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ETUDE COMPARATIVE DE DEUX TECHNIQUES CHIRURGICALES DANS LE TRAITEMENT DES FRACTURES INSTABLES DE L'OS ZYGOMATIQUE : EMBROCHAGE TRANSFACIAL VERSUS OSTEOSYNTHESE PAR PLAQUES

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TABLE DES MATIÈRES

LISTE DES ABREVIATIONS

3D	Three-Dimensional
CBCT	Cone Beam Computed Tomography
ZMC	Zygomatico-Maxillary Complex
CRWF	Closed Reduction with transfacial Kischner Wire fixation
ORIF	Open Reduction Internal Fixation
PACS	Picture Archiving and Communication System

Radiographic evaluation of two surgical techniques for the unstable zygomatic bone fractures: The close percutaneous transfacial wiring versus Open Reduction and Internal Fixation with miniplates

Key words: Kirschner Wires, Zygomatic Fracture, Open Fracture Reduction, Fracture Osteosynthesis, Bone Plate, Cephalometry

ABSTRACT

Introduction - Zygomatico-maxillary complex (ZMC) fractures are common traumatic injuries. Among surgical techniques available to repair the unstable zygomatic fractures, the closed reduction with transfacial Kischner wire fixation (CRWF) and open reduction with rigid internal fixation (ORIF) can be proposed. The purpose of this study was to radiographically assess the symmetry and the protrusion of the cheekbone in unstable ZMC fractures treated by ORIF or CRWF.

Materials and methods - Sixty patients presenting with a surgical unstable tetrapodal fracture of the zygomatic bone were included in this multicentric retrospective study. Coordinates of 5 landmarks representing the zygomatic protrusion, were comparatively studied on healthy and broken side in preoperative and postoperative tridimensional CT-scans. The two surgical technique were compared according to these landmarks.

Results - A same zygomatic position was found in postoperative time whatever the surgical technique used. The study of preoperative imaging suggested a same shape and a same fracture displacement in the two groups of patients. The zygomatico-maxilllar ansa was found to be the most complicated area to reduce particularly regarding the CRWF technique. There were no differences in complication rate between the two surgical techniques, and the mean surgery duration was significantly lower in the CRWF group than in the ORIF group.

Conclusion - This study provides strong arguments to use K wire fixation in patients presenting with tetrapodal fracture of ZMC.

INTRODUCTION

The fractures of the zygomatico-maxillary complex (ZMC) are common injuries in maxillo-facial surgery. ZMC have long been described as a tripod bone, involving the three supports of the zygomatic bone (the arch of the zygomatic bone, the zygomatic process of the frontal bone, and the zygomatic process of the maxillary bone). Actually it is more considered as a tetrapod bone (1) by separating the "zygomatic process of the maxillary bone" in the orbital rim and in the zygomatico-malar ansa.

The ZMC fractures represent the most common facial fracture. A recent European multicentric study showed a 24% rate of ZMC fractures (2,3). Assaults, falls, road traffic and sports accidents represent the most common etiologies with respectively 39%, 31%, 11%, 11% rates (3). The number of males outnumbers females throughout most studies with a sex ratio 3.6/1. The age of occurrence is average between 30 and 40 years (3).

CT scan and Cone-Beam Computed Tomography (CBCT) are commonly used as imaging exams for evaluation of ZMC fractures in preoperative and postoperative times. The CT imaging with multiplanar and tridimensional (3D) reconstructions allows the identification of fractures of the 4 components (4). With less radiation generated and as valuable for bone examination, CBCT trends to replace the CT scan, apart from the fracture of orbital floor or associated brain injury (5).

Several classifications of ZMC fractures have been proposed in the literature. Among them, the classification of Zingg et al. is based on the energy of the injury, the pattern of comminution, the degree of dislocation, and the number of fractured zygomatic pillars (6). Three types are thus distinguished (Fig 1): A- Incomplete low-energy fractures in which at least one pillar of the ZMC remains intact. B- Tetrapod fractures: all four pillars of the ZMC are fractured. C- Comminuted high-energy fractures: the ZMC is divided into 2 or more fragments by additional fractures trough the zygomatic body, lateral orbit or infraorbital rim. Knight and North, in 1961, subdivided tetrapodal fracture including the type of displacement. They described the group I as no significant displacement, and group II as isolated arch fractures. Group III was defined as unrotated body fractures; downward and inward displacement, but no rotation, and group IV was medially rotated body fractures; downward, inward, and backward displacement with medial rotation. Finally, group V was laterally rotated body fractures; downward, backward, and medial displacement with lateral rotation of the zygoma (7,8).

A conservative treatment is commonly proposed for ZMC fractures with no or minimal displacement. However surgery is indicated for ZMC fractures with dislocation (9,10). The surgical treatment has two outcomes: Functional goal, by improving the mouth opening with the restoration of the zygomatic arch and the infraorbital nerve function by the reduction of the fracture; and an aesthetic one, by improving projection of the cheek and a symmetrical orbital shape. Among surgical techniques available to repair the unstable zygomatic fractures, the closed reduction with transfacial Kischner wire fixation (CRWF) (Fig 2), and open reduction with rigid internal fixation (ORIF) can be proposed. Although ORIF has been considered as the gold standard treatment for unstable fractures (11–14) offering a direct bone exposure to evaluate quality reduction, there is no evidence of its superiority upon CRWF. The K-wire fixation takes its advantages in a faster and costless procedure. Furthermore, it requires a minimum of specialized instruments, and leaves less scar (15). Depending on the team, both methods can be used and sometimes combined, as an adaptive treatment in order to restore the shape of the cheekbone and orbit (16). The main clinical criteria giving witness to the quality of reduction is symmetry of the broken side compared to the healthy side. Interestingly, facial bones are relatively and physiologically asymmetric. Farkas showed that facial asymmetry is very common, with differences between right and left sagittal measurements on average of 3 mm, and a largest asymmetry found in the right side and in the upper third of the face (17). More recently and focusing on ZMC, Belcastro *et al.* showed similar results in 3D imaging with a slight (<3mm) deviation from perfect symmetry comparing ZMC between hemifaces (18). To our knowledge, there are very few reports in the literature regarding ZMC fractures treatment using CRWF. The purpose of this study was to radiographically assess the symmetry and the projection of cheekbone after unstable ZMC fractures treated by ORIF or CRWF.

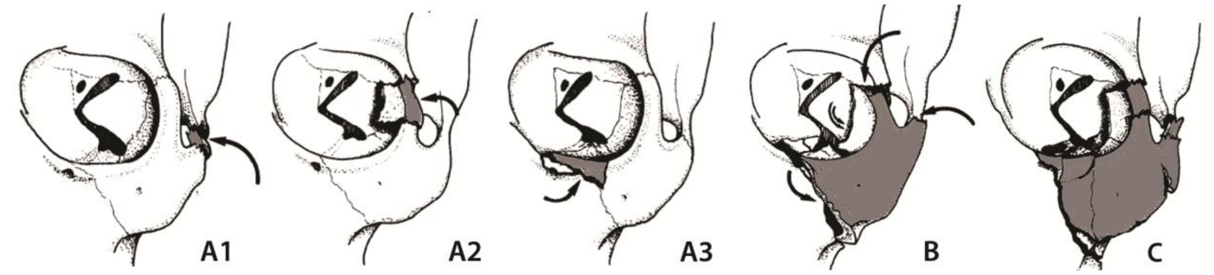

Figure 1. ZMC fractures classification according to Zingg *et al*. 1992. A1: isolated zygomatic arch fracture, A2: isolated lateral orbital wall fracture, A3: isolated infraorbital rim fracture, B: Tetrapod fracture, C: multifragment zygoma lateral orbital complex fracture.

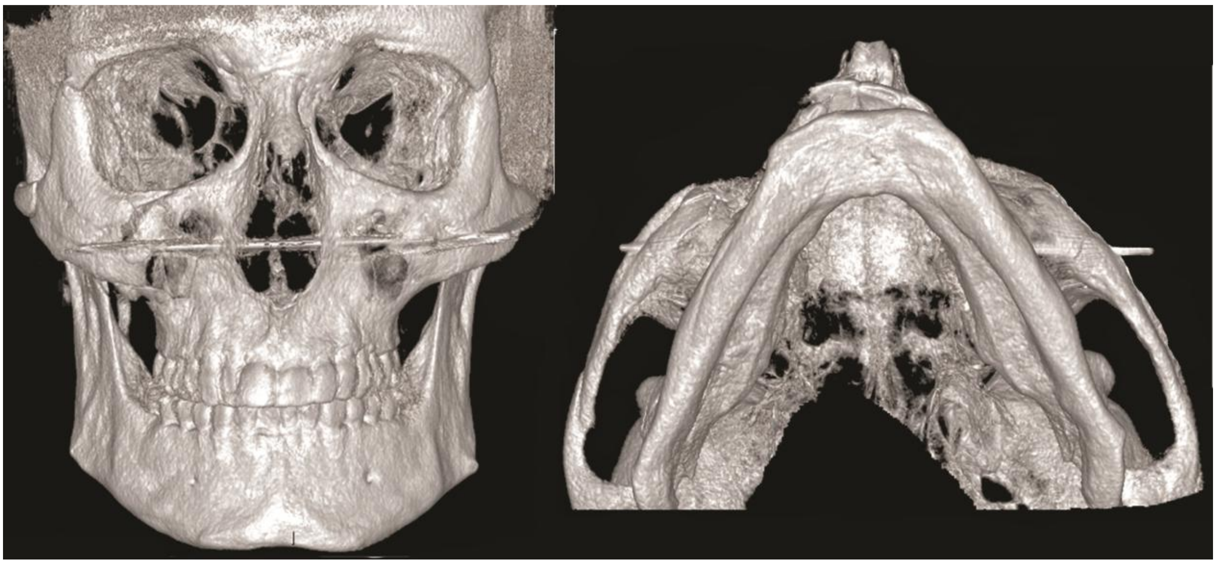

Figure 2. Transfacial Kirshner’s wire, Facial CBCT 3D reconstruction.

MATERIAL AND METHODS

Data collection

Between 2010 and 2017, patients presenting with a unilateral ZMC fractures in the Oral and Maxillo-facial Surgery Department of Nantes University Hospital (Center 1), and in the Maxillo-facial and Facial Plastic Surgery Department of Tours University Hospital (Center 2) were included in the study, and analyzed retrospectively. All patients presented with a surgical unstable tetrapodal fracture, defined as B type in the Zingg *et al.* classification (6) (Fig.1). The exclusion criteria were a fracture of the contralateral ZMC, an isolated zygomatic arch fracture, a ZMC comminutive fracture, and any combined middle face fracture. Patients presenting with no preoperative or postoperative imaging were also excluded. The patient charts were reviewed, and data documenting date of birth, the side involved (i.e. right vs. left), mechanism of fracture, clinical findings, types of surgery and surgery duration were compiled.

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.

Surgical technique

Whatever the surgical approach used, a close reduction with a Ginestet's hook was carried out. Fixation was realized in unstable fractures when necessary.

The CRWF was proposed in Center 1. A 18 or 20 mm diameter Kirshner wire was introduced with a motor, in the corpus of the healthy contralateral zygomatic bone, then passed through the maxillary sinus, the nasal septum, and pricked the inner cortex of broken zygomatic bone. The direction was controlled in the 3 different planes by the surgeon and an assistant placed at the head of the patient. In some cases, when a large bony gap was felt at the fronto-zygomatic suture, a titanium loop wire was first placed on the suture before moving the ZMC up.

The ORIF was performed in Center 2. A subcilliary, eyebrow and intra-oral approaches were often performed to expose the infra-orbital rim, the maxillozygomatic and fronto-zygomatic sutures. Reduction was controlled using a Ginestet or a Dot hook. When anatomic reduction was obtained, internal fixation was performed using different types of miniplates; a straight 5 holes plate properly adapted was first applied on the fronto-zygomatic fracture area. Then, L-shaped plate was used for the fixation of the zygomaticomaxillary fracture. Finally, an orbital rim plate (arciform), generally from 5 to 7 holes plates, properly adapted, was applied for the inferior orbital rim reparation.

Radiographic evaluation

Preoperative and postoperative CT scans or CBCT were comparatively analyzed. Pictures were downloaded in Dicom format from both centers Picture Archiving and Communication System (PACS*).* X-ray scans UHC Facial skeleton multi-detector computed tomography was used with a tube voltage at 120 KV and a tube current of 300 mA, an acquisition matrix of 512·512 and a 230 mm display field of view. Each CT-scan was reconstructed with a slice thickness of 0.67 mm / 0.33 mm. The ultra-high-resolution mode was used. CT-scans and CBCT pictures were reviewed and the ZMC fracture was classified according to Zingg et al. classification.

Landmarking were placed manually by the same operator, either on sagittal, coronal or axial sequences using the software Simplant O&O (for Intel X86 Platform v. 3.0.0.59, 2013; Materialise Dental n.v., Leuwen, Belgium). Five landmarks were drawn on 3D imaging to assess ZMC projection. The four classical landmarks Zygo-maxillare (Mp), Orbitale (Or), Zygo-temporale inferior (Zt) and Zygomatico-frontale (FZS) were chosen in order to represent each pillar of the zygomatic tetrapod. These anatomical points of the skull base were considered as stable according to their use in craniometry analysis, forensic sciences and anthropology (19). The fifth landmark was the foramen of the zygomaticofacial nerve (Fzf), chosen to be reproducible, it represents the projection of the zygomatic body. These landmarks are listed in Table 1 and presented in Fig. 3.

Name		***Definition***	***Type***
Foramen of the zygomatico-facial nerve	Fzf	Opening of the zygomatico-facial branch of the trigeminal nerve at the center of the zygomatic bone	Bilateral
Zygomaxillare point	Mp	Lower point of the zygomatico-maxillary suture	Bilateral
Zygotemporale inferior point	Zt	Lower point of the zygomatico-temporal suture, at the top of the zygomatic tubercle	Bilateral
Fronto-zygomatic suture	FZS	Cranial suture between the zygomatic bone and the frontal bone	Bilateral
Orbitale	Or	Lowest point on the inferior edge of the orbit	Bilateral
Foramen caecum	Fc	Lower end of the frontal crest of the frontal bone, at the junction with the ethmoid bone on the skull base	Midline
Metanasion point	M	Continuation of the upward extension of the anterior lacrymal ridge to the fronto-nasal suture	Bilateral
Midpoint of RM - LM	MidM	Midpoint of fronto-nasal sutures points	Midline
Posterior Clinoid process	Clp	Highest part of the posterior clinoid process	Bilateral
Midpoint of RpCl - LpCl	MidClp	Midpoint of posterior clinoid process points	Midline
Origin	O	Point at the intersection of X, Y and Z plan	Midline

Table 1. Skeletal landmarks used for cephalometric measurements.

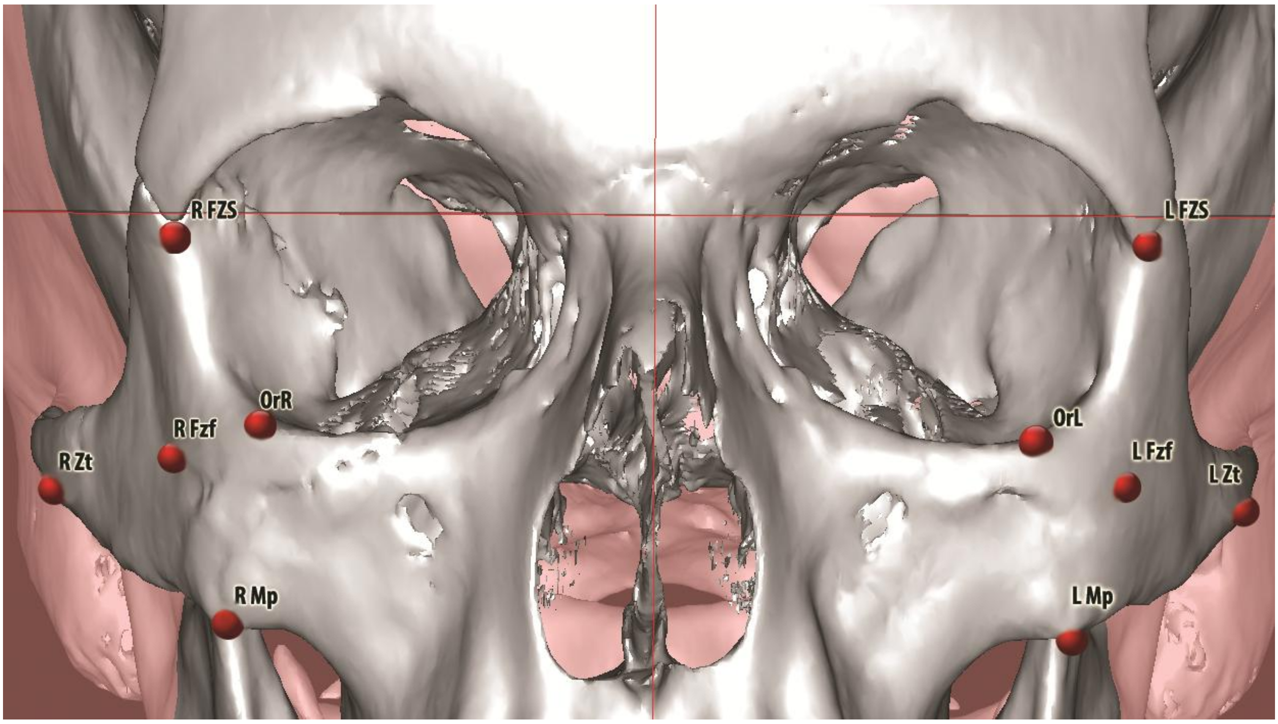

Figure 3. Schematic representation of landmarks used: Fzf (Foramen of the zygomaticofacial nerve), FZS (Zygomatico frontal suture), Mp (Zygomaxillare point), Zt (Zygotemporale inferior), Or (Orbitale).

An orthonormal coordinate system was constructed as follow (Fig. 4):

1. Z median plane passing through the three points MidM, MidClp and Fc.
2. X plane, corresponding to the 3D reconstruction of the C1 line of Delaire (20), perpendicular to the Z plane, and passing through MidM and MidpCl.
3. Y plane, representing a 3D reconstruction of the C0 line described by Nimersken for the Delaire's cephalometric analysis (21), constructed perpendicular to Z and X and passing through MidClp.

Results obtained were distance, expressed in mm, in an orthonormal basis with three dimensional coordinates (Tab.2 and 3). Landmarks for the zygomatic projection were then studied comparatively between the broken side and the normal side; then results were compared between the two fixation techniques.

Plane		Definition	Type
Midsagittal plane	Z	MidM, MidClp and Fc	Defined by 3 landmarks
Axial plane	X	Perpendicular to Z and through MidM and MidClp	Defined by 2 landmarks and perpendicular to Z plane
Coronal plane	Y	Perpendicular to Z and X through MidClp	Defined by 1 landmark and perpendicular to Z and X planes

Table 2. Planes used to build a 3D orthonormal system in zygomatic cephalometry.

Distance	Definition	Type
Between Foramen of the zygomaticofacial nerve and X, Y and Z planes	Fzf X , Fzf Y and Fzf Z	Bilateral
Between Zygomaxillare point and X, Y and Z planes	MpX, MpY and MpZ	Bilateral
Between Zygotemporale inferior point and X, Y and Z planes	ZtX, ZtY and ZtZ	
Between Fronto-zygomatic suture and X, Y and Z planes	FZSX, FZSY and FZSZ	
Between Orbitale and X, Y and Z planes	OrX, OrY, and OrZ	

Table 3. Distances measured in zygomatic cephalometry.

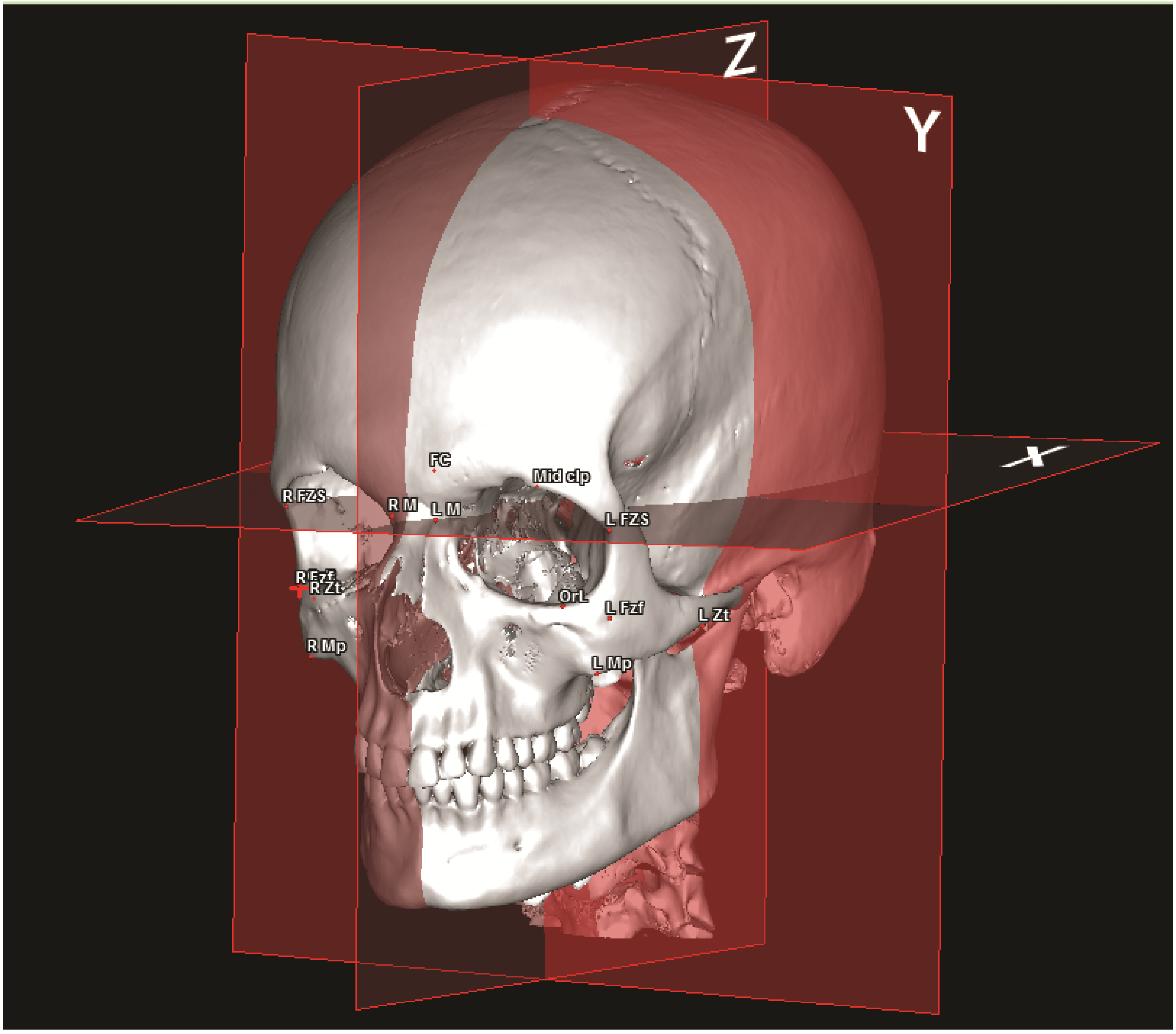

Figure 4. Orthonormal coordinate system constructed in the three planes X, Y and Z:

1. Z median plane through three points: MidM, MidClp and FC.

2. X plane, as 3D reconstruction of C1 line of Delaire perpendicular to Z and through MidM and MidpCl.

3. Y plane, as 3D reconstruction of C0 line described by Nimersken for Delaire cephalometric analysis, perpendicular to Z and X through MidClp.

Secondary endpoints

The type of displacement was assessed on the preoperative radiographic images, using the 5 landmarks previously described and comparing their coordinates on the broken side versus the healthy side. Epidemiologic data and surgical duration were also collected and studied.

Statistical analysis

The methodical error of cephalometric measurements was 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 is the number of double measurements) (22). To determine the inter-observer error, cephalometric landmarks were positioned twice by two different operators in a 20 (30%) randomly selected patients.

The statistical analysis was performed using GraphPad Prism® 6.0 for Windows (GraphPad Software, la Jolla, CA, United-States). The parametric function of our series was tested with a Shapiro wilk test. Comparative analysis of non-inferiority was carried out with a confidence interval of [-2.5 ; 2.5], considering that an asymmetry of 2.5 mm was the limit for an acceptable result (Farkas, 1982). Data were secondary adjusted on age and sex. Quantitative data were analysed using a paired t-test for paired observations and a Mann-Whitney test for non-paired values. Qualitative data were compared using a Chi-squared test. A p value less than 0.05 ($p<0.05$) indicated as statistically significant.

RESULTS

Epidemiologic data

Sixty patients (30 patients from each center) presenting with a surgical ZMC fracture were reviewed and included in this study (Excluded patients are listed in supplementary Tab. S1). Two hundreds and five patients were rejected based on the exclusion criteria (132 from Center 1 and 73 from Center 2). Among included patients, 48 (80%) were men (23 in Center 1 and 25 in Center 2) and 12 (20%) were women (7 in Center 1 and 5 in Center 2). Male over-represented female with a sex-ratio of 4/1. The average age at the time of the surgery was 35 ±16,4 years in Center 1 and 40,1 ±18,9 years in Center 2 (Table 4). We noted a significant predominance of the affected side being on the left malar bone (60% versus 40% for the right side). According to the etiologies of fractures, assault represented 24/60 cases (40%), followed by road traffic accidents 13/60 (22%), falls 12/60 (20%) and sports injuries 11/60 (18%). Most of the assault's ZMC fractures at the right side were due to elbow assaults. ZMC fractures due to sport accidents were mainly related to football, rugby and basketball. Majority of ZMC fractures due to falls were associated with an alcoholic intoxication in 7/12 cases (58%). RTA's described in our study were a large majority of scooter 3/13 (23%) and lightweight 7/13 (54%) car accidents.

	Center 1 N=30	***Center 2 N=30***	***TOTAL N=60***
Female/Males, n (%)	7 (22%) / 23 (78%)	5 (17%) / 25 (83%)	12 (20%) /48 (80%)
Age (years), mean ± SD	35.51 ± 16.4	40.1 ± 18.9	37.8 ± 17.53
Right/left broken side, n (%)	16 (53%) / 14 (47%)	8 (27%) / 22 (73%)	24 (40%) /36 (60%)
Traumas etiologies, n (%)			
Assault, n (%)	14 (47%)	10 (33%)	24 (40%)
Road traffic accident, n (%)	4 (13%)	9 (31%)	13 (22%)
Fall, n (%)	5 (17%)	7 (23%)	12 (20%)
Sports, n (%)	7 (23%)	4 (13%)	11 (18%)

Table 4. Patients characteristics; n, number of patients; SD, standard deviation.

Concerning the clinical findings, 57 patients (95%) had a lack of zygomatic protrusion clinically objectived. The 3 other patients had an important edema or no clinical trouble. Fifty-nine patients (98%) presented with an infra-orbital nerve (V2) sensitivity troubles. Fourteen patients (23%) had a mouth opening limitation. Twelve patients (20%) had an associated surgical orbital floor, whose 5 (8%) presented a binocular diplopia, and one case of oculomotor trouble was highlighted. Ten patients presented facial wounds affecting preferentially the eyelid, the cheek and the eyebrows.

Primary outcome

The mean Dahlberg standard error for the cephalometric measurement was 0.81mm ± 0.38mm (0.23 - 1.64) (Supplementary Tab. S2). The zygomatic protrusion was compared between healthy and broken sides in the two surgical groups (CRWF and ORIF). No significant difference was found whatever the landmark studied (Fig. 5 and 6). Results are showed in Tab. 5. The MpZ point was found to widely change between postoperative and preoperative time in the CRWF group, with no significant difference with the ORIF group (2.53mm vs 1.77mm). Adjustments on age and sex showed no significant differences (Supplementary Tab.S3).

Differences	*CRWF Mean (mm)*	*ORIF Mean (mm)*	*Differences CRWF - ORIF*	*IC95%*	*Interpretation*
OrRX_OrLX	0.99	1.60	-0.6087	[-1.1604; -0.0570]	Equivalent
OrRY_OrLY	2.19	1.73	0.4607	[-0.3341; 1.2554]	Equivalent
OrRZ_OrLZ	1.99	2.11	-0.1193	[-0.1193; -0.8829]	Equivalent
RZFSX_LZFSX	1.08	1.57	-0.487	[-0.9795; 0.0055]	Equivalent
RZFSY_LZFSY	1.56	2.18	-0.623	[-1.3249; 0.0789]	Equivalent
RZFSZ_LFZSZ	1.14	0.67	0.4767	[0.1096; 0.8437]	Equivalent
RFzfX_LFzfX	1.86	2.32	-0.455	[-1.2693; 0.3593]	Equivalent
RFzfY_LFzfY	1.66	2.38	-0.7243	[-1.5652; 0.1165]	Equivalent
RFzfZ_LFzfZ	1.93	1.67	0.2563	[-0.4210; 0.9337]	Equivalent
RMpX_LMpX	1.27	1.87	-0.6013	[-1.1921; -0.0106]	Equivalent
RMpY_LMpY	2.53	1.77	0.7593	[-0.0759; 1.5945]	Equivalent
RMpZ_LMpZ	1.41	1.29	0.126	[-0.6244; 0.8764]	Equivalent
RZtX_LZtX	2.08	2.27	-0.196	[-1.0405; 0.6485]	Equivalent
RZtY_LZtY	2.46	2.31	0.1443	[-0.8892; 1.1779]	Equivalent
RZtZ_LZtZ	2.07	1.93	0.1433	[-0.5970; 0.8837]	Equivalent

Table 5. Non inferiority test, comparison of the differences in zygomatic protrusion between the healthy and the broken sides in the two fixation techniques. Confidence Interval: [-2.5 ; 2.5], as described by Farkas et al., 1981.

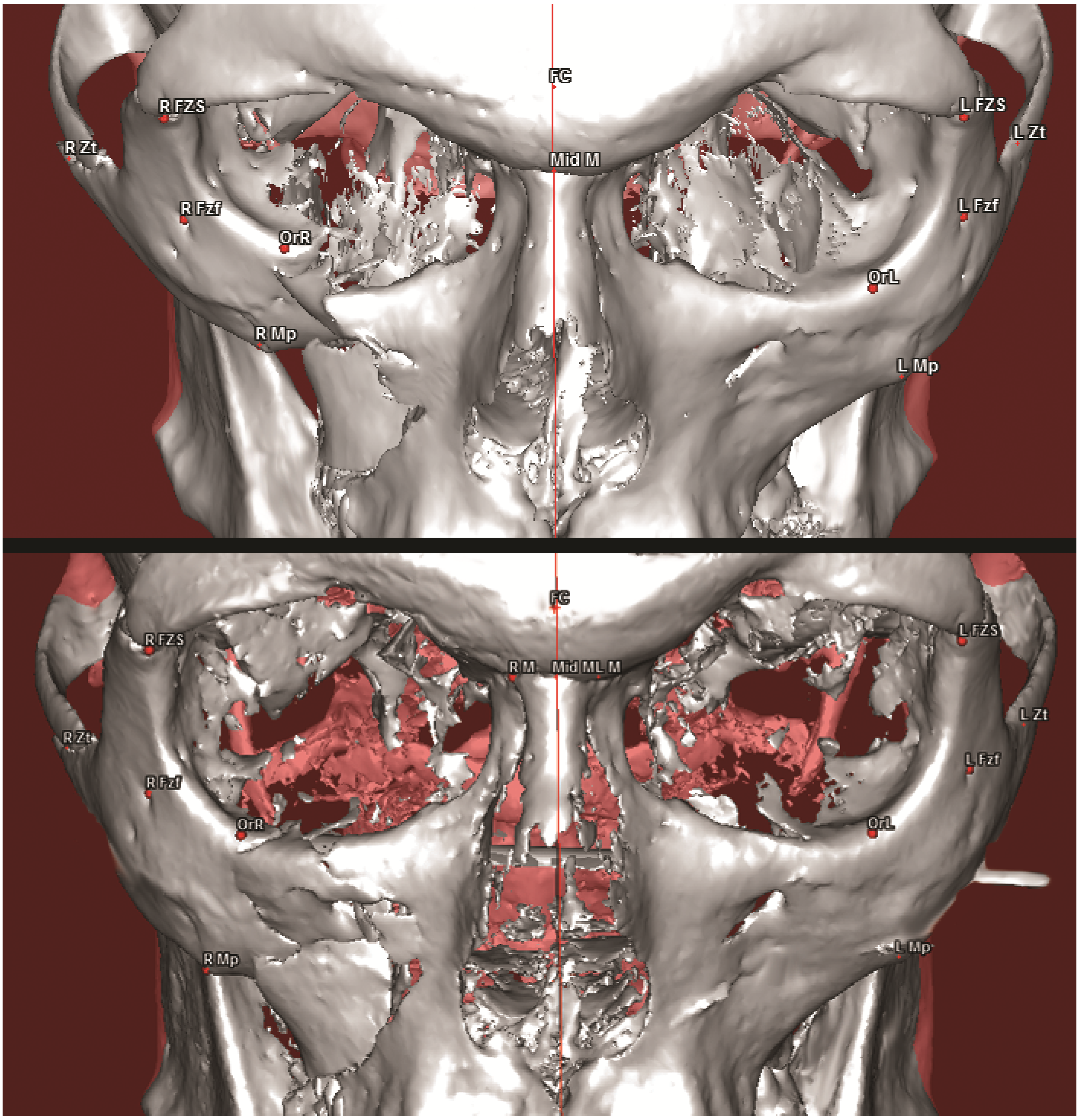

Figure 5. Ct-scan and CBCT 3D reconstruction, comparison before and after surgery with CRWF technique. Up: before surgery. Down: after surgery.

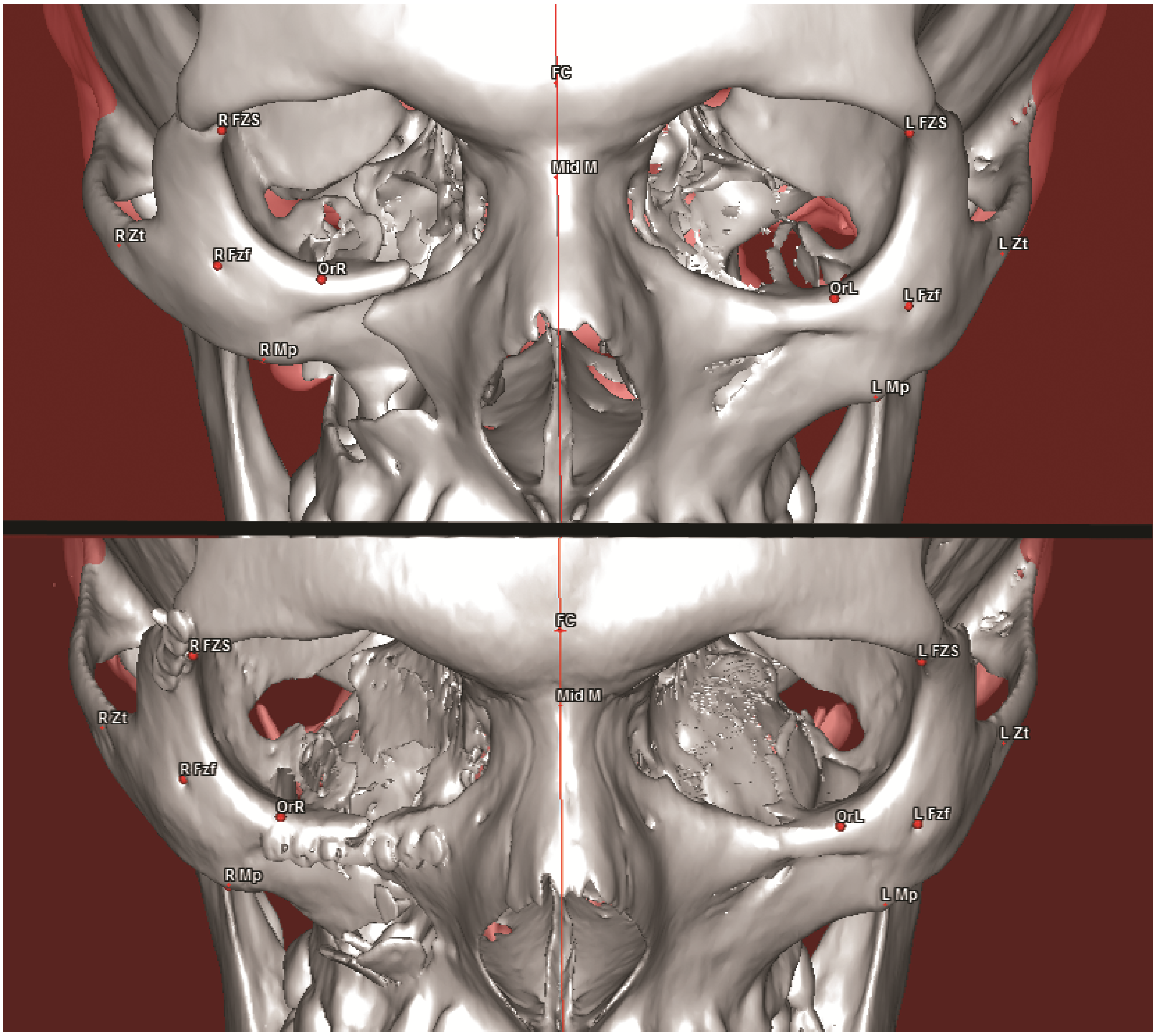

Figure 6. Ct-scan 3D reconstruction, comparison before and after surgery with ORIF technique. Up: before surgery. Down: after surgery.

Secondary endpoints

The projection of healthy side was compared between ORIF and CRWF. There were no significant differences in zygomatic shapes between the two groups (Supplementary Tab. S4).

Then, the broken side was compared between the ORIF and the CRWF groups in preoperative time. No significant difference in zygomatic coordinates was observed suggesting a same fracture displacement in the two groups (Supplementary Tab. S5).

For each group, the projection of the zygomatic bone was radiographically compared in postoperative time between the broken side and the healthy side. In the patients treated with CRWF, the four landmarks MpZ, MpY, FzfY and OrY varied significantly in the operated side (Tab. 6). MpZ and MpY were significantly different and decreased in the broken side compared to the healthy side, with mean values 41.51mm vs 43.74mm (p=0.004) and 42.42 vs 44.82 (p=0,001) respectively. FzFy and OrY was also significantly lower in broken side than in healthy side, with mean values 45.91mm vs 48.02mm (p=0.001), and 54.51mm vs 57.05mm (p=0.002) respectively (Supplementary Tab. S6).

Landmark		***Broken N=30***	***Healthy N=30***	***Total N=60***	***p-value***
FzfY	N	30	30	60	0.0016
	Min-Max	[37.73;54.78]	[37.79;61.95]	[37.73;61.95]	
	Mean	45.91	48.02	46.97	
	SD	4.89	4.91	4.97	
	Median	45.59	48.20	46.36	
	Q1-Q3	[42.23;50.46]	[44.90;49.93]	[43.29;50.15]	
MpY	N	30	30	60	0.0010
	Min-Max	[32.09;54.27]	[36.72;53.65]	[32.09;54.27]	
	Mean	42.42	44.82	43.62	
	SD	5.70	4.57	5.26	
	Median	43.01	44.51	43.83	
	Q1-Q3	[38.86;45.63]	[41.65;48.24]	[40.20;47.59]	
MpZ	N	30	30	60	0.0046
	Min-Max	[32.80;51.94]	[37.84;50.13]	[32.80;51.94]	
	Mean	41.51	43.74	42.63	
	SD	4.30	2.84	3.78	
	Median	42.64	44.02	42.98	
	Q1-Q3	[38.59;43.97]	[41.40;45.58]	[40.87;44.62]	
OrY	N	30	30	60	0.0020
	Min-Max	[44.76;69.27]	[49.41;65.14]	[44.76;69.27]	
	Mean	54.51	57.05	55.78	
	SD	6.36	4.39	5.56	
	Median	53.94	56.88	55.71	
	Q1-Q3	[49.61;59.23]	[53.64;60.79]	[52.06;60.00]	

Table 6. Comparison of the zygomatic projection between the healthy and the broken side in the CRWF technique. Paired Student's t test. N, number of patients; SD, standard deviation.

In the patients treated with ORIF, a significant variation was found in the position of the points MpY and OrZ (Tab. 7). MpY and OrZ were differently positioned on the affected side with a lower projection of Mp and a medium position of Or (43.62mm vs 46.30mm, p= 0.0009; and 35.49mm vs 37.32mm, p=0.02 respectively) (Supplementary Tab. S7).

Landmarks		***Broken N=30***	***Healthy N=30***	***Total N=60***	***p-value***
FzfY	N	30	30	60	0.0677
	Min-Max	[37.41;57.27]	[39.99;57.27]	[37.41;57.27]	
	Mean	47.69	49.04	48.37	
	SD	4.44	4.48	4.47	
	Median	47.63	48.75	47.71	
	Q1-Q3	[45.60;49.49]	[45.74;51.71]	[45.65;51.33]	
MpY	N	30	30	60	0.0009
	Min-Max	[28.69;53.32]	[32.35;53.32]	[28.69;53.32]	
	Mean	43.62	46.30	44.96	
	SD	5.01	4.76	5.03	
	Median	44.36	47.08	45.76	
	Q1-Q3	[40.51;47.26]	[45.14;49.39]	[41.70;47.92]	
OrZ	N	30	30	60	0.0020
	Min-Max	[27.30;43.04]	[32.57;41.19]	[27.30;43.04]	
	Mean	35.49	37.32	36.40	
	SD	3.15	2.21	2.85	
	Median	35.60	37.74	36.91	
	Q1-Q3	[33.61;37.83]	[36.28;38.54]	[34.42;38.36]	

Table 7. Comparison of the zygomatic projection between the healthy and the broken side in the ORIF technique. Paired Student’s t test. N, number of patients; SD, standard deviation.

The surgery duration was compared between both groups and was significantly lower in the CRWF group than in the ORIF group, with 28.32min (18-45) vs 107.7min (32-202) respectively ($p<10^{-4}$).

No more post-surgery complication was observed in one technique compared to the other one. An acute maxillary sinusitis was observed in one patient of the CRWF population, and one infection on the maxillary buttress osteosynthesis was noted in the ORIF group.

DISCUSSION

The surgical restoration of the protrusion of the cheek can be challenging in the zygomatic complex fractures. The ORIF is the most commonly used surgical technique in maxillofacial surgery centers (11). It allows an open sky approach of the different pillars of the zygomatic bone, but raises the disadvantages of facial scars, increased surgery duration and expensive cost (23,24). Another drawback is the remain of the foreign osteosynthesis material in the body, that can be avoided by using bioresorbable plate system (25). K-wire fixation seems to represent a mini-invasive reliable technique with a low rate of morbidity (15). However it necessitates a systematic removal at least 3 weeks after implanting the K-wire, and raises the risk of epistaxis, internal orbit or homolateral coronoid process injuries and penetration of the nasotracheal tube (15). Our study aimed to compare the both surgical technique in term of zygomatic projection, radiographically assessed in postoperative time. We showed a same zygomatic position in the broken side compared to the healthy side whatever the technique used, providing strong arguments to use K wire fixation in patients presenting with type B tetrapodal fracture of ZMC. These results are all the more reliable, as the study of preoperative imaging showed a same zygomatic bone shape and fracture severity. In a serie of 216 patients treated with Kirshner's wire, Raoul *et al.* showed a high benefits/risk ratio for the patient considering material costs, time of surgery, and scar. They concluded to keep the K-wire fixation as the first intention treatment in case of insufficient stability, eventually associated with internal fixation in case of deficient alignment of a buttress (15). Others authors argue for a plate osteosynthesis of the lateral orbital rim in association with the K-wire fixation (16,26) to obtain a strong stability of the reduced zygomatic bone. In our experience, only the comminutive ZMC fractures (Type C in Zingg *et al.* classification) need an internal fixation. Others authors conclude that the miniplate fixation gives more ease for the surgeon than wire osteosynthesis, with more time and skills for K-wire fixation (27).

We highlighted that the Mp landmark, representing zygomatico-maxilllar ansa, was the most complicated area to reduce particularly regarding the CRWF technique. This insufficient reduction can be explained by the existence of a comminuted fracture with the difficulty to control reduction in this area. Bujtar *et al.* proposed to use a guide to help in osteosynthesis of ZMC maxillary ansa comminuted fracture. This custom made guide based on mirroring technique can help to realign zygoma with the correct craniocaudal and antero-lateral protrusion (28). In fact, the zygomatico-maxillar ansa is anatomically hidden under soft part (malar fat pad, zygomaticus muscles and masseter) and does not really affect the aesthetic and functional outcomes.

No complication was reported with the two surgical techniques. Concerning economical purposes, the cost of an osteosynthesis plate is more expensive reaching 94.76 Euros for a bend microplate; while Kirshner's wire costs 1,82 Euros. Advantages/disadvantages of the CRWF and ORIF are resumed in Table 8.

Surgical technique	***Advantages***	***Disadvantages***
CRWF	Reduced operating time	Removal of the wire under local anesthesia
	Minimally invasive approach	Difficulty controlling projection
	No material remains after removal	No visual reduction
	Low material price	
ORIF	Visual reduction	Increased operating time
	Control of the four pillars	Scars
	Approach to the orbit floor	Material remains
		Material price

Table 8. Comparison of advantages and disadvantages expected with the ORIF and CRWF surgical techniques.

Patient's characteristics and etiologies of the fractures were consistent with the literature review (3,24,29); most of them were due to assaults (40%), followed by Road traffic accidents (RTA), falls and sports injury. The mainly affected left side in assault's injuries is due to the majority of right-handers in the aggressor population. RTA's described in our study were a majority of scooter and lightweight car accidents. It seems logical because ZMC fractures are usually non isolated when the accidents occurs with trucks or other heavyweight vehicles.

The analysis of the displacement of the ZMC fractures showed a clockwise rotation, with an impaction of the medial part of the ZMC complex, classified as type IV in Knight and North system (7). This was highlighted by a major displacement of the Or, Mp and Fzf landmarks in a negative direction focusing on the Y projection plane. Our results are consistent with those of Toriumi *et al.,* who noted a buffering effect of the masseter and the temporal muscles on the vertical movement enlightening the bone rotation clockwise on itself following the vertical axis (8). Knight and North have already recognized this pattern back in the 1960s. Indeed, empirical evidence shows that zygomatic summit follows this movement and tends toward retrusion. Hence, the postoperative asymmetry can be explained by a failure in the restoration of zygomatic summit projection (7).

The CBCT and Ct-scan analysis model used in this study allowed us to avoid errors due to manual measurements by calculating the position of different points through the software, and automatically compiles them into a spreadsheet. In order 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 is easily reproducible. The four landmarks used to represent zygomatic shape are commonly used in anthropometry and anthropology sciences (19). However the zygomatico-facial foramen is few described in the literature; this point can anatomically change between people, but remains easy to process when analyzed in the same patient (30). The low Dahlberg score found in our work suggest a high reproductibility of the landmarks evaluation method.

The main drawback of this study is the lack of patients to statistically assess the equivalence of the two surgical techniques. Furthermore, our study was retrospective, and 26 different operators performed the surgery in two centers. Long-term stability was not comparatively studied between the two surgical techniques. A possible improvement of the bone protrusion due to the bony callus and the distribution of soft parts could also mislead our long term clinical results. Pre-existing asymmetries were eliminated by choosing unilateral ZMC fractures and by comparing preoperative imaging of healthy side in patients. Esthetical results were not compared on photographs. Landmarks used for Z plans were very close and this plan was difficult to build.

The surgical outcome in ZMC fractures can be improved by using peroperative imaging. Indeed, peroperative tomography such as C-Arm has been described in maxillo-facial traumatology. This technique improves the surgical results in term of reduction, and it does not significantly extend the procedure duration (31,32). According to the ALARA principles, radiation must be limited during intraoperative imaging, that's why a navigation device with referential in 3 dimensions could be used in ZMC fracture surgery (33). Moreover, the arrival of the surfacic CBCT will help maxillo-facial surgeons to measure more objectively the projection of the soft parts, as well as the aesthetic results of the surgery (34). This study appeals for prospective and randomized controlled works including more population to compare osseous and soft tissues projection results for both surgical techniques.

CONCLUSION

ZMC fractures are very common in maxillo-facial surgery and usually need to be surgically treated. In this postoperative radiographic evaluation, we report same surgical result obtained by CRWF and ORIF for tetrapodal fracture of ZMC. Though the zygomatico-maxillary ansa represent the most difficult area to reduce whatever the surgical technique used.

SUPPLEMENTARY MATERIAL

	Center 2	***Center 1***
Database: keywords patients (n)	ZMC fractures:103	ZMC and/or Maxillary fracture: 162
Images issues:	45 only Xrays	25 incomplete or missing
No surgery	13	11
Stable reduction	0	46
Other fractures	6 Lefort 4 zygomatic arch only 5 Comminutives	15 Lefort 4 zygomatic arch only 2 Comminutives 7 maxillary disjunction 10 alveolar fractures 4 infrorbital rim only
Title error	0	8 (mandibular fracture, ZMC osteotomy, maxillary osteotomy)
Finally included	30	30

Table S1. Excluded patients after Database researches in Center 2 and Center 1.

	Mean results (mm)	
Coordinates	***Before surgery***	***After surgery***
RZFSZ	0,705281859	0,225355275
RZFSX	0,654278228	0,466438635
RFZSY	1,021093776	0,444690904
R ZtZ	0,672132799	0,475930667
R ZtY	1,356688063	1,075435958
R ZtX	0,639269114	0,665890381
R MpZ	1,041087172	0,573085945
R MpY	1,468417516	0,722684233
R MpX	0,571565832	0,475005263
R FzfZ	0,705281859	0,225355275
R FzfY	0,962979751	0,277033391
R FzfX	1,048182952	0,469616865
OrRZ	1,491348383	1,643724429
OrRY	1,493564528	1,149603192
OrRX	0,474626169	0,445042133
OrLZ	1,438858054	1,486240223
OrLY	0,926461008	1,071741573
OrLX	0,308374772	0,398948618
L ZtZ	0,893932324	0,670727217
L ZtY	1,167194285	0,896097093
L ZtX	0,691407984	0,973374286
L MpZ	1,571961354	1,424599944
L MpY	1,147767398	1,114108388
L MpX	0,497169488	0,5571288
L FZSZ	0,683672071	0,546984918
L FZSY	0,972554626	0,671472263
L FZSX	0,488362058	0,644301948
L FzfZ	0,314602924	0,524251848
L FzfY	0,639701102	0,636123023
L FzfX	1,05827572	0,704556598

Table S2. Results of Dhalberg’s formula on every landmarks. Differences in millimeters between the two landmarkings.

	Differences CRWF - ORIF	*IC95%*	*Interpretation*
OrRX_OrLX	-0.5696	[-1.1359; -0.0032]	Equivalent
OrRY_OrLY	0.4396	[-0.3804; 1.2595]	Equivalent
OrRZ_OrLZ	-0.04747	[-0.8269; 0.7319]	Equivalent
RZFSX_LZFSX	-0.4477	[-0.9509; 0.0556]	Equivalent
RZFSY_LZFSY	-0.6531	[-1.3762; 0.0699]	Equivalent
RZFSZ_LFZSZ	0.4938	[0.1166; 0.8710]	Equivalent
RFzfX_LFzfX	-0.3603	[-1.1883; 0.4677]	Equivalent
RFzfY_LFzfY	-0.6631	[-1.5192; 0.1931]	Equivalent
RFzfZ_LFzfZ	0.3192	[-0.3664; 1.0048]	Equivalent
RMpX_LMpX	-0.6546	[-1.2570; -0.0522]	Equivalent
RMpY_LMpY	0.7086	[-0.1505; 1.5677]	Equivalent
RMpZ_LMpZ	0.0783	[-0.6932; 0.8498]	Equivalent
RZtX_LZtX	-0.1397	[-0.9960; 0.7166]	Equivalent
RZtY_LZtY	0.211	[-0.8519; 1.2739]	Equivalent
RZtZ_LZtZ	0.1738	[-0.5864; 0.9340]	Equivalent

Table S3. Non inferiority test, comparison of projection differences healthy-broken sides between the two fixation techniques adjusted on age and sex. Confidence Interval: [-2.5 ; 2.5],(35).

		Center 1 N=30	*Center 2 N=30*	*Total N=60*	*p-value*
FZSY	N	30	30	60	0.6703
	Min-Max	[42.71;61.76]	[45.80;60.88]	[42.71;61.76]	
	Mean	52.93	53.40	53.17	
	SD	4.35	4.11	4.20	
	Median	53.48	53.13	53.24	
	Q1-Q3	[50.35;56.02]	[50.96;56.49]	[50.48;56.25]	
FzfX	N	30	30	60	0.1876
	Min-Max	[19.79;33.59]	[19.43;34.00]	[19.43;34.00]	
	Mean	26.91	25.71	26.31	
	SD	3.64	3.35	3.52	
	Median	25.89	25.20	25.59	
	Q1-Q3	[24.10;29.70]	[23.57;27.71]	[24.02;28.92]	
FzfY	N	30	30	60	0.7426
	Min-Max	[38.30;55.76]	[41.61;55.39]	[38.30;55.76]	
	Mean	48.48	48.86	48.67	
	SD	4.78	4.13	4.43	
	Median	48.64	49.35	49.16	
	Q1-Q3	[44.53;53.16]	[45.55;52.24]	[44.95;52.48]	
FzfZ	N	30	30	60	0.9574
	Min-Max	[43.34;53.79]	[43.59;53.46]	[43.34;53.79]	
	Mean	49.17	49.20	49.19	
	SD	2.59	1.89	2.25	
	Median	49.73	49.06	49.29	
	Q1-Q3	[47.62;50.42]	[48.17;50.38]	[47.98;50.41]	
MpX	N	30	30	60	0.2510
	Min-Max	[39.24;51.70]	[37.46;52.72]	[37.46;52.72]	
	Mean	45.13	44.19	44.66	
	SD	3.27	3.00	3.15	
	Median	45.28	43.79	44.21	
	Q1-Q3	[43.30;47.32]	[42.82;45.84]	[42.82;46.67]	
MpY	N	30	30	60	0.9167
	Min-Max	[38.27;55.69]	[32.70;51.40]	[32.70;55.69]	
	Mean	46.07	46.19	46.13	
	SD	4.50	4.40	4.41	
	Median	46.23	47.02	46.77	
	Q1-Q3	[43.89;49.50]	[44.88;49.18]	[44.20;49.34]	
MpZ	N	30	30	60	0.8735
	Min-Max	[38.79;48.22]	[35.57;50.09]	[35.57;50.09]	

	Mean	43.69	43.80	43.74	
	SD	2.51	2.73	2.60	
	Median	43.94	43.89	43.89	
	Q1-Q3	[41.73;45.70]	[42.53;45.16]	[42.05;45.32]	
OrX	N	30	30	60	0.3375
	Min-Max	[20.71;30.87]	[21.62;29.56]	[20.71;30.87]	
	Mean	25.55	25.01	25.28	
	SD	2.41	1.90	2.17	
	Median	25.00	25.03	25.02	
	Q1-Q3	[24.10;27.15]	[23.83;26.38]	[23.97;26.54]	
OrY	N	30	30	60	0.8325
	Min-Max	[47.67;66.14]	[47.89;65.40]	[47.67;66.14]	
	Mean	57.39	57.63	57.51	
	SD	4.92	3.99	4.44	
	Median	57.39	57.53	57.52	
	Q1-Q3	[53.98;61.16]	[55.24;60.73]	[54.40;61.05]	
OrZ	N	30	30	60	0.5313
	Min-Max	[33.30;45.52]	[33.54;42.21]	[33.30;45.52]	
	Mean	38.04	37.63	37.83	
	SD	2.81	2.23	2.52	
	Median	37.92	37.64	37.79	
	Q1-Q3	[36.88;39.66]	[36.30;39.14]	[36.46;39.47]	
ZFSX	N	30	30	60	0.2043
	Min-Max	[0.08;6.57]	[0.16;6.90]	[0.08;6.90]	
	Mean	2.02	2.57	2.29	
	SD	1.51	1.77	1.66	
	Median	1.76	2.23	1.83	
	Q1-Q3	[1.01;2.63]	[1.31;3.68]	[1.16;2.99]	
ZFSZ	N	30	30	60	0.9810
	Min-Max	[43.29;54.25]	[43.59;52.25]	[43.29;54.25]	
	Mean	49.13	49.14	49.14	
	SD	2.20	1.65	1.93	
	Median	49.04	48.94	48.94	
	Q1-Q3	[48.09;50.34]	[48.23;50.09]	[48.16;50.24]	
ZtX	N	30	30	60	0.8279
	Min-Max	[25.55;35.62]	[24.95;38.68]	[24.95;38.68]	
	Mean	31.32	31.50	31.41	
	SD	2.60	3.46	3.04	
	Median	31.87	31.14	31.39	
	Q1-Q3	[29.33;33.41]	[30.00;33.09]	[29.73;33.18]	

ZtY	N	30	30	60	0.6439
	Min-Max	[13.75;32.49]	[12.45;29.06]	[12.45;32.49]	
	Mean	22.08	22.63	22.35	
	SD	4.60	4.66	4.60	
	Median	21.46	23.29	22.52	
	Q1-Q3	[19.42;25.90]	[21.04;26.24]	[19.46;26.23]	
ZtZ	N	30	30	60	0.8135
	Min-Max	[52.01;66.93]	[53.82;63.51]	[52.01;66.93]	
	Mean	59.53	59.36	59.45	
	SD	3.31	2.34	2.84	
	Median	59.48	59.41	59.48	
	Q1-Q3	[57.92;61.70]	[57.77;61.27]	[57.85;61.52]	

Table S4. Comparison healthy sides between both groups. Confidence Interval: [-2.5 ; 2.5], (35).

		Center 1 N=30	Center 2 N=30	Total N=60	p-value
FZSY	N	30	30	60	0.0645
	Min-Max	[40.18;60.22]	[41.82;62.64]	[40.18;62.64]	
	Mean	52.05	54.27	53.16	
	SD	4.40	4.68	4.64	
	Median	52.06	54.26	53.24	
	Q1-Q3	[49.67;55.81]	[51.67;57.54]	[50.54;56.17]	
FzfX	N	30	30	60	0.7325
	Min-Max	[20.49;32.21]	[21.10;32.54]	[20.49;32.54]	
	Mean	26.21	25.93	26.07	
	SD	2.78	3.43	3.10	
	Median	26.37	25.50	26.14	
	Q1-Q3	[24.03;27.89]	[23.00;28.54]	[23.63;28.32]	
FzfY	N	30	30	60	0.1461
	Min-Max	[37.73;54.78]	[37.41;57.27]	[37.41;57.27]	
	Mean	45.91	47.69	46.80	
	SD	4.89	4.44	4.71	
	Median	45.59	47.63	46.15	
	Q1-Q3	[42.23;50.46]	[45.60;49.49]	[44.29;50.14]	
FzfZ	N	30	30	60	0.7846
	Min-Max	[43.67;57.06]	[37.73;55.87]	[37.73;57.06]	
	Mean	48.96	48.73	48.85	
	SD	2.77	3.60	3.19	
	Median	49.20	48.43	48.51	
	Q1-Q3	[46.97;50.20]	[46.65;50.62]	[46.74;50.32]	
MpX	N	30	30	60	0.1627
	Min-Max	[38.21;54.90]	[38.01;52.64]	[38.01;54.90]	
	Mean	45.38	44.09	44.74	
	SD	3.29	3.75	3.56	
	Median	45.52	44.53	44.91	
	Q1-Q3	[43.32;46.75]	[41.16;45.79]	[42.38;46.67]	
MpY	N	30	30	60	0.3901
	Min-Max	[32.09;54.27]	[28.69;53.32]	[28.69;54.27]	
	Mean	42.42	43.62	43.02	
	SD	5.70	5.01	5.35	
	Median	43.01	44.36	43.33	
	Q1-Q3	[38.86;45.63]	[40.51;47.26]	[40.20;46.48]	
MpZ	N	30	30	60	0.6686

	Min-Max	[32.80;51.94]	[30.75;48.92]	[30.75;51.94]	
	Mean	41.51	41.98	41.74	
	SD	4.30	3.99	4.12	
	Median	42.64	42.37	42.45	
	Q1-Q3	[38.59;43.97]	[39.18;45.26]	[39.05;44.40]	
OrX	N	30	30	60	0.9798
	Min-Max	[20.76;30.67]	[21.67;29.40]	[20.76;30.67]	
	Mean	25.22	25.24	25.23	
	SD	2.42	2.14	2.27	
	Median	25.01	25.15	25.11	
	Q1-Q3	[23.85;26.51]	[23.93;26.78]	[23.87;26.63]	
OrY	N	30	30	60	0.2315
	Min-Max	[44.76;69.27]	[43.31;64.87]	[43.31;69.27]	
	Mean	54.51	56.30	55.41	
	SD	6.36	5.03	5.75	
	Median	53.94	56.49	55.81	
	Q1-Q3	[49.61;59.23]	[52.35;60.16]	[51.46;59.41]	
OrZ	N	30	30	60	0.2381
	Min-Max	[29.80;41.73]	[27.30;43.04]	[27.30;43.04]	
	Mean	36.43	35.49	35.96	
	SD	2.90	3.15	3.04	
	Median	37.06	35.60	36.18	
	Q1-Q3	[34.41;38.47]	[33.61;37.83]	[33.68;38.22]	
ZFSX	N	30	30	60	0.4603
	Min-Max	[0.06;7.12]	[0.14;5.94]	[0.06;7.12]	
	Mean	2.59	2.29	2.44	
	SD	1.52	1.58	1.54	
	Median	2.39	1.98	2.09	
	Q1-Q3	[1.37;3.50]	[0.98;3.11]	[1.32;3.28]	
ZFSZ	N	30	30	60	0.9590
	Min-Max	[43.79;53.00]	[42.26;54.13]	[42.26;54.13]	
	Mean	48.97	49.00	48.98	
	SD	2.20	2.29	2.23	
	Median	49.00	49.13	49.05	
	Q1-Q3	[47.39;50.34]	[47.91;50.39]	[47.58;50.36]	
ZtX	N	30	30	60	0.2221
	Min-Max	[24.98;38.14]	[24.94;37.80]	[24.94;38.14]	
	Mean	31.81	30.80	31.30	

	SD	3.13	3.16	3.16	
	Median	32.03	30.54	31.51	
	Q1-Q3	[29.86;33.97]	[28.25;33.01]	[28.76;33.64]	
ZtY	N	30	30	60	0.4284
	Min-Max	[12.64;28.00]	[11.24;33.33]	[11.24;33.33]	
	Mean	21.70	22.59	22.15	
	SD	3.91	4.72	4.32	
	Median	22.77	22.52	22.52	
	Q1-Q3	[18.85;24.95]	[20.48;24.71]	[18.95;24.83]	
ZtZ	N	30	30	60	0.9420
	Min-Max	[49.62;69.82]	[49.42;68.65]	[49.42;69.82]	
	Mean	59.49	59.57	59.53	
	SD	4.79	3.98	4.36	
	Median	60.05	59.63	59.95	
	Q1-Q3	[56.10;63.33]	[56.74;62.60]	[56.61;62.66]	

Table S5. Comparison broken sides between both groups. Confidence Interval: [-2.5 ; 2.5],(35).

CRWF		Broken N=30	Heathy N=30	Total N=60	p-value
FZSY	N	30	30	60	0.2604
	Min-Max	[40.18;60.22]	[43.61;59.19]	[40.18;60.22]	
	Mean	52.05	52.48	52.27	
	SD	4.40	3.82	4.09	
	Median	52.06	52.25	52.22	
	Q1-Q3	[49.67;55.81]	[49.98;55.36]	[49.92;55.55]	
FzfX	N	30	30	60	0.2350
	Min-Max	[20.49;32.21]	[20.68;34.00]	[20.49;34.00]	
	Mean	26.21	26.69	26.45	
	SD	2.78	3.39	3.09	
	Median	26.37	27.06	26.44	
	Q1-Q3	[24.03;27.89]	[24.71;29.01]	[24.17;28.68]	
FzfY	N	30	30	60	0.0016
	Min-Max	[37.73;54.78]	[37.79;61.95]	[37.73;61.95]	
	Mean	45.91	48.02	46.97	
	SD	4.89	4.91	4.97	
	Median	45.59	48.20	46.36	
	Q1-Q3	[42.23;50.46]	[44.90;49.93]	[43.29;50.15]	
FzfZ	N	30	30	60	0.6482
	Min-Max	[43.67;57.06]	[40.89;54.62]	[40.89;57.06]	
	Mean	48.96	48.70	48.83	
	SD	2.77	2.78	2.75	
	Median	49.20	48.87	49.07	
	Q1-Q3	[46.97;50.20]	[46.68;50.04]	[46.96;50.17]	
MpX	N	30	30	60	0.6798
	Min-Max	[38.21;54.90]	[39.34;51.73]	[38.21;54.90]	
	Mean	45.38	45.24	45.31	
	SD	3.29	3.02	3.13	
	Median	45.52	45.52	45.52	
	Q1-Q3	[43.32;46.75]	[43.44;46.68]	[43.34;46.72]	
MpY	N	30	30	60	0.0010
	Min-Max	[32.09;54.27]	[36.72;53.65]	[32.09;54.27]	
	Mean	42.42	44.82	43.62	
	SD	5.70	4.57	5.26	
	Median	43.01	44.51	43.83	
	Q1-Q3	[38.86;45.63]	[41.65;48.24]	[40.20;47.59]	
MpZ	N	30	30	60	0.0046
	Min-Max	[32.80;51.94]	[37.84;50.13]	[32.80;51.94]	

	Mean	41.51	43.74	42.63	
	SD	4.30	2.84	3.78	
	Median	42.64	44.02	42.98	
	Q1-Q3	[38.59;43.97]	[41.40;45.58]	[40.87;44.62]	
OrX	N	30	30	60	0.2186
	Min-Max	[20.76;30.67]	[20.98;29.32]	[20.76;30.67]	
	Mean	25.22	25.60	25.41	
	SD	2.42	2.16	2.28	
	Median	25.01	26.11	25.33	
	Q1-Q3	[23.85;26.51]	[24.27;27.00]	[24.02;26.92]	
OrY	N	30	30	60	0.0020
	Min-Max	[44.76;69.27]	[49.41;65.14]	[44.76;69.27]	
	Mean	54.51	57.05	55.78	
	SD	6.36	4.39	5.56	
	Median	53.94	56.88	55.71	
	Q1-Q3	[49.61;59.23]	[53.64;60.79]	[52.06;60.00]	
OrZ	N	30	30	60	0.0877
	Min-Max	[29.80;41.73]	[32.21;40.56]	[29.80;41.73]	
	Mean	36.43	37.35	36.89	
	SD	2.90	2.45	2.70	
	Median	37.06	38.18	37.45	
	Q1-Q3	[34.41;38.47]	[35.73;39.23]	[34.79;38.88]	
ZFSX	N	30	30	60	0.2666
	Min-Max	[0.06;7.12]	[0.02;5.11]	[0.02;7.12]	
	Mean	2.59	2.30	2.45	
	SD	1.52	1.47	1.49	
	Median	2.39	2.62	2.51	
	Q1-Q3	[1.37;3.50]	[0.87;3.59]	[1.32;3.54]	
ZFSZ	N	30	30	60	0.5263
	Min-Max	[43.79;53.00]	[44.27;54.83]	[43.79;54.83]	
	Mean	48.97	49.17	49.07	
	SD	2.20	2.07	2.12	
	Median	49.00	49.06	49.00	
	Q1-Q3	[47.39;50.34]	[47.99;50.44]	[47.80;50.36]	
ZtX	N	30	30	60	0.2600
	Min-Max	[24.98;38.14]	[25.26;36.36]	[24.98;38.14]	
	Mean	31.81	31.28	31.54	
	SD	3.13	2.51	2.83	
	Median	32.03	31.32	31.59	
	Q1-Q3	[29.86;33.97]	[29.42;33.19]	[29.51;33.71]	

ZtY	N	30	30	60	0.3670
	Min-Max	[12.64;28.00]	[15.68;31.83]	[12.64;31.83]	
	Mean	21.70	22.24	21.97	
	SD	3.91	4.19	4.02	
	Median	22.77	21.62	21.90	
	Q1-Q3	[18.85;24.95]	[19.85;25.56]	[19.03;25.01]	
ZtZ	N	30	30	60	0.9761
	Min-Max	[49.62;69.82]	[52.98;65.90]	[49.62;69.82]	
	Mean	59.49	59.47	59.48	
	SD	4.79	3.15	4.02	
	Median	60.05	59.43	59.73	
	Q1-Q3	[56.10;63.33]	[56.94;62.12]	[56.67;62.34]	

Table S6. Comparison broken sides and healthy sides in CRWF group. Confidence Interval: [-2.5 ; 2.5], (35).

ORIF		Broken N=30	Healthy N=30	Total N=60	p-value
FZSY	N	30	30	60	0.2299
	Min-Max	[41.82;62.64]	[45.04;61.02]	[41.82;62.64]	
	Mean	54.27	53.71	53.99	
	SD	4.68	4.25	4.44	
	Median	54.26	53.70	53.78	
	Q1-Q3	[51.67;57.54]	[51.45;57.10]	[51.54;57.22]	
FzfX	N	30	30	60	0.2575
	Min-Max	[21.10;32.54]	[17.99;32.81]	[17.99;32.81]	
	Mean	25.93	25.39	25.66	
	SD	3.43	3.80	3.60	
	Median	25.50	25.35	25.45	
	Q1-Q3	[23.00;28.54]	[22.75;29.06]	[22.97;28.80]	
FzfY	N	30	30	60	0.0677
	Min-Max	[37.41;57.27]	[39.99;57.27]	[37.41;57.27]	
	Mean	47.69	49.04	48.37	
	SD	4.44	4.48	4.47	
	Median	47.63	48.75	47.71	
	Q1-Q3	[45.60;49.49]	[45.74;51.71]	[45.65;51.33]	
FzfZ	N	30	30	60	0.4948
	Min-Max	[37.73;55.87]	[44.04;53.49]	[37.73;55.87]	
	Mean	48.73	49.13	48.93	
	SD	3.60	1.91	2.87	
	Median	48.43	48.79	48.56	
	Q1-Q3	[46.65;50.62]	[47.98;50.47]	[47.72;50.55]	
MpX	N	30	30	60	0.6398
	Min-Max	[38.01;52.64]	[36.14;53.68]	[36.14;53.68]	
	Mean	44.09	43.87	43.98	
	SD	3.75	3.55	3.62	
	Median	44.53	43.93	44.10	
	Q1-Q3	[41.16;45.79]	[41.61;46.51]	[41.24;45.99]	
MpY	N	30	30	60	0.0009
	Min-Max	[28.69;53.32]	[32.35;53.32]	[28.69;53.32]	
	Mean	43.62	46.30	44.96	
	SD	5.01	4.76	5.03	
	Median	44.36	47.08	45.76	
	Q1-Q3	[40.51;47.26]	[45.14;49.39]	[41.70;47.92]	
MpZ	N	30	30	60	0.0754

	Min-Max	[30.75;48.92]	[36.72;48.88]	[30.75;48.92]	
	Mean	41.98	43.36	42.67	
	SD	3.99	3.01	3.57	
	Median	42.37	43.18	42.49	
	Q1-Q3	[39.18;45.26]	[41.14;45.44]	[40.68;45.35]	
OrX	N	30	30	60	0.1280
	Min-Max	[21.67;29.40]	[21.10;28.55]	[21.10;29.40]	
	Mean	25.24	24.63	24.93	
	SD	2.14	2.18	2.17	
	Median	25.15	24.64	25.03	
	Q1-Q3	[23.93;26.78]	[22.83;26.27]	[23.12;26.51]	
OrY	N	30	30	60	0.0827
	Min-Max	[43.31;64.87]	[47.44;65.61]	[43.31;65.61]	
	Mean	56.30	57.81	57.06	
	SD	5.03	4.88	4.97	
	Median	56.49	57.79	57.38	
	Q1-Q3	[52.35;60.16]	[55.11;62.06]	[53.04;61.54]	
OrZ	N	30	30	60	0.0020
	Min-Max	[27.30;43.04]	[32.57;41.19]	[27.30;43.04]	
	Mean	35.49	37.32	36.40	
	SD	3.15	2.21	2.85	
	Median	35.60	37.74	36.91	
	Q1-Q3	[33.61;37.83]	[36.28;38.54]	[34.42;38.36]	
ZFSX	N	30	30	60	0.6834
	Min-Max	[0.14;5.94]	[0.05;6.38]	[0.05;6.38]	
	Mean	2.29	2.18	2.24	
	SD	1.58	1.84	1.70	
	Median	1.98	1.58	1.86	
	Q1-Q3	[0.98;3.11]	[0.66;3.55]	[0.73;3.15]	
ZFSZ	N	30	30	60	0.8374
	Min-Max	[42.26;54.13]	[44.04;52.18]	[42.26;54.13]	
	Mean	49.00	49.05	49.02	
	SD	2.29	1.87	2.07	
	Median	49.13	48.76	48.83	
	Q1-Q3	[47.91;50.39]	[47.97;49.96]	[47.95;50.33]	
ZtX	N	30	30	60	0.2808
	Min-Max	[24.94;37.80]	[25.03;39.19]	[24.94;39.19]	
	Mean	30.80	31.33	31.07	

	SD	3.16	3.62	3.38	
	Median	30.54	31.03	30.74	
	Q1-Q3	[28.25;33.01]	[29.49;32.73]	[28.76;33.01]	
ZtY	N	30	30	60	0.4987
	Min-Max	[11.24;33.33]	[12.07;32.83]	[11.24;33.33]	
	Mean	22.59	23.14	22.87	
	SD	4.72	5.30	4.98	
	Median	22.52	23.71	22.86	
	Q1-Q3	[20.48;24.71]	[19.86;26.91]	[20.44;26.07]	
ZtZ	N	30	30	60	0.4810
	Min-Max	[49.42;68.65]	[53.25;63.61]	[49.42;68.65]	
	Mean	59.57	59.14	59.36	
	SD	3.98	2.54	3.31	
	Median	59.63	59.51	59.51	
	Q1-Q3	[56.74;62.60]	[57.52;60.99]	[57.33;61.67]	

Table S7. Comparison broken sides and healthy sides in ORIF group. Confidence Interval: [-2.5 ; 2.5], (35).

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ETUDE COMPARATIVE DE DEUX TECHNIQUES CHIRURGICALES DANS LE TRAITEMENT DES FRACTURES INSTABLES DE L'OS ZYGOMATIQUE : EMBROCHAGE TRANSFACIAL VERSUS OSTEOSYNTHESE PAR PLAQUES

RESUME

Introduction - Les fractures de l'os zygomatique (ZMC) sont fréquentes en traumatologie faciale. Parmi les techniques disponibles pour traiter les fractures instables du zygoma, la technique fermée par embrochage transfacial (CRWF) et la technique ouverte par ostéosynthèse par plaques (ORIF) peuvent être proposées. L'objectif de cette étude était d'évaluer radiologiquement la symétrie et la projection du zygoma lors de fractures instables traitées par ORIF et CRWF.

Matériel and Méthode – Soixante patients présentant une fracture instable chirurgicale de l'os zygomatique ont été inclus dans cette étude rétrospective et multicentrique. Les coordonnées de 5 points représentant la position de l'os zygomatique ont été recueillies des cotés sains et fracturés grâce à des reconstructions tridimensionnelles de scanners pré et post opératoires. Les deux techniques chirurgicales ont été comparées grâce à ces coordonnées.

Résultats – La position du zygoma était similaire après chirurgie quelque soit la technique utilisée. L'étude des images pré opératoires a montré une anatomie similaire et un même type de déplacement dans les deux groupes de patients. Le cintre zygomato-maxillaire s'est avéré être la fracture la plus difficile à réduire, et plus particulièrement avec la technique CRWF. Il n'y avait pas plus de complications dans une des techniques par rapport à l'autre et la durée opératoire était significativement inferieure dans la technique CRWF.

Conclusion – Cette étude apporte de forts arguments pour l'utilisation de l'embrochage transfacial chez les patients présentant une fracture tétrapodale instable du zygoma.

MOTS CLES : Kirschner Wires, Zygomatic Fracture, Open Fracture Reduction, Fracture Osteosynthesis, Bone Plate, Cephalometry