Tmj related short-term outcomes comparing two different osteosynthesis techniques for bilateral sagittal split osteotomy

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INTRODUCTION

Bilateral sagittal split osteotomy (BSSO), first described by Trauner and Obwegeser , is a commonly-used technique in orthognathic surgery. Epker and Dal Pont subsequently described popular modifications of the original technique [1]. Initially, the proximal and distal mandibular segments were fixed with a wire that was looped around the ramus, combined with immobilization of the jaw by intermaxillary fixation (IMF). Miniplate technique as a method of osteosynthesis was first introduced by Michelet [2], using small plates with monocortical screws in trauma and orthognathic patients. Subsequently, it has become another way to stabilize the mandibular segments after BSSO. Most of the modifications of the original splitting procedure were meant to minimize risk of pseudarthrosis, nonunion, and 2 split segments. With the introduction of osteosynthesis by screws or by miniplates, most these risks–have been alleviated. On the other hand, rigid internal fixation (RIF) allows to decrease considerably duration of intermaxillary blocking and contributes to patient comfort. Currently there are two main types of osteosynthesis; osteosynthesis by miniplates fixed with monocortical screws or rigid osteosynthesis with bicortical retro-molar screws with or without miniplates.

The effects of orthognathic surgery on temporomandibular joint (TMJ) adaptation and health remain uncertain, and the best type of osteosynthesis continues to be debated [3]. Some supporters of flexible osteosynthesis consider protection as a top priority, while others favor rigid osteosynthesis to reduce risk of pseudarthrosis, especially for large mandibular advancements. Yet neither approach has reportedly better stability, according to the most recent literature review [4]. However, bi-cortical retro-molar screws have been criticized for their possible consequences on TMJ health, by aggravating temporo-mandibular disorders (TMD)[5][6]. Bicortical screw fixation may produce greater torque in the proximal segment, which leads to more condyle displacement than would occur with semi-rigid fixation [7] (Figure1). For patients with pre-operative symptoms, many authors have reported improvement in TMJ function subsequent to combined orthodontic and surgical treatment of malocclusion, particularly for the relief of pain [8] [9]. TMJ improvement has also been observed after combined orthodontic and surgical procedures when rigid osteosynthesis was used[10][11].

Our main hypothesis was that the presence of bicortical screws was not a risk factor of TMD. The aim of our study was to compare TMD and TMJ symptoms after orthognathic surgery according to the type of osteosynthesis used, using the original Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) [12] and the Jaw Pain Function score (JPF) [13] [14] before the procedure and one year postoperatively.

MATERIALS AND METHODS

Patients

Consecutive patients with dentofacial deformities were included in this study, between February 2013 and April 2015, at Lille University. All patients had orthognathic surgery and belong to a cohort studying musculoskeletal heritable influence on malocclusion. This cohort protocol was validated by the French independent ethical committee, and the Temple University institutional review board. All subjects had at least a mandibular bilateral sagittal split osteotomy using Epker's technique [1]. Exclusion criteria were systemic conditions, facial trauma, tumor, condylar hypertrophy, arthritis, or developmental conditions that might influence TMJ disorder.

Age, sex, facial biometrics and TMJ symptoms, were listed during the preoperative examination. Cephalometric data and classification were obtained by Delaire et al. [15] analysis method.

Type of osteosynthesis

The type of osteosynthesis was noted retrospectively, using a cohort of patients recruited from previous prospective studies [10]. The type of osteosynthesis used was operator-dependent:

- "semi-rigid": involving one or two titanium mini plates connecting the osteotomy site. Screws thread only engages the buccal cortex (Figure 2A).
- "rigid" or "hybrid fixation": which had additional retromolar bi-cortical screws fixating the segments (Figure 2B). Two screws are usually used, engaging the buccal cortex of the proximal fragment and the lingual cortex of the distal

fragments behind the mini plates (Figure 2C). The term “Hybrid fixation” corresponds to osteosynthesis with bicortical retro-molar screws associated with miniplates.

TMJ evaluation

The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) [12] and the JPF score [13,14,16] were used before the surgical procedure and then one year postoperatively to evaluate TMJ health. The detailed method has been described previously [10].

RDC/TMD allowed classification of TMD according to the international guides, by screening TMJ symptoms before and one year after the surgical procedure**.** The examination noticed signs and symptoms according to the original RDC/TMD: including myalgia, arthralgia, headache, disc displacement with reduction (DDR) and disc displacement with reduction with intermittent locking (DDWR).

The JPF score was collected using a questionnaire divided into two parts: the first one relating to pain (PART A: PAIN with 8 questions) and the other one relating to temporomandibular functional disorders (PART B: FUNCTION with 5 questions). This final score obtained has been validated in the literature for the detection of TMD if it is greater than or equal to 6 with sensitivity of 90.3% and 97.7% and specificity between 95.7% and 100%. JPF score has mainly been chosen because, given that it is a score, it also makes it possible to assess changes in articular health.

The two scores have been used in two independent ways to determine the presence or change in TMD as follows:

1. We first considered RDC/TMD and JPF score before and one year after orthognathic surgery to select patients with postoperative TMD. Considering the JPF score and using the validated threshold, we obtained a qualitative variable: patients with JPF score ≥ 6 having TMD and patients with a JPF score < 6 were considered with no dysfunction. We then generated three groups: Iatrogenic TMD (JPF Score T0 < 6 and JPF SCORE T1 ≥ 6), TMD healing (JPF SCORE T0 ≥ 6 and JPF Score T1 < 6) and no change (JPF Score T0 and T1 < 6 or JPF Score T0 and T1 ≥ 6).
2. We then generated a variable based on JPF score change. This allowed us to identify patients who had worsening symptoms postoperatively. The variable was obtained by subtracting the postoperative score from the preoperative score (JPF = JPF preoperative score - postoperative score). Considering a threshold of –2, we obtained a qualitative variable in three groups. Patients with JPF Δ ≤ –2 represented the “significantly” worsening subpopulation while patients with JPF Δ > 2 were classified in the subpopulation with no worsening. We generated three groups: Improvement (JPF Δ > 2), worsening (JPF Δ ≤ –2) and no change (-2 ≥ JPF Δ < 2).

Statistical analysis

Quantitative variables are expressed as means (standard deviation, SD) in the case of normal distribution or medians (interquartile range) otherwise. Categorical variables are expressed as numbers (percentage). Normality of distributions was assessed using histograms and the Shapiro-Wilk test. Bivariate comparisons in baseline characteristics between the two study groups (semi-rigid vs rigid osteosynthesis) were made using Student t test for Gaussian continuous variables, Mann-Whitney U test for non-Gaussian continuous and ordinal categorical variables, Chi-Square test (or Fisher's exact test when the expected cell frequency was < 5) for categorical variables, as appropriate. One-change in RDC/TMD criteria and JPF scores from orthognathic surgery categorized as worsening, no-change and improvement, were compared between the two study groups using multinomial logistic regression models. For change in JPF scores, multinomial logistic regression models were adjusted on JPF scores assessed before orthognathic surgery.

Statistical testing was conducted at the two-tailed α-level of 0.05. Data was analyzed using the SAS software version 9.3 (SAS Institute, Cary, NC).

RESULTS

Between February 2013 and April 2015, 237 patients were included in the study. A total of 183 patients completed the postoperative evaluation. Patient selection is represented by the flow chart (Figure 3). Two groups were finally formed with 183 patients according to the type of osteosynthesis used: “semi-rigid” (n=42) and “rigid” (n=141).

As shown table 1, there was a greater proportion of women (64.5%, n = 118) equitably distributed in both groups: 67% in the rigid osteosynthesis group and 55% in the semi-rigid osteosynthesis group (p=0,13). The two groups were comparable for age (p=0,74), type of movement (p=0,92), biomedical characteristics (0,92) and RDC/TMD criteria (all p>0.087) except for headache rate that was higher in semi-rigid type of osteosynthesis (14,3% vs 3,5%, p=0.019). The median JPF score at inclusion was also higher in the semi-rigid compared to the type of osteosynthesis (p=0.024).

We did not find a significant difference regarding changes in the JPF score absolute value, whether it is aggravated (JPF Δ ≤ –2), improved (JPF Δ > 2) or unchanged (-2 ≥ JPF Δ < 2) according to the type of osteosynthesis used. (p=0,29) adjusted on JPF score at baseline.

With the JPF SCORE threshold ≥ 6 as a positive diagnosis of TMD, 135 patients remained unchanged, 26 were cured and 22 developed a postoperative TMD but we did not find a significant difference according to the type of osteosynthesis used (p=0,40).

Utilizing the criteria of the RDC / TMD we did not find significant differences for myalgia (p=0,93), arthralgia (p=0,91), DDR (p=0,95) according to the osteosynthesis used. Statistical analysis could not be performed for changes in DDWR and headache because the number of patients in each group was too small (table 2).

DISCUSSION

Mandibular osteotomy in dentofacial deformities patients following orthognathic surgery can directly affect TMJ symptoms, masticatory muscles and surrounding soft tissues. Female sex, amount of mandibular advancement and degree of counterclockwise rotation of the mandible are the main factors influencing the TMJ health after BSSO [17,18]. In our cohort the two techniques of osteosynthesis compared are equivalent in TMJ health after BSSO.

Kundert et al found that condylar displacements like rotation or tilting of the axis of the condyle are frequently found after BSSO. He concluded that the method of osteosynthesis and direction of movement of dental arch influenced the direction and the amount of condylar displacement [19]. The importance of correct positioning of the condyles before fixation is well-known and a suitable position of the condyle relative to the condylar axis is one of the conditions for a successful outcome of BSSO [7]. Reproducing the original condylar position during BSSO is difficult, too much pressure can be placed against the articular disc or unfavorable condylar position can be created during BSSO. These conditions can potentially result in joint noise or pain and can worsen any pre-existing TMD symptoms.

Multiple animal studies have assessed the osseous changes that have been associated with condylar displacement [20]. These studies have shown consistent osseous resorption of the postglenoid spine and posterior condylar surface when the condyle is posteriorly displaced and compressed in the glenoid fossa. On the other hand, Arnett and Tamborello have demonstrated morphologic changes of the human mandibular condyle associated with posteriorization and/or medial or lateral condylar torquing during orthognathic surgery [21] [22]. They highlighted that sagittal osteotomy techniques included no segment clamping, no bicortical screws, plate fixation, a short split and anterior bone anchor placement prevent condylar torque. When bicortical screws are applied, the proximal segment is positioned, and a bone clamp is placed across the osteotomy to maintain the position. If the clamp is not completely passive it will compress the segments and it can produce lingual or rotational movement of the proximal segment, this negates the advantage of the position screw, and makes it function like a lag screw (figure1). This is the main criticism of bicortical screws, since condylar torquing may occur due to segment clamping and resultant condylar resorption [7]. In this condition, bicortical screws are probably more responsible of dysfunctional TMJ remodeling or condylar resorption due to condylar torquing [23]. According to their computer models analysis, Ureturk et al [24] also found that using bicortical screws amount the stress on the condyle. However, some studies do not confirm this hypothesis. In a retrospective cohort study patients Tabrizi compared the changes in the condylar position and stability after BSSO for mandibular setback in plate fixation with monocortical screws and bicortical screws. He could not find significant differences in surgical stability between miniplate fixation with monocortical screws and bicortical screw fixation after 1 year of follow-up [3]. A possible explanation for this difference is that it is easier to set the condyles correctly in the fossa before rigid fixation when the soft tissues, as in the case of setbacks, are not extensively stretched. It is less difficult to obtain a stable result after surgical setback than after mandibular advancement. Another study suggested that there were no significant differences in postoperative skeletal stability and condylar position between miniplate and bicortical screw fixation groups after BSSO [25].

Hybrid technique fixation is advantageous since it combines advantages of each technique; while limiting condylar torqueing, which is probably the main disadvantage of bicortical screws. With hybrid fixation the miniplate is indeed applied first using monocortical screws. There is no need to place a clamp across the osteotomy and the segments are not compressed. The bicortical position screw is then applied, so that there is no alteration in the intersegmental relationship. This technique shares the advantage of permitting the surgeon to check the occlusion and the condylar movements before conclusion of the operation. Nevertheless, this technique needs a learning curve and the risk of complications is reduced when experienced surgeons perform the procedure.

It seems intuitive to think that condylar displacement generates TMJ symptoms and even more so TMD. The debate still remains open on the impact factor of the technique of osteosynthesis in the origin of TMD. Many studies compare stability according to the technique of osteosynthesis used but none compared the influence of the technique for TMJ health. Bruxism and dysfunctional oral habits were shown to be risk factors for the presence of TMD symptoms also after combined orthodontic and surgical treatment[26]. Age, female sex, amount of advancement and counterclockwise rotation of the mandible are the main factors currently highlighted in health joint after BSSO. Few studies focused on the role of osteosynthesis in TMJ health probably because of these confounding factors. We took the necessary precautions for the two groups to be comparable for those factors.

Determining the influence of osteosynthesis on the articular dysfunctional symptomatology requires an evaluation criterion adapted to the dysfunctional articular symptoms. TMD have been defined by the American Academy of Orofacial Pain (AAOP) as a group of musculoskeletal and neuromuscular disorders, which involve the masticatory musculature, the temporomandibular joints and associated structures [24]. Although JPF score does not distinguish between different subtypes of TMD as recommended by the International Association for Dental Research (IADR) and the International Association of Study of Pain (IASP) [28] or the AAOP[12], we have chosen to use both RDC / TMD and JPF score for TMD evaluation. This quantitative score with a pathological threshold defined in the literature then allowed us to consider patients with iatrogenic TMD (JPF Score T0 < 6 and JPF SCORE T1 ≥ 6), TMD healing (JPF SCORE T0 ≥ 6 and JPF Score T1 < 6) and no change (JPF Score T0 and T1 < 6 or JPF Score T0 and T1 ≥ 6). The main criticism of this distribution is that it does not make it possible to distinguish patients whose symptomatology has evolved significantly but remains above or below the defined threshold. Patient with JPF T0 equal to 1 and JPF T1 equal to 5 is considered unchanged although another one with JPF T0 equal to 6 and JPF T1 equal to 5 is considered improved. Therefore, the variable Δ JPF takes on its full meaning to determine patients with symptoms worsening (JPF $\Delta \leq -2$), improved (JPF $\Delta > 2$) or unchanged ($-2 \geq$ JPF $\Delta < 2$). The threshold selected was determined arbitrarily and corresponds to a 30% worsening of the threshold defined in the literature for the detection of TMD. Scolozzi et al [29] evaluated the predictive value of preoperative clinical factors for postoperative TMDs in patients receiving combined surgical-orthodontic treatment using the Helkimo index. The assessment of TMJ symptoms with a reliable score is difficult. Currently, TMJ diagnosis has to be assess with

DC/TMD according to recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. Nevertheless, this assessment method does not allow to obtain a nation of symptoms intensity and is therefore less effective in determining an evolution of these symptoms. This prospective study has begun before publication of DC/TMD explaining why the authors have chosen the RDC/TMD. Here, authors completed RDC/TMD assessment with the JPF questionnaire to get this notion of worsening. Helkimo index is another reliable assessment system which could have been used instead of JPF questionnaire.

This study has some limitations. The first limit noted is related to power of the study. Considering the retrospective character of osteosynthesis modalities collection, power of the study was not initially adapted to respond to the question asked. Absence of randomization generated on the other hand an imbalance between the two groups of osteosynthesis. On 237 consecutive patients included in this study, only 42 patients were distributed in the group “semi-rigid osteosynthesis”. However, by increasing the number of patients included compared to the previous study carried out, we noticed a decrease in the threshold of significance [10], suggesting that increasing the power of the study does not affect statistical analysis and limits power bias. Otherwise the two groups were not comparable preoperatively for the JPF score and we needed to adjust the statistical analysis. We did not test the interaction between osteosynthesis and mandibular movement as there was no significant effect of osteosynthesis on the outcomes studied. Furthermore, we compared TMJ response after bimaxillary osteotomy and after BSSO. There was no significant effect of osteosynthesis on the outcomes studied (all $p > 0,65$).

On the other hand, testing an interaction requires more statistical power than testing a link and our strength remains limited.

IRF have the benefits of securing the osteotomy segments, preventing displacement from muscular pull, shortening the healing period, obviating the need for maxillomandibular fixation, and preventing relapse. Comparing osteosynthesis by miniplates with the hybrid fixation we did not find differences in postoperative TMJ health as detected by the RDC/TMD criteria or JPF score. In our experience the hybrid technique fixation affords many advantages and does not influence postoperative TMD compared with osteosynthesis by miniplates.

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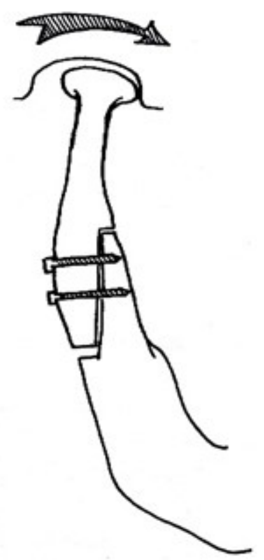

Figure 1A - Frontal view of TMJ with bicortical screws fixation and condylar torquing simulation.

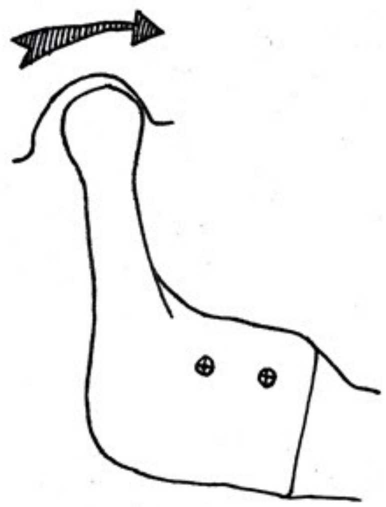

Figure 1B - Lateral view of TMJ with bicortical screws fixation and condylar torquing simulation.

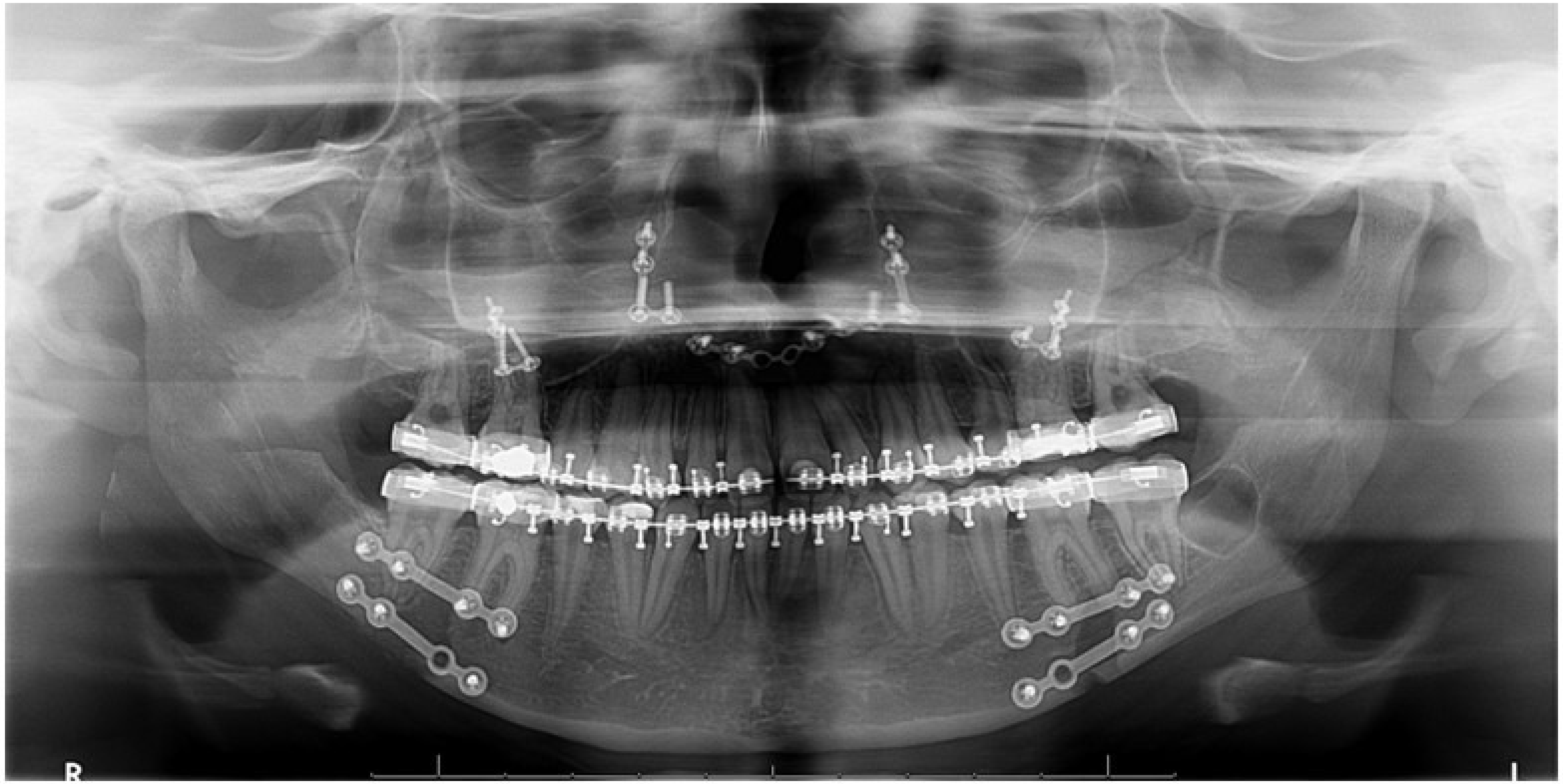

Figure 2A : Classic osteosynthesis by plates : screws thread only engage buccal cortex.

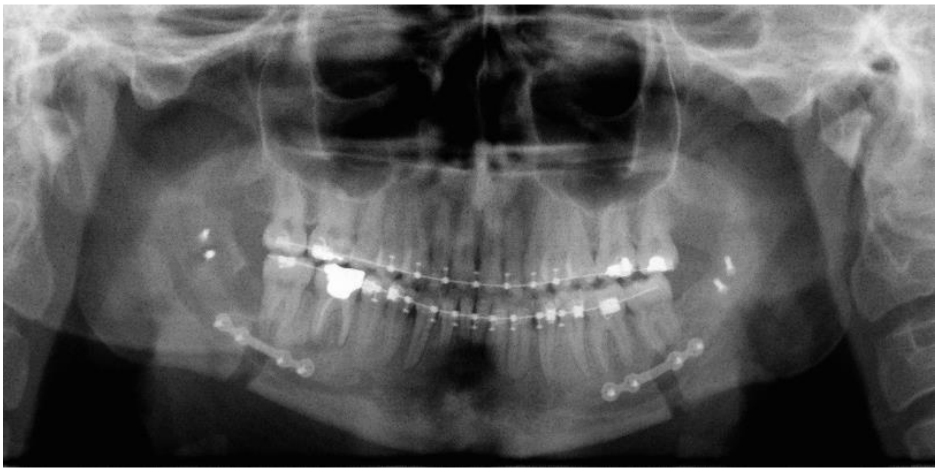

Figure 2B: Rigid osteosynthesis or hybrid fixation: retromolar bi-cortical screws fixating the segments

Figure 2C: Frontal view of retromolar bi-cortical screws, engaging the buccal cortex of the proximal fragment and the lingual cortex of the distal seqment.

Table 1. Comparison of preoperative factors between the two study groups

	Type of osteosynthesis		
	RIGID (n=141)	SEMI-RIGID (n=42)	p value
Characteristics			
Age, mean (SD)	25.9 (10.9)	24.6 (9.4)	0.74
Women	95 (67.4)	23 (54.8)	0.13
Bimaxillary osteotomy	95 (67,4)	19 (45,2)	
BSSO	46 (32,6)	23 (54,8)	
Mandibular advancement	103 (73)	31 (73.8)	0.92
Biometrical characteristics sagittal			
- **Class 2**	103 (73)	31 (73.8)	0.92
- **Class 3**	38 (27)	11 (26,2)	
RDC/TMD criteria			
Myalgia	23 (16.3)	7 (16.7)	0.96
Arthralgia	17 (12.1)	9 (21.4)	0.13
DDR	29 (20.6)	14 (33.3)	0.087
DDWR	1 (0.7)	1 (2.4)	-
Headache	5 (3.5)	6 (14.3)	0.019*
JPF Score, median (IQR)	2.0 (0 to 6.0)	4.0 (1.0 to 6.0)	0.024*

Values are expressed as number (%) otherwise indicated. DDR=Disc displacement with reduction, DDWR=Disc displacement with reduction with intermittent locking, IQR=interquartile range, JPF=Jaw Pain function, NA=Not applicable.

*Groups were not comparable for headache and JPF score at inclusion and required a statistical adjustment.

Table 2. Comparison of JPF and RDC/TMD criteria changes before and one year after orthognathic surgery between the two study groups

		Type of osteosynthesis		
		RIGID (n=141)	SEMI-RIGID (n=42)	p-value
JPF score *n (%)*	Worsening[a]	40 (28.4)	12 (28.6)	0.29*
	no change	57 (40.4)	10 (23.8)	
	Improvement[b]	44 (31.2)	20 (47.6)	
	Iatrogenic TMD [c]	18 (12.8)	4 (9.5)	0.40*
	no change	102 (72.3)	33 (78.6)	
	TMD healing [d]	21 (14.9)	5 (11.9)	
MYALGIA *n (%)*	Worsening[e]	9 (6.4)	2 (4.8)	0.93
	no change	115 (81.6)	35 (83.3)	
	improvement[f]	17 (12.0)	5 (11.9)	
ARTHRALGIA *n (%)*	Worsening[e]	12 (8.5)	3 (7.1)	0.91
	no change	118 (83.7)	35 (83.3)	
	Improvement[f]	11 (7.8)	4 (9.5)	
DDR *n (%)*	Worsening[e]	9 (6.4)	3 (7.1)	0.95
	no change	113 (80.1)	34 (81.0)	
	Improvement[f]	19 (13.5)	5 (11.9)	
DDWR *n (%)*	Worsening[e]	7 (5.0)	1 (2.4)	NA
	no change	133 (94.3)	40 (95.2)	
	Improvement[f]	1 (0.7)	1 (2.4)	
HEADACHE *n (%)*	Worsening[e]	0 (0)	0 (0)	NA
	no change	137 (97.2)	36 (85.7)	
	Improvement[f]	4 (2.8)	6 (14.3)	

[a] JPF $\Delta \leq -2$, [b] JPF $\Delta > 2$, [c] JPF Score T0 < 6 and JPF SCORE T1 ≥ 6, [d] JPF SCORE T0 ≥ 6 and JPF Score T1 < 6, [e]appearance of symptoms between T0 and T1, [f]disappearance of symptoms between T0 and T1. * P-value obtained with multinomial logistic model adjusted on JPF score at baseline. NA indicates not applicable.