a setback of osseous and cutaneous pogonion resulting in a deeper labiomental fold. Postoperative variations in vertical plane have rarely been reported. However a downward movement of osseous pogonion is generally observed, and can result in a recurrence of labial incompetence associated with continuous chin tension.

Frontal and lateral cephalograms as well as panoramic x-ray have long been an essential tool in the evaluation of genioplasty results. The evaluation of bone remodeling throught lateral cephalometry analysis contains many biases due to frequent fake-profiles, osseous superimpositions, dental prosthesis artifacts, manual measurement errors. Thus, these studies have significant margins of error that can interfere with data acquisition and results interpretation. Recent advances in radiology have led to the transition from two- to three-dimensional (3D) assessment using cone beam computed tomography (CBCT) images [14]. With a lower radiation doses delivery compared to conventional computed tomography scan [15,16], CBCT provides a very precise vision [17] of postoperative osseous changes, osteosynthesis quality, and, through soft tissues 3D rendering, an indirect view of the long term clinical results.

The objective of the present study was to accurately assess the short- and long-term bone remodeling after functional genioplasties throught CBCT analysis.

PATIENTS AND METHODS

This retrospective study included 36 patients who received a functional genioplasty, combined or not with a Le Fort 1 and/or mandibular sagittal split osteotomies. The study extended from June 2013 to December 2015 in the Oral and Maxillofacial Department of the Nantes University Hospital, France. For all patients, functional genioplasties consisted in a forward movement of chin, and for most of them, in a simultaneous vertical chin reduction. All procedures were performed by four trained surgeons using two different surgical procedures: "sliding genioplasty" (SL) or "jumping genioplasty" (JG) [18].

Inclusion criteria were:

- Preoperative CBCT (T0).
- Immediate postoperative CBCT or within 2 months after surgery.
- CBCT in "early" postoperative period, from month 5 to 9.
- And/or a CBCT in "late" postoperative period, from month 10 to 20 after surgery.

Exclusion criteria :

- CBCT that did not include the skull base.
- Short face patients who had undergone a vertical increase of the chin.
- Patients with significant facial asymetry, especially mandibular deviation with a dental shift superior to one mandibular incisor.

Patients were divided into three groups:

- Group A (early postoperative follow-up): CBCT performed at T0, T1 and T2
- Group B (late postoperative follow-up): CBCT performed at T0, T1 and T3
- Group C (complete postoperative follow-up): CBCT performed at T0, T1, T2 and T3. This group could therefore contain patients of group A and B.

Bone remodeling was study sagittaly, focusing on bone resorption, and vertically, as recurrence of anterior vertical excess.

This non-interventional study did not require the approval of an ethics committee, according to the Articles L. 1121-1 and R 1121-2, paragraph 1 of the French Public Health Code. Data were collected retrospectively based on CBCT exams performed initially for patients radiological follow-up.

Method of analysis

It was decided to study the sagittal and vertical changes of the two most frequently used points [19] for the analysis of the symphysis:

- Pogonion point (Pg point) : the most anterior point on the mandibular symphysis.
- Menton point (Me point) : the most inferior point on the mandibular symphysis.

Three-dimensional modeling of each CBCT was done througt SIMPLANT O&O® software system (DENTSPLY Implants, Rueil Malmaison, France).

These anatomical landmarks of the skull base were considered stable in time, as they are commonly used in current practice for lateral and frontal cephalometric analyzes [20]:

- RM Right Metanasion point
- LM Left Metanasion point
- MidM Midpoint of [RM-LM]
- MidpCl Midpoint of [RpCl - LpCl]
- RpCl Right Posterior Clinoid process
- LpCl Left Posterior Clinoid process
- CG Top of Crista Galli
- RMf Right Mandibular Foramen
- LMf Left Mandibular Foramen
- MidMF Midpoint of [RMf-LMf]

Due to those landmarks, three reference planes X, Y and Z were established as follow:

1. Z median plane through three points : MidM, MidpCl and CG.
2. X plane, as 3D reconstruction of C1 line of Delaire [20], perpendicular to Z and through MidM and MidpCl.
3. Y plane, as 3D reconstruction of C0 line described by Nimersken for Delaire cephalometric analysis [21], perpendicular to Z and X through MidClp.

In order to pass by the postoperative mandibular movement after BSSO, that could dramatically affect the chin position, X1 and Y1 planes were created, going through MidMf and respectively parallels to X and Y (figure 1).

For each case, all the points were placed manually, either on sagittal, coronal or axial CBCT multiplanar reconstruction (MPR), or directly on the three-dimensional reconstruction. Automated measurements of distances between Pg/Me points and X1/Y1 planes were then carried out for each CBCT (preoperative, immediate postoperative time, early and late postoperative times) by the SIMPLANT O&O® software, and their coordinates were collected in x-axis and y-axis, respectively on X1 and Y1 (figure 2).

Sagittal and vertical variations of Pg and Me points positions were calculated at T1, T2 and T3 after compiling data on a spreadsheet.

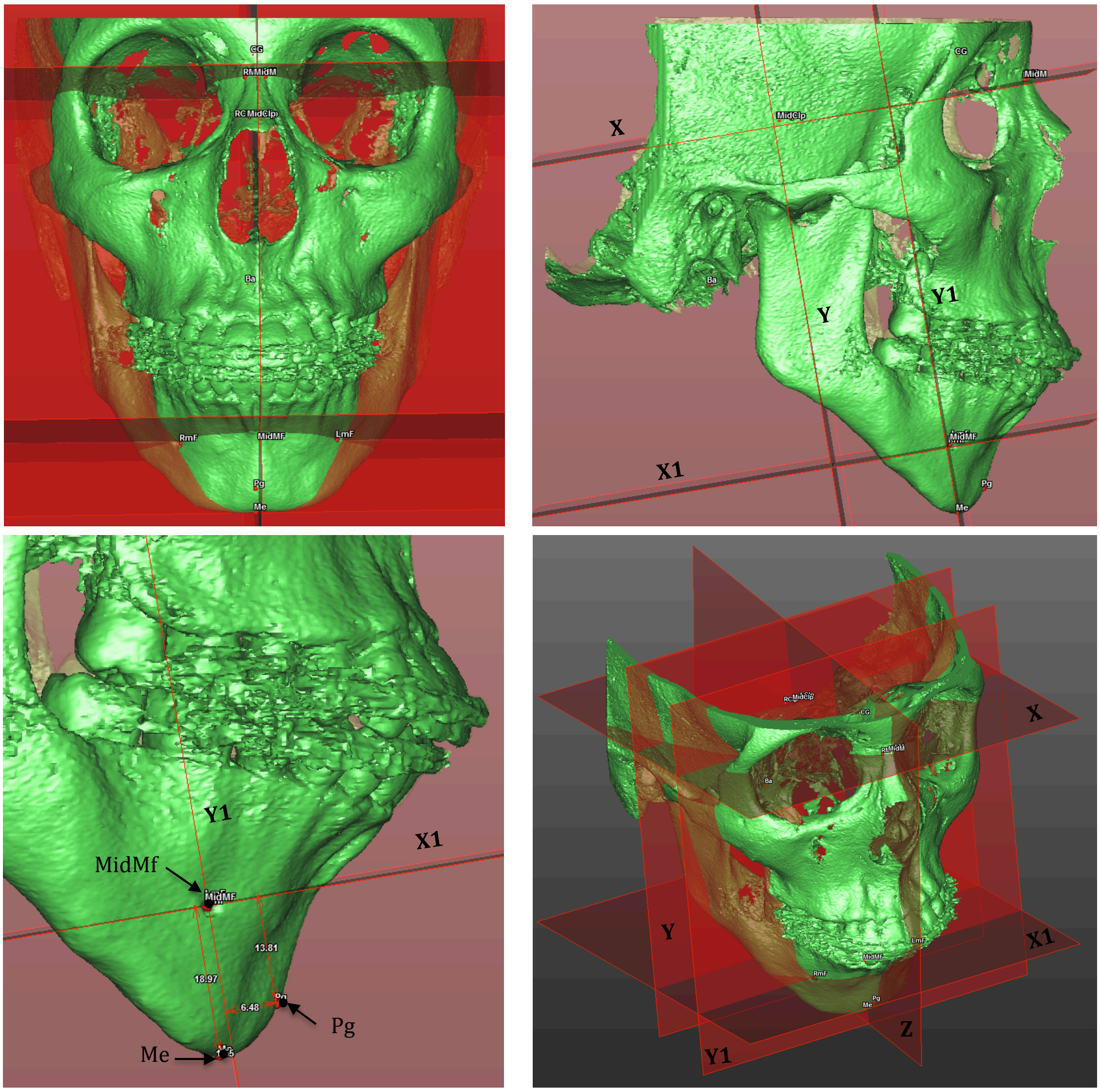


Fig. 1. *Three-dimensional representing of X, Y, Z, X1 and Y1 planes on SIMPLANT O&O® software. From left to right and top to bottom:*

- *Anterior view*
- *Right lateral view : planes X, Y, X1, and Y1.*
- *Zoom on mandibular symphysis: position of MidMf, Pg and Me point. Representing of X1 and Y1 planes. Automatic measurements of Pg and Me points are plotted on X1 and Y1 plans.*
- *Overview of the CBCT 3D modelling with X, Y, Z, X1, and Y1 planes.*

Pg= Pogonion; Me= Menton; MidMF= Midpoint of [RMf-LMf]; RMf= right mental foramen; LMf= left mental foramen; CBCT= cone beam computed tomography

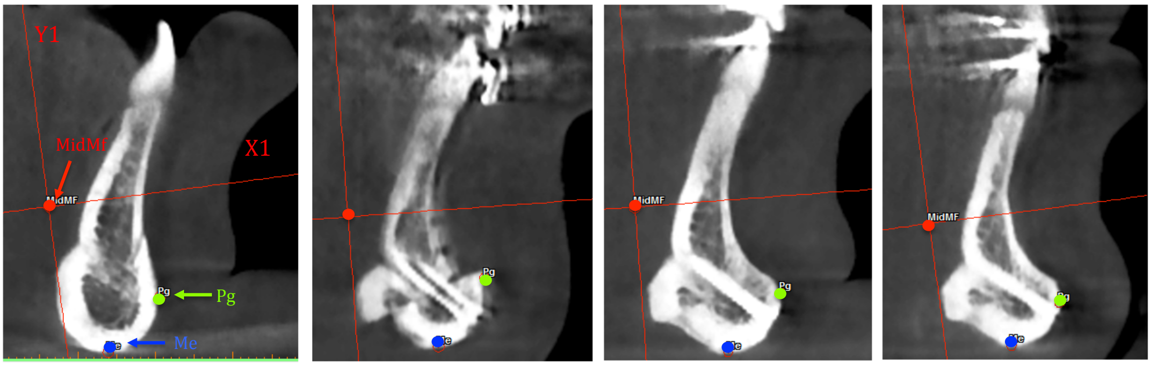


Fig. 2. *Sagittal section of mandibular symphysis at different follow-up times. Representing of X1 and Y1 planes; Positioning of Pg, Me, and MidMF points.*
From left to right :
TO= preoperative time,
T1= immediate postoperative time,
T2= early postoperative time, from month 5 to 9,
T3= late postoperative time, from month 10 to 20.
Pg= pogonion; Me= menton; MidMF= Midpoint of [RMf-LMf]; RMf= right mental foramen; LMf= left mental foramen;

Statistical analysis

To test the reproducibility of this measurement method, the average inter-observer error was determined with a new measurement performed by a different operator on 11 (30%) randomly selected patients.

Methodical error of cephalometric and facial measurements were assessed by 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* the number of double measurements).

Statistical analysis were performed using the GraphPad software Prism® 6.0 (GraphPad Software, la Jolla, CA, United-States). Comparative analysis was done using a Mann-Whitney test for non-paired data or a Wilcoxon test for paired data. When more than two groups were compared, a Kruskal-Wallis test was done. Qualitative data were compared using a Chi2 test. A linear regression model estimated correlations between associated variables. A statistically significant difference was determined when the p value was less than 0.05 ($p < 0.05$).

RESULTS

Epidemiologic data

Taking into account inclusion and exclusion criteria, 36 patients were included in this study: 17 men (47.2%) and 19 women (52.8%). The average age at time of surgery was 19.9 years (± 6.7). Preoperatively, 29 patients (80,6%) were in dental and skeletal class II, 5 patients (13,8%) in class III, and 2 patients (5,6%) in Class I. Twenty-nine patients received a SG and 7 patients a JG. Fifty percent of them received and additional maxillar or mandibular osteotomy (Le Fort 1 osteotomy for 11% and bilateral sagittal split osteotomy (BSSO) for 39%), 44% a bimaxillar surgery, and 6% a single genioplasty. Due to missing radiological data for some patients at T2 and T3, different groups A, B and C were created to carefully evaluate the chin remodeling along the follow-up. The average advancement on Pg at immediate postoperative time (T1) differed significantly between the three groups (table 1).

	Group A n = 23	**Group B** n = 19	**Group C** n = 6	
Sex: Females/males, n (%)	12 (52,2) / 11 (47,8)	8 (42,1) / 11 (57,9)	3 (50) / 3 (50)	p=0,8
Age of intervention (years), mean ± SD	20,2 ±7,4	20,3 ±5,9	22,2 (±6,3)	p=0,6
Additional osteotomies, n (%)				
Bimaxillar osteotomy	10 (43,5)	12 (63,1)	6 (100)	
BSSO	8 (34,8	6 (31,6)	0 (0)	p=0,15
Le Fort 1 osteotomy	4 (17,4)	0 (0)	0 (0)	
Single genioplasty, n (%)	1 (4,3)	1 (5,3)	0 (0)	
Genioplasty technique, n (%)				
Sliding	22 (95,6)	13 (68,4)	3 (50)	**p=0,01**
Jumping	1 (4,3)	6 (31,6)	3 (50)	
Postoperative sagittal advancement (T1), mean ±SD				
Pg point	6,6 ±3,9	8,8 ±3,6	9,5 ±4,8	**p=0,029**
Me point	7,2 ±3,6	9,7 ±3,6	10,5 ±4,1	**p=0,025**
Postoperative reduction in height (T1), mean ±SD				
Pg point	4,1 ±2,5	4,7 ±2,2	5,25 ±2,6	P=0,65
Me point	2,9 ±2,6	3,7 ±2,4	4,4 ±3,8	p=0,55

***Table 1**. General characteristics of groups A, B and C.*
n= number of patients; SD= standard deviation; BSSO: bilateral sagittal split osteotomy; Pg : pogonion; Me: menton; T1= immediate postoperative time; Significant if p<0,05.

Estimation of average inter-observers error

The results of Dahlberg formula application for Pg and Me points were summarized in table 2:

	Mean error (mm)	
	Vertical	Sagittal
Pg	2,3	0,61
Me	1,6	1,12

***Table 2.** Results of Dahlberg's formula on Pg and Me points. Pg= pogonion; Me= menton.*

Sagittal analysis

Average advancement measurements at Pg and Me point were compared at different postoperative times, with separate focus on groups A and B, and within each group, specific evaluation of SG and JG (table 3).

For patients who received a SG, a significant difference was demonstrated:

- In the group A: between the average advancement measured at T1, and the average advancement measured at T2, at Pg and Me point ($p<0,0001$).
- In the group B: between the average advancement measured at T1, and the average advancement measured at T3, at Pg ($p=0,0002$) and Me point ($p=0,0005$).

For patients who received a JG:

- In the group A: It was not found any significant difference between the average advancement measured at T1 and the average advancement measured at T2, at Pg and Me point ($p=0,12$).
- In the group B: a significant difference was demonstrated between the average advancement in Pg point measured at T1 and the average advancement at T3 ($p=0,031$). No significant difference was found at Me point ($p=0,062$).

			T1	T2	Resorption (%)	
Sliding	Group A	Advancement at Pg (mm), mean, ±SD	5,1 ±1,7	3,9 ±1,6	23,5	**p<0,0001**
		Advancement at Me (mm), mean, ±SD	5,8 ±1,8	4,6 ±1,8	20,7	**p<0,0001**
			T1	**T3**	Resorption (%)	
	Group B	Advancement at Pg (mm), mean, ±SD	7 ±2,1	5,5 ±2	21,4	**p=0,0002**
		Advancement at Me (mm), mean, ±SD	8,1 ±3	5,7 ±2,6	29,6	**p=0,0005**
			T1	**T2**	Resorption (%)	
Jumping	Group A	Advancement at Pg (mm), mean, ±SD	13,8 ±3,5	11,3 ±2,7	18,1	p=0,12
		Advancement at Me (mm), mean, ±SD	14 ±2	10,7 ±1,9	23,6	p=0,12
			T1	**T3**	Resorption (%)	
	Group B	Advancement at Pg (mm), mean, ±SD	12,7 ±2,8	9,6 ±2,6	24,4	**p=0,031**
		Advancement at Me (mm), mean, ±SD	13,6 ±2,2	10,7 ±1,3	21,3	p=0,062

Table 3*. Sliding and jumping genioplasties in groups A and B. Comparison of the amount of sagittal advancement at Pg and Me. Reporting of bone resorption percentage.*
SD: standard deviation. Pg= pogonion; Me= menton; T1= immediate postoperative time; T2= early postoperative time; T3= late postoperative time; Significant if p<0,05

A linear regression model was run to study the relationship between the horizontal advancement and horizontal relapse in early and late postoperative period. The correlation between the degree of horizontal advancement and bone resorption on Pg and Me point was statistically significant. This correlation was also significant within Group A and within Group B (figure 3).

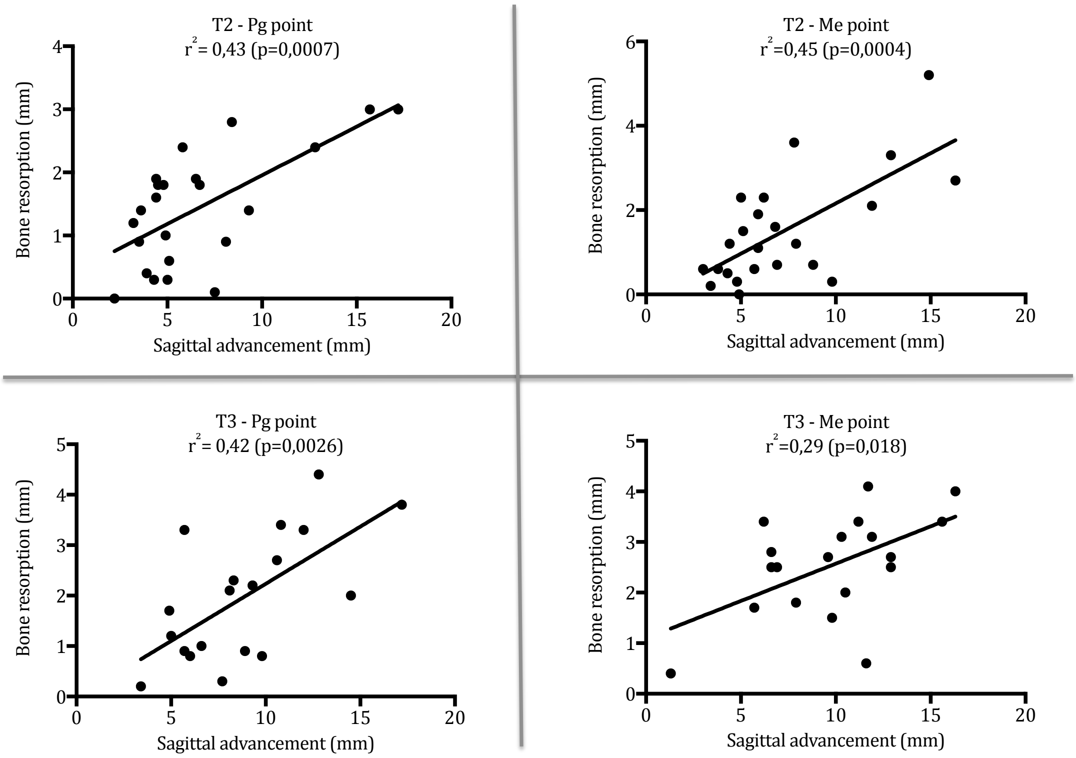


***Fig. 3**. Relation between sagittal advancement at Pg and Me points and bone resorption at T2 and T3.*
r^2= coefficient of determination; Pg=pogonion; Me= menton; T2= early postoperative time; T3= late postoperative time; significant if p<0,05.

Analysis of resorption process evolution between T2 and T3, using group C after matching data, showed a statistically significant difference both between the resorption percentages on Pg point (p=0,031), at T2 (14,9%) and T3 (27,3%), and both between the resorption percentages at Me point, at T2 (18,5%) and T3 (29,6%) (figure 4).

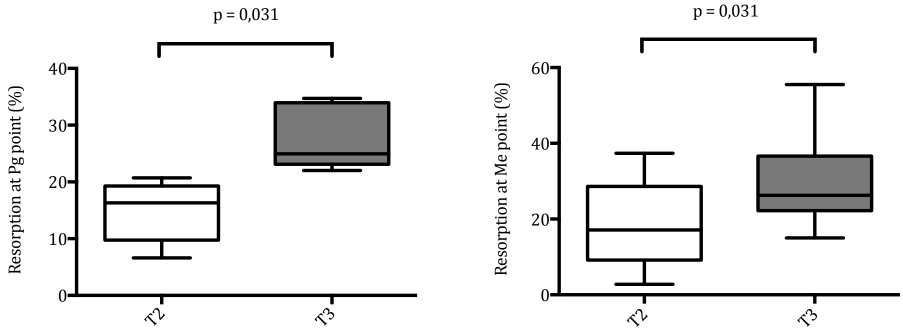


***Fig. 4**. Sagittal bone resorption between T2 and T3 (group C).*
Pg= pogonion; Me=menton; T2= early postoperative time; T3= late postoperative time; Significant if p<0,05.

The average advancement in immediate postoperative period (T1), and bone resorption in T2 and T3 pogonion were compared between the SG and the JG, respectively in groups A and B (figure 5). A significant difference between the degrees of initial advancement at pogonion was demonstrated for groups A (p=0.0002) and B (p=0.0005). However, no significant difference has been shown between their percentages of resorption at T2 and T3 (respectively p=0,46 and p=0,47).

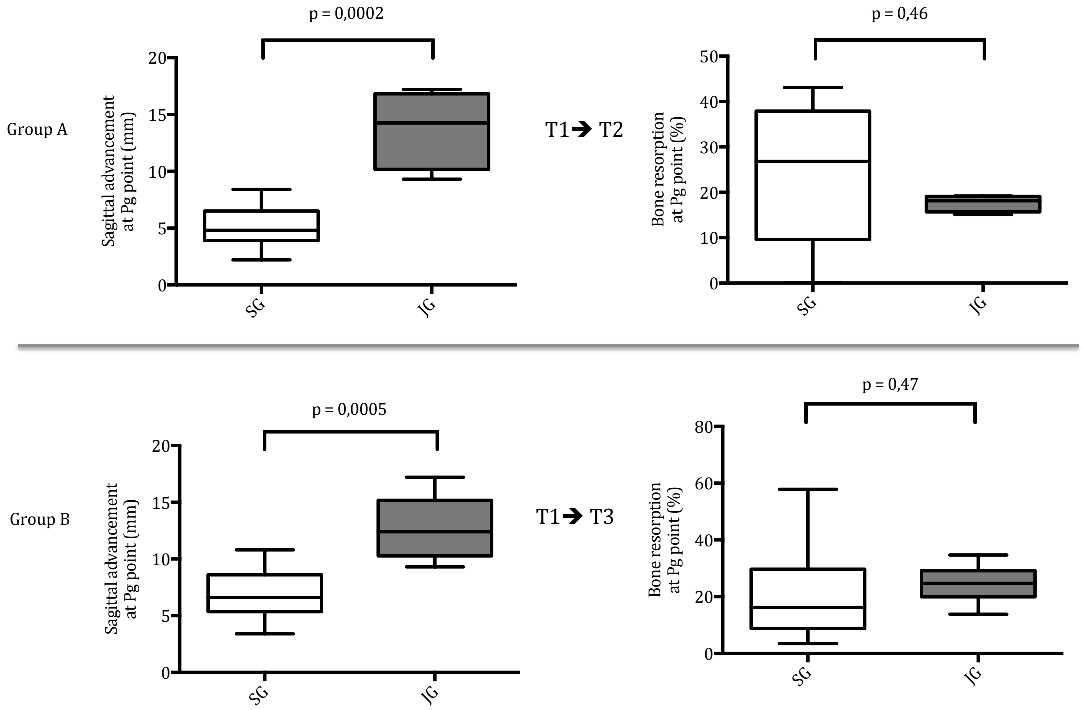


***Fig. 5.** From right to left : comparison of sagittal advancement on Pg point at T1 between SG and JG both in groups A and B. Comparison of sagittal bone resorption on Pg point at T2 and T3 between SG and JG respectively in groups A and B.*
Pg= pogonion; T1= immediate postoperative time; T2= early postoperative time; T3= late postoperative time; SG= sliding genioplasty; JG= jumping genioplasty; Significant if p<0,05.

Vertical analysis

The average height reductions measured between the different postoperative times were compared, with separate focus on groups A and B and, within each group, the SG and the JG (table 5).

For patients who received a SG, a significant statistical difference was shown between height reductions on Pg point in the groups A (p=0,0009) and B (p=0,002). On the other hand, no significant difference was detected at Me point in either group.

For patients who received a JG, a significant statistical difference was shown between height reductions on Pg point, but only in the group B (p=0,031). No significant difference was detected at Me point in either group.

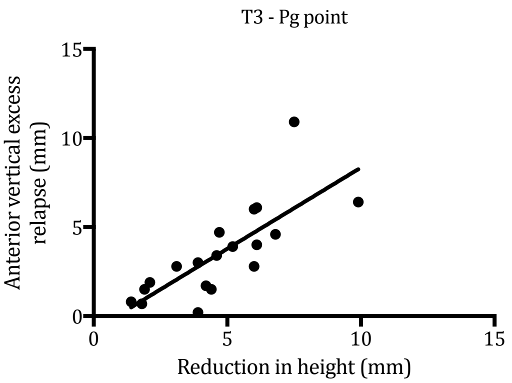
Sliding			**T1**	**T2**	Anterior vertical excess relapse (%)	
	Group A	Reduction in height at Pg, mean ±SD	3,6 ±2,2	2,5 ±2,1	30,5	**p=0,0009**
		Reduction in height at Me, mean ±SD	2,3 ±1,8	2 ±1,7	10	p=0,25
			T1	**T3**	Anterior vertical excess relapse (%)	
	Group B	Reduction in height at Pg, mean ±SD	4,5 ±1,9	3,6 ±2,8	24,3	**p=0,002**
		Reduction in height at Me, mean ±SD	3,2 ±2	3,4 ±1,9	8,1	p=0,13
Jumping			**T1**	**T2**	Anterior vertical excess relapse (%)	
	Group A	Reduction in height at Pg, mean ±SD	6,4 ±2,3	4,6 ±2,6	28,1	p=0,12
		Reduction in height at Me, mean ±SD	5,5 ±3,1	4,9 ±3,1	10,9	p=0,25
			T1	**T3**	Anterior vertical excess relapse (%)	
	Group B	Reduction in height at Pg, mean ±SD	5,1 ±2,8	2,7 ±2	47	**p=0,031**
		Reduction in height at Me, mean ±SD	3,9 ±3,3	3,4 ±2,8	12,8	p=0,06

Table 4. *Sliding and jumping genioplasties. Comparison of the amount of reduction in height at Pg and Me both for group A and B. Reporting of anterior vertical excess relapse percentage.*
SD: standard deviation. Pg= pogonion point; Me= Menton point; T1= immediate postoperative time; T2= early postoperative time; T3= late postoperative time; Significant if p<0,05

As no significant difference in the two groups have been found in the height variations at Me point, it was then decided to study statistical analysis on Pg point only.

A linear regression model was designed to study the relationship between the initial height reduction on Pg point, and the trend to recurrent anterior vertical excess, for both early (T2) and late (T3) postoperative period.

The correlation between the magnitude of the reduction in height, and the trend to relapse the anterior vertical excess was statistically significant, but only at late postoperative follow up period (Fig 6).



	Group A	Group B
Point	**T1/T2**	**T1/T3**
Pg	r^2 =0,17 p = 0,059	r^2 =0,59 p = 0,0001

Fig. 6. *Correlation between the amount of reduction in height and anterior vertical excess relapse.*
R2 = coefficient of determination; Pg point = pogonion point; T1= immediate posoperative time; T2= early postoperative time; T3= late postoperative time; significant if p<0,05.

Focusing on group B, the comparison of average height reductions at Pg point at T1, between patients who received a SL and patients who received a JG did not show any statistical difference (p=0,98). However, the JG had a statistically significant trend to relapse anterior vertical excess (p=0,02) (Fig. 7).

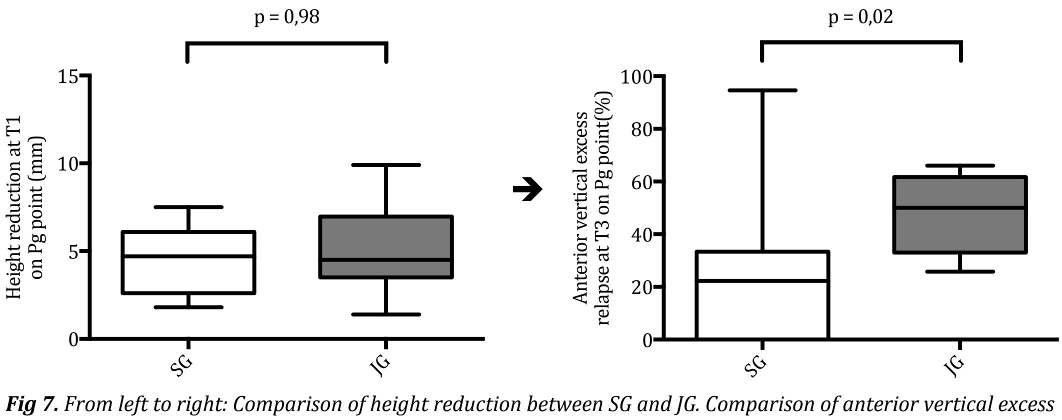


Fig 7. *From left to right: Comparison of height reduction between SG and JG. Comparison of anterior vertical excess relapse between SG and JG on Pg point. Group B.*
Pg point = pogonion point; SG: sliding genioplasty; JG: jumping genioplasty; T1= immediate postoperative time; T3= late postoperative time; significant if p<0,05

Complementary analysis

A linear regression model was also used to determine whether there was a correlation between bone resorption, and age at time of surgery, and a correlation between bone resorption, and the importance of mandibular advancement for patients who received an associated mandibular osteotomy. No statistically significant correlation was demonstrated ($p>0.05$), neither in vertical plane, nor in sagittal plane.

The degree of resorption according to the type of osteosynthesis was also investigated (3 wires versus 1, 2 or 3 screw and 1 versus 2 or 3 screw). No statistically significant difference could be demonstrated ($p> 0.05$).

DISCUSSION

Interest of using Cone Beam CT.

Long-term stability in orthognathic surgery has been studied many times, using cephalometric analyzes on lateral cephalograms. These studies contain many risks of error, independent or dependent on observers. Independent risks, as fake-profiles or osseous superimpositions are removed with CBCT analysis. Some artifacts may occur when the patient did not stay completely at rest during CBCT acquisition.

The CBCT analysis model used in this study also attempt to reduce intra-observer errors [22]. It allowed to remove errors due to manual measurements [17] by calculating the position of different points through the software, and automatically compile them into a spreadsheet. To increase the accuracy, the software allows positioning a point three-dimensionally, simultaneously on the sagittal, axial, coronal section, and on the 3D modeling section. By using X, Y, and Z planes with usual anatomical cephalometric landmarks, this model of study is easily reproducible. Moreover, X1 and Y1 planes, created to ignore mandible and/or maxilla movements seemed to be suitable. Mental foramens are easy to find on CBCT. They are located onward of the sagittal split. So postoperative variations in distance between pogonion or menton points and X1 or Y1 planes were strictly due to chin variations.

The average inter-observer error measurement shows a good accuracy in sagittal measurements, including an average error of 0.61 mm on the Pg point. Anyway, accuracy decreases in vertical direction for the Pg and Me point (1.9 mm on average).

Several others 3D studies with CBCT have been published [23,24] using cranial bases superimposition at different postoperative times. A color map represented outward and inward displacements. Precise evaluation about bone resorption seemed to be difficult to perform with this technique because usual cephalometric landmarks were not used.

A radio-clinical correlation study should be interesting to complete these results, and to evaluate if soft tissues postoperative movement would be correlated to bone remodeling. Because analysis of chin soft tissues is not accurate (a chin rest is necessary for data acquisition), it was impossible to evaluate variation in projection of cutaneous points with CBCT.

Discussion on results.

This study showed a significant correlation between the importance of sagittal advancement and bone resorption, from the early postoperative period. There was also a correlation in the vertical direction, between the amount of the reduction in height and the relapse of anterior vertical excess. *Vedtofte* et al. [10] confirmed these results. The average age of patients at surgery time was 19.9 years (± 6.7; rank 14-44) and did not influence sagittal bone resorption. *Tulasne* [6] and *Chamberland* et al. [25] reported a higher sagittal bone resorption in prepubescent teen. Our results could be explained because of the higher age of our cohort.

Concerning patients who received an associate mandibular osteotomy, and in accordance with *Vedtofte* et al. [10] and *McDonnell* et al. [26], we have not found any correlation between the importance of mandibular movement and the amount of bone resorption. *Tulasne* [6] and *Shaughnessy* et al. [13] reported no difference in resorption between patients who received a single genioplasty and those who had an combined mandibular osteotomy.

No difference in bone resorption has been reported depending on osteosynthesis technique as confirmed by *Reyneke* et al [27].

Tulasne [6] and *Reddy* et al. [11] reported the absence of bone remodeling after few months postoperatively. In a group of patient with high average advancement (9.5 ± 4.8 mm), a more significant resorption was found at 1 year of follow up. As a consequence, the patient's radio-clinical follow-up should be required for a minimum of one year, especially for patients who had a large advancement of the symphysis. It would be interesting to study the evolution of resorption process. It would require, in a long term follow up, more CBCT with additional radiation doses for patients, and so the approval of an ethics committee.

The stability of the two techniques frequently used in clinical practice (sliding and jumping genioplasties) was also studied. The sagittal advancement was higher for patients who received a jumping genioplasty. On the other hand, there was no difference in bone resorption between both techniques during both early, and late follow up. In the vertical plane, no difference was found between the mean postoperative height reduction of both techniques. Anyway, patients who had a JG had statistically higher anterior vertical excess relapse. There were no significant vertical variations at Me point for both early and late postoperative times, as suggested by *Reddy* et al. [11]. So, the greater instability at Pg point in jumping genioplasties could be explained by a clockwise rotation of the chin, with Me as pivotal point. These relapse seemed not to be due to osteosynthesis technique. *Reyneke* et al [27] showed a significant difference in vertical relapse between wire and screw fixation due to the benefice of non rigid fixation, but clinically unimportant. A more important traction of supra-hyoid muscles could be a hypothesis for this relapse.

Jumping genioplasty provides opportunities for larger advancements, with sagittal stability comparable to conventional techniques but had a greater risk of vertical anterior excess relapse (figure 8).

Sliding genioplasty remains the gold standard surgical procedure to treat the majority of sagittal and/or vertical mandibular symphysis deformities [28]. Combined with a slice of bone resection, it provides good capacities to correct anterior vertical excess [29], with results that appear to be more stable over time (figure 9).

The surgeon might consider this bone remodeling, and determine which plans, sagittal or vertical, must be corrected first before choosing the genioplasty technique.

Disclosure of interest

The authors declare that they have no conflict of interest.

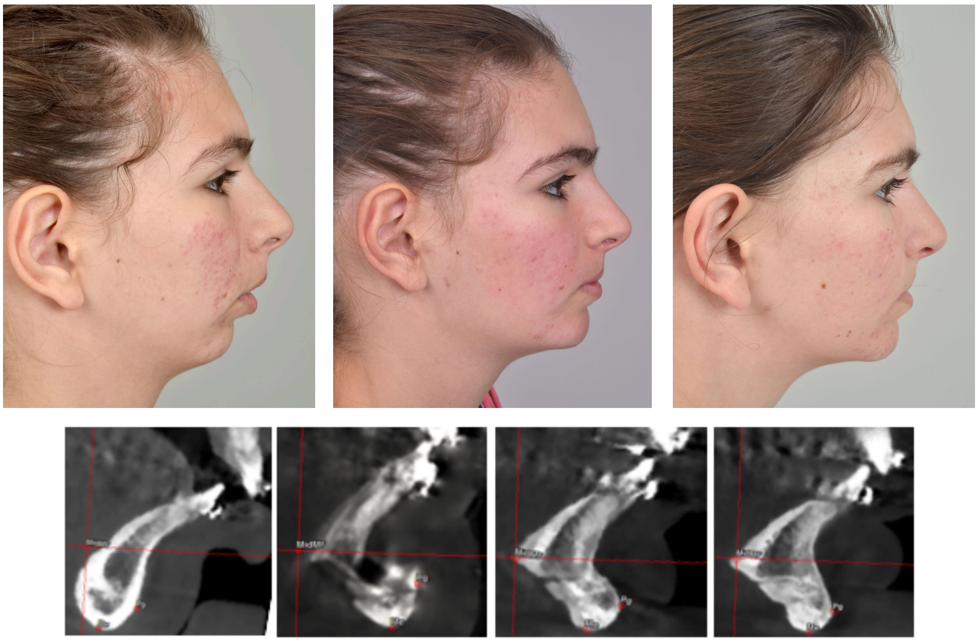


Fig. 8. *14-years-old patient with a class II malocclusion and severe retrogenia.*
A jumping genioplasty combined with a bimaxillar procedure has been performed.
At Pg point : horizontal advancement= 9,3 mm ; height reduction= 6 mm.
From left to right, and from top to bottom : Profile pictures at T0, T1, and T2 ; Sagittal section of mandibular symphysis at T0, T1, T2, and T3.
Partial relapse of clinical results: sagittal decrease in cutaneous Pg projection, and chin tuft ptosis. Sagittal bone resortion was calculated to 24%, and height rec was 50% at Pg point.
Pg= pogonion; T0= preoperative time; T1= immediate postoperative time; T2= early postoperative time; T3= late postoperative time

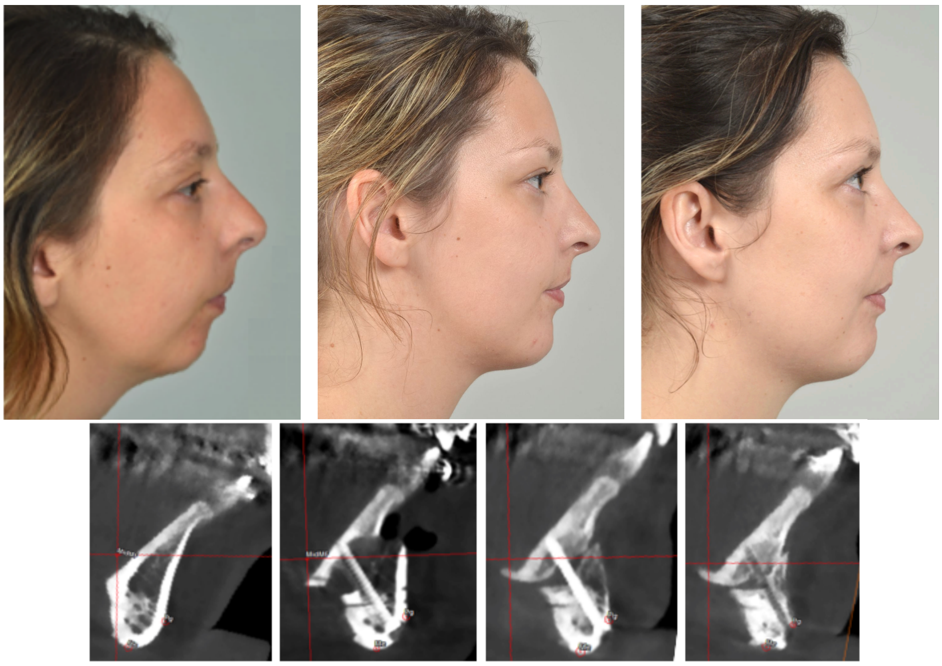


Fig. 9. *31-years-old patient with a class II malocclusion, and anterior vertical excess of mandibular symphysis.*
A sliding genioplasty combined with a bimaxillar surgery has been performed.
At Pg point : horizontal advancement = 8,1mm ; height reduction = 2mm.
From left to right, and from top to bottom : Profile pictures at T0, T1, and T2 ; Sagittal section of mandibular symphysis at T0, T1, T2, and T3.
Partial relapse of this clinical results: sagittal decrease in cutaneous Pg projection, and chin tuft ptosis with relapse of continous chin tension.
Sagittal bone resortion was calculated to 26%, and height relapse was 15% at Pg point.
Pg= pogonion; T0= preoperative time; T1= immediate postoperative time; T2= early postoperative time; T3= late postoperative time

REFERENCES

[1] Precious DS, Delaire J. Correction of anterior mandibular vertical excess: the functional genioplasty. Oral Surg Oral Med Oral Pathol 1985;59:229–35.

[2] Tulasne JF, Raulo Y. [Anterior vertical excess of the inferior third of the face, and genioplasty]. Ann Chir Plast 1981;26:332–6.

[3] Trauner R, Obwegeser H. The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. I. Surgical procedures to correct mandibular prognathism and reshaping of the chin. Oral Surg Oral Med Oral Pathol 1957;10:677–689; contd.

[4] Schendel SA. Sagittal Split Genioplasty: A New Technique. J Oral Maxillofac Surg 2010;68:931–4.

[5] Huet P, Vincent C, Corre P, Mercier J-M. [Modified functional genioplasty]. Rev Stomatol Chir Maxillofac 2010;111:308–13.

[6] Tulasne JF. The overlapping bone flap genioplasty. J Cranio-Maxillo-Fac Surg 1987;15:214–21.

[7] Triaca A, Furrer T, Minoretti R. Chin shield osteotomy--a new genioplasty technique avoiding a deep mento-labial fold in order to increase the labial competence. Int J Oral Maxillofac Surg 2009;38:1201–5.

[8] Triaca A. Chin wing osteotomy - a new facial concept. Head Face Med 2014;10:O6.

[9] Talebzadeh N, Pogrel MA. Long-term hard and soft tissue relapse rate after genioplasty. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;91:153–6.

[10] Vedtofte P, Nattestad A, Hjørting-Hansen E, Svendsen H. Bone resorption after advancement genioplasty. Pedicled and non-pedicled grafts. J Cranio-Maxillo-Fac Surg 1991;19:102–7.

[11] Reddy PS, Kashyap B, Hallur N, Sikkerimath BC. Advancement genioplasty--cephalometric analysis of osseous and soft tissue changes. J Maxillofac Oral Surg 2011;10:288–95.

[12] Franco AA, Cevidanes LHS, Phillips C, Rossouw PE, Turvey TA, Carvalho F de AR, et al. Long-term 3-dimensional stability of mandibular advancement surgery. J Oral Maxillofac Surg 2013;71:1588–97.

[13] Shaughnessy S, Mobarak KA, Høgevold HE, Espeland L. Long-term skeletal and soft-tissue responses after advancement genioplasty. Am J Orthod Dentofac Orthop 2006;130:8–17.

[14] Caloss R, Atkins K, Stella JP. Three-Dimensional Imaging for Virtual Assessment and Treatment Simulation in Orthognathic Surgery. Oral Maxillofac Surg Clin N Am 2007;19:287–309.

[15] Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. Am J Orthod Dentofac Orthop 2008;133:640.e1–5.

[16] Loubele M, Bogaerts R, Van Dijck E, Pauwels R, Vanheusden S, Suetens P, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol 2009;71:461–8.

[17] Ludlow JB, Gubler M, Cevidanes L, Mol A. Precision of cephalometric landmark identification: cone-beam computed tomography vs conventional cephalometric views. Am J Orthod Dentofac Orthop 2009;136:312.e1–10;

[18] Drissi Qeytoni H, Zribi A, Raphaël B, Lebeau J, Bettega G. [Genioplasty: technique and applications]. Rev Stomatol Chir Maxillofac 2007;108:441–50.

[19] San Miguel Moragas J, Oth O, Büttner M, Mommaerts MY. A systematic review on soft-to-hard tissue ratios in orthognathic surgery part II: Chin procedures. J Cranio-Maxillo-Fac Surg Off Publ Eur Assoc Cranio-Maxillo-Fac Surg 2015;43:1530–40.

[20] Delaire J, Schendel SA, Tulasne JF. An architectural and structural craniofacial analysis: a new lateral cephalometric analysis. Oral Surg Oral Med Oral Pathol 1981;52:226–38.

[21] Nimeskern N, Mercier J-M. [The C0 line: from Delaire's analysis of craniofacial structure to modeling it on a computer spreadsheet]. Rev Stomatol Chir Maxillofac 2002;103:327–34.

[22] Farronato G, Salvadori S, Nolet F, Zoia A, Farronato D. Assessment of inter- and intra-operator cephalometric tracings on cone beam CT radiographs: comparison of the precision of the cone beam CT versus the latero-lateral radiograph tracing. Prog Orthod 2014;15:1.

[23] Cevidanes LHS, Bailey LJ, Tucker GR, Styner MA, Mol A, Phillips CL, et al. Superimposition of 3D cone-beam CT models of orthognathic surgery patients. Dento Maxillo Facial Radiol 2005;34:369–75.

[24] Motta AT, Cevidanes LHS, Carvalho FAR, Almeida MAO, Phillips C. Three-dimensional regional displacements after mandibular advancement surgery: one year of follow-up. J Oral Maxillofac Surg 2011;69:1447–57.

[25] Chamberland S, Proffit WR, Chamberland P-E. Functional genioplasty in growing patients. Angle Orthod 2015;85:360–73.

[26] McDonnell JP, McNeill RW, West RA. Advancement genioplasty: a retrospective cephalometric analysis of osseous and soft tissue changes. J Oral Surg Am Dent Assoc 1965 1977;35:640–7.

[27] Reyneke JP, Johnston T, van der Linden WJ. Screw osteosynthesis compared with wire osteosynthesis in advancement genioplasty: a retrospective study of skeletal stability. Br J Oral Maxillofac Surg 1997;35:352–6.

[28] Hoenig JF. Sliding osteotomy genioplasty for facial aesthetic balance: 10 years of experience. Aesthetic Plast Surg 2007;31:384–91.

[29] Delaire J, Tulasne JF. [Labiomental imbalance caused by anterior vertical excess of the lower level of the face. Contribution of horizontal segmental geniectomy]. Orthod Fr 1979;50:353–75.

Vu, le Président du Jury,
(tampon et signature)

Vu, le Directeur de Thèse,
(tampon et signature)

Vu, le Doyen de la Faculté,
(tampon et signature)

NOM : KOUDOUGOU PRENOM : Carine

REMODELAGE OSSEUX SAGITTAL ET VERTICAL APRES GENIOPLASTIE FONCTIONNELLE : ETUDE RETROSPECTIVE TRIDIMENSIONNELLE A PROPOS DE 36 CAS.

RESUME

Introduction : La dégradation des résultats cliniques après génioplastie fonctionnelle est souvent associé à un remodelage osseux symphysaire dont l'évaluation est imprécise sur radiographies conventionnelles. L'objectif de cette étude était d'évaluer le remodelage osseux postopératoire des génioplasties par une analyse tridimensionnelle sur Tomographie volumique à faisceau conique (CBCT).

Matériel et méthodes : 36 patients opérés d'une génioplastie fonctionnelle ont été inclus dans cette étude rétrospective. Ils ont été divisés en groupes de suivi précoce et/ou tardif. Les génioplasties par glissement ont été distinguées des génioplasties de transposition. Les variations sagittales et verticales du pogonion et du point menton ont été recueillies selon un modèle d'analyse tridimensionnelle.

Résultats : La résorption osseuse était statistiquement significative et corrélée à l'amplitude d'avancée ($p<0,05$) mais équivalente entre les « sliding » et « jumping génioplasties » (21,4% versus 24,4% au pogonion à 12 mois, $p=0,47$). La résorption était encore active entre 6 et 12 mois (14,9% versus 27,3% au pogonion, 18,5% versus 29,6%, $p=0,031$). Il existait une corrélation significative entre la diminution de hauteur symphysaire et l'importance de la récidive verticale. Les « jumping genioplasties » avaient une tendance significativement plus élevée à la récidive de l'excès vertical antérieur (47% versus 24,3%, $p=0,02$).

Discussion : Cette étude a permis d'évaluer de façon précise le remodelage osseux sagittal et vertical et les facteurs l'influençant. Le choix de la technique chirurgicale doit tenir compte de l'importance des corrections à réaliser. Le suivi radio-clinique après génioplastie fonctionnelle semble indispensable sur une durée minimale d'un an.

MOTS-CLES

Génioplastie, remodelage osseux, chirurgie orthognathique, tomodensitométrie à faisceau conique