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Transmucosal pterygomaxillary disjunction using a piezoelectric device, in the context of the minimally invasive Le Fort I osteotomy protocol

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Abstract. The aim of this study was to assess the accuracy and clinical implications of pterygomaxillary junction (PMJ) disjunction with a transmucosal PMJ osteotomy using a piezoelectric hand-piece device, in the context of Le Fort I osteotomy, by evaluating the level of PMJ disarticulation and the need for bone trimming around the pedicle. An ambidirectional 1-month follow-up cohort study was designed involving consecutive patients undergoing minimally invasive maxillary Le Fort I osteotomy through the twist technique. Two cohorts were defined according to whether or not the transmucosal PMJ osteotomy was performed. The site of PMJ disjunction was analysed radiographically. A total of 114 patients were included in the study, 57 in each group. The overall accuracy of the PMJ disjunction path was higher in the test group (43.9%) than in the control group (15.8%). Multiple logistic regression analysis identified the need for bone trimming (odds ratio 0.02; $P < 0.001$) and removal of the upper third molar (odds ratio 0.17; $P < 0.001$) as relevant factors. In conclusion, compared with the originally described twist technique, combination of the latter with the PMJ osteotomy increased its accuracy at the level of the PMJ. As a result, there is a decrease in resistance during down-fracture and decrease in the need for bone trimming around the pedicle, with preservation of the minimally invasive concept.

Keywords: Cone-beam computed tomography; Cranial suture; Le Fort osteotomy; Orthognathic surgery; Piezo-electric surgery.

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Multiple intraoral procedures are used to correct dentofacial deformities. One of the most popular procedures is the Le Fort I osteotomy for the treatment of skeletal deformities of the maxilla and middle and lower face.[1] Although the Le Fort I osteotomy has become a routine procedure in elective orthognathic surgery, it is not without complications. Multiple technical modifications, as well as the development of instrumentation tailored to the operation, have been introduced in the literature since the original Le Fort I osteotomy was described,[2] in order to reduce the associated potential morbidities and complications of the technique.[3–8] Most of these drawbacks are a consequence of improper separation of the maxilla posteriorly at the level of the pterygomaxillary junction (PMJ), or of unfavourable propagation of the fractured bones.[4,9–11]

Ideally, the separation between the maxilla and the pterygoid process should begin laterally in the pterygomaxillary groove and progress medially through the PMJ. However, separation often occurs in front of it at the level of the posterior wall of the maxillary sinus, or behind it at the level of the pterygoid plate.[12,13] Although all fracture patterns afford pterygomaxillary separation, the one involving the pterygoid plate is more often related to involvement of the skull base or orbital structures and to potential neurovascular complications, such as bleeding of the maxillary or carotid arteries, and cranial nerve injury with blindness, for example.[9,10,14,15]

Since PMJ disjunction should be as clean and precise as possible, several surgical techniques have been proposed, using both direct approaches (lateral placement of a swan's neck, curved, or pterygoid osteotome, or with a right-angled micro-oscillating saw) and indirect approaches (anterior placement of a straight separator, osteotome, or ultrasonic bone curette) to perform the PMJ disjunction.[6,16,17] Similarly, several manoeuvres have been described for maxillary down-fracture, such as using an osteotome or by digital pressure alone.[8] To date, however, there is no experimental evidence to support which is safer in order to guarantee accurate separation through the PMJ.[18–21] Moreover, whatever approach is used, it is considered a blind and operator-sensitive technique, and therefore constitutes a challenging and technically risky procedure for most surgeons.

In this context, the authors have added a transmucosal PMJ osteotomy using a piezoelectric device, while preserving the minimally invasive approach of our previously published 'twist' technique.[18] For the first patients treated, a surgical guide was designed using computer-aided design and manufacturing (CAD/CAM) technology, which was printed in-house (Tiertime UP Box3D; Beijing Tiertime Technology Co., Ltd, Beijing, China). This guide was placed in the maxillary tuberosity supported by the molars, and a flapless vertical pterygomaxillary osteotomy was performed with a piezosaw device.[22] Following the accumulation of more surgeries, as well as increased experience with the suture osteotomy, and having acquired fluency with the technique, the surgical guide was no longer used. It was thus hypothesized that this manoeuvre increased the accuracy of the PMJ disjunction path, decreased the force required during the twist manoeuvre, minimized the need for bone trimming around the pedicles, and therefore improved the overall safety of the technique while preserving the minimally invasive concept.

The aim of this study was therefore to assess the accuracy and clinical implications of the transmucosal PMJ osteotomy using a piezoelectric hand-piece device in the context of the twist technique, by evaluating the level of PMJ disarticulation radiographically and the need for bone trimming around the pedicles clinically. The safety of the technique in turn was evaluated by assessing its potential related complications.

Materials and methods

Study design and sample selection

An ambidirectional 1-month follow-up cohort study was designed involving consecutive patients undergoing maxillary osteotomy, either as a single procedure or as part of bimaxillary surgery, performed by the senior author (F.H.A.) at the Institute of Maxillofacial Surgery, Teknon Medical Center, Barcelona, Spain.

Two cohorts were defined according to whether or not the transmucosal PMJ osteotomy was performed. The control group consisted of a sample of patients treated prior to the introduction of the new technique. This group was subjected to the standard minimally invasive twist technique at the study centre.[18] The control group data were collected retrospectively, and the patients were operated on between January and June 2020. The test group underwent the same Le Fort I twist technique as the control group, but with the addition of the PMJ osteotomy, which was performed transmucosally using a piezoelectric hand-piece device. The test group data were collected prospectively, and the patients were operated on between July 2020 and June 2021.

The patients were selected on the basis of the following inclusion criteria: age ≥18 years with non-growing status, dentofacial deformity in need of maxillary correction involving Le Fort I osteotomy, and written informed patient consent. Patients with an isolated bilateral sagittal split osteotomy were excluded, as were those presenting any craniofacial syndrome and patients with missing follow-up visits.

The study was approved by the Ethics Committee of the Teknon Medical Center, Barcelona, Spain (Ref. PtMxDys), and was conducted in accordance with the ethical standards laid down in the Declaration of Helsinki (1964 and later amendments).

Surgical procedure

All surgeries were virtually planned using specific orthognathic surgery planning software (Dolphin 3D Surgery, version 11.8; Dolphin Imaging and Management Solutions, Chatsworth, CA, USA). The splints were produced using a melted extrusion modelling (MEM) 3D printer (Tiertime UP Box3D; Beijing Tiertime Technology Co., Ltd). At this point, the overall anatomy of the PMJ region was analysed. Specifically, the greater palatine neurovascular bundle was located and then the depth and length of the planned PMJ osteotomy were calculated, in order to avoid soft tissue damage and preserve the greater palatine canal.

The surgical procedure was performed under general anaesthesia and controlled hypotension. In the test group, after infiltration with local anaesthetic and prior to proceeding with surgery, the tuberosity notch was palpated to identify it. Then, the pterygomaxillary disjunction was conducted using a piezoelectric hand-piece device (Piezomed; W&H, Bürmoos, Austria) with a fine-toothed saw (instrument B1): the tip of the piezo-saw blade was

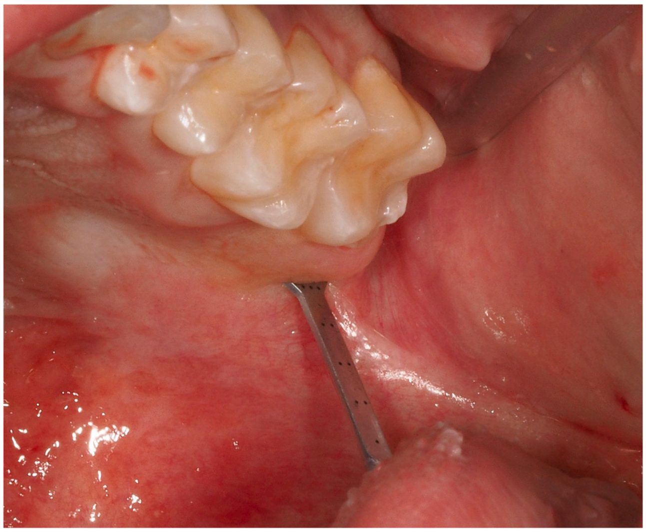

Fig. 1. Intraoperative view of the transmucosal pterygomaxillary disjunction osteotomy, showing the piezo-saw blade tip angulation.

pointed towards the tuberosity notch and the hand-piece was tilted distally so that the micro-saw blade cut at about 45 degrees to the vertical axis of the molars (Figs. 1 and 2). No incisions were made, and the mucosa of the tuberosity notch was incised with the oscillating movement of the cutting end of the piezo-saw blade. Next, suture resistance was felt and the osteotomy was performed through the junction. The resistance feeling of bone to the cutting end of the piezo-saw disappeared once the PMJ osteotomy had been completed. After performing this step bilaterally, the mucosal entry was sutured in a figure of eight fashion with 4–0 polyglactin suture. The Le Fort I osteotomy surgery was then performed via the minimally invasive approach using the twist technique described elsewhere,[18] with maxillary down-fracture being done through an anterior approach. For complete mobilization of the maxilla, when required, the piezoelectric micro-saw was used to remove the bony interferences between the pterygoid process and the posterior part of the maxilla, and to free the palatine neurovascular bundles without damaging them. Finally, after maxillary repositioning and fixation, a modified alar cinch suture and V–Y closure were performed.[23]

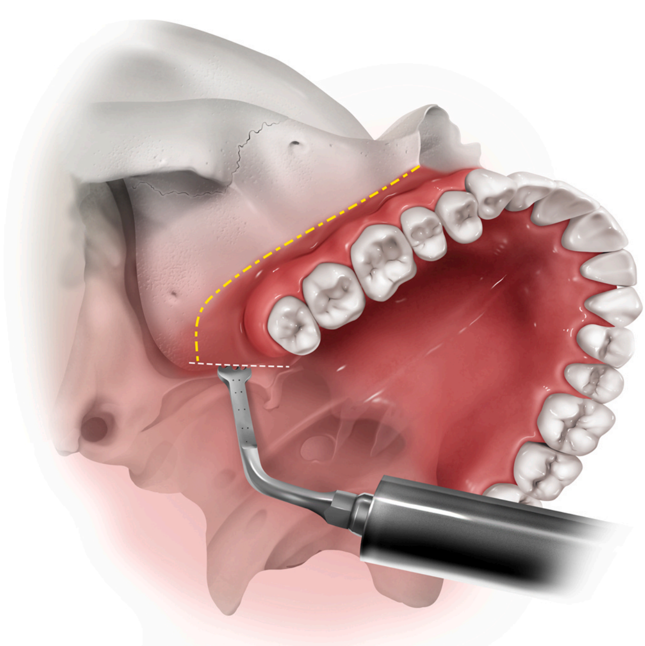

Fig. 2. Schematic representation of the transmucosal pterygomaxillary disjunction osteotomy and regional anatomy.

All patients wore a closed-circuit cold mask (17 °C) during hospital admission and were discharged 24 h after the surgery. Identical postoperative recommendations and antibiotic and analgesic medication were prescribed in both groups. Functional training using light guiding elastics was performed for 1 month, while maintaining a soft diet for the same period in both groups.

Data acquisition and evaluation of study variables

Cone beam computed tomography (CBCT) (i-CAT; Imaging Sciences International, Hatfield, PA, USA) was performed prior to surgery and at 1 month postoperatively for all patients as part of the study centre protocol for patients undergoing orthognathic surgery.[24] The patients were instructed to breathe calmly, sitting in normal head position, with the tongue in a relaxed position and the mandible in centric relation with a 2-mm wax bite in place to avoid direct contact between the teeth.

In order to assess the location of the disjunction at the posterior maxilla, the CBCT volumes from the two intervals were subsequently superimposed using Dolphin 3D Imaging software (version 11.8; Dolphin Imaging and Management Solutions) with a voxel-based protocol consisting of three successive 'side-by-side superimposition' steps.[25] Two examiners (M.G. and A.V.O.) evaluated the level of PMJ separation twice; moreover, comparisons were made with new evaluations performed after a 2-week interval, to ensure accuracy and reproducibility. The level of the PMJ disjunction was assessed at the level of the posterior nasal spine (Fig. 3) on the axial view of the images[11] and classified as follows: (1) in front of the PMJ, at the level of the maxillary tuberosity, with part of the posterior wall of the maxillary sinus remaining attached to the PMJ after separation (Fig. 4a); (2) at the pterygomaxillary suture (Fig. 4b); (3) behind the PMJ, at the pterygoid plate (Fig. 4c).

In addition, the following variables were recorded: patient age and sex, the need for bone trimming around the pedicle intraoperatively, concomitant

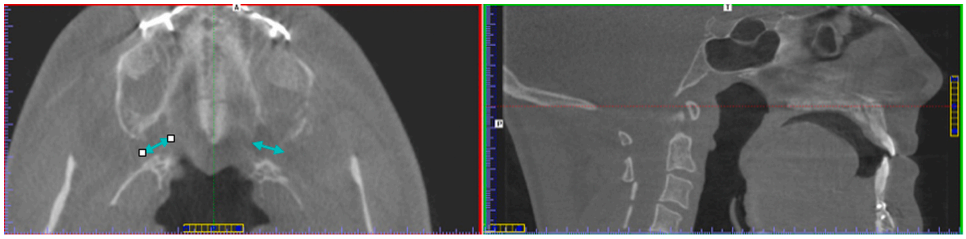

Fig. 3. Assessment of pterygomaxillary separation at the level of the posterior nasal spine.

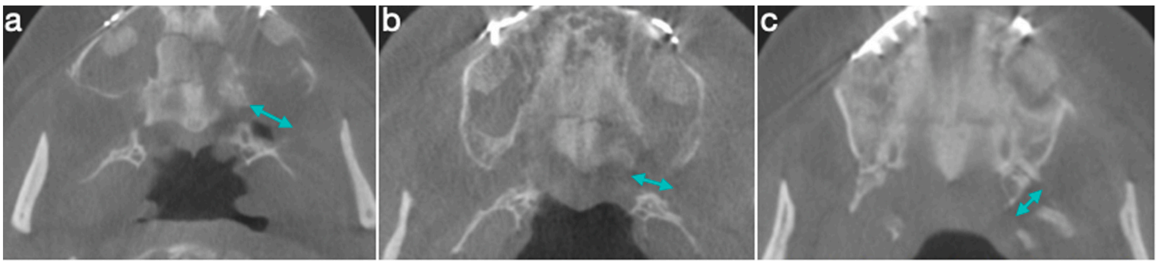

Fig. 4. Levels of pterygomaxillary separation: (a) at the level of the posterior wall of the maxillary sinus; (b) at the level of the pterygomaxillary junction; and (c) at the level of the pterygoid plate.

upper third molar extraction, and intra- and postoperative complications related to the studied transmucosal PMJ osteotomy, such as bleeding, soft tissue tearing with bone exposure, infection, and secondary soft tissue and bone healing problems.

Statistical analysis

The data analysis was performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). A descriptive study was made of categorical variables (reported as absolute and relative frequencies) and continuous variables (reported as the mean, standard deviation (SD), range, and median). In turn, 95% confidence intervals (95% CI) were generated to estimate the rate of success, i.e. separation at the PMJ, in both groups, using a normal distribution.

The inferential analysis included all the statistical tests needed to describe the presence and location of the PMJ separation and to establish correlations with other variables, as outlined below.

At the patient level, simple logistic regression analysis was used to assess the association between the success of separation and the patient group. Non-adjusted odds ratios (OR) and 95% CI were obtained. The influence of the presence of the third molar and the demographic profile was also assessed using the same method. Multiple logistic regression analysis was then used to develop an adjusted model including all of the previous independent factors. The adjusted OR and 95% CI were obtained.

The McNemar test was used to analyse the symmetry of the success of the intervention on both sides.

The sample was then transformed into a side-level structure in order to assess efficiency and associations independently of the side. Similar logistic models using generalized estimating equations (GEE) were developed and the OR (95% CI) values from the Wald χ^2 test were obtained. This method was used to control for dependence between observations (two sides per patient).

The significance level used in the analyses was 5% ($\alpha = 0.05$). The χ^2 test reached a statistical power of 80% in identifying success rates of 25% and 50% in the two groups as being significantly different, assuming a 95% confidence level.

Results

A total of 114 patients undergoing Le Fort I osteotomy were included in the study, 57 in the test group and 57 in the control group; a total of 228 sides were thus evaluated. There were 80 female patients (70.2%) and 34 male patients (29.8%), with a mean age of 31.8 ± 10.1 years (range 18–58 years).

The upper third molars were extracted in 26 patients in the control group (25 bilaterally and one unilaterally) and in 21 patients in the test group (19 bilaterally and two unilaterally). After maxillary down-fracture, bone trimming around the pedicle was required in 28.1% of the surgical sides in the test group versus in 62.3% of the surgical sides in the control group (Table 1). No intraoperative or postoperative complications related to the PMJ osteotomy and transmucosal approach were reported.

The radiographic analysis revealed no fractures in the cranial base. Regarding the level of disarticulation, ideal separation at the PMJ was more frequent in the test group (43.9%) than in the control group (15.8%). Similar results were obtained when considering the two sides independently: on the right side, the ideal separation rate was 38.6% versus 15.8%, while on the left side the rate was 49.1% versus 15.8% (Table 1, Fig. 5). Thus, the results showed the conventional technique to yield the same efficacy on both sides, although the pterygomaxillary osteotomy seemed to work a little better on the left side. Nevertheless, the success rate of the tested technique was similar on both sides ($P = 0.345$).

On evaluating the other independent variables, while dependence referred to sex, age, and the presence of the third molar was ruled out, bone trimming proved relevant on both sides ($P < 0.001$) (Table 2). In other words, when ideal separation at the PMJ occurred, the probability of bone trimming decreased significantly.

After adjusting to the multiple model in order to control for potential confounding factors, differences in the level of separation between the groups became non-significant (OR 1.40; $P = 0.448$),

Table 1. Level of the PMJ disjunction, necessity for bone trimming around the pedicle, and concomitant upper third molar extraction by group (control vs test).

	Group					
	Total		Control		Test	
	n	%	*n*	%	*n*	%
Level of PMJ disjunction—total sample						
Total	228	100.0	114	100.0	114	100.0
PMJ	68	29.8	18	15.8	50	43.9
Maxillary tuberosity/sinus[a]	72	31.6	37	32.5	35	30.7
Pterygoid plate[b]	88	38.6	59	51.8	29	25.4
Level of PMJ disjunction—right side						
Total	114	100.0	57	100.0	57	100.0
PMJ	31	27.2	9	15.8	22	38.6
Maxillary tuberosity/sinus[a]	33	28.9	17	29.8	16	28.1
Pterygoid plate[b]	50	43.9	31	54.4	19	33.3
Level of PMJ disjunction—left side						
Total	114	100.0	57	100.0	57	100.0
PMJ	37	32.5	9	15.8	28	49.1
Maxillary tuberosity/sinus[a]	39	34.2	20	35.1	19	33.3
Pterygoid plate[b]	38	33.3	28	49.1	10	17.5
Bone trimming—right side						
Total	114	100.0	57	100.0	57	100.0
No	60	52.6	20	35.1	40	70.2
Yes	54	47.4	37	64.9	17	29.8
Bone trimming—left side						
Total	114	100.0	57	100.0	57	100.0
No	65	57.0	23	40.4	42	73.7
Yes	49	43.0	34	59.6	15	26.3
Extraction of upper right third molar						
Total	114	100.0	57	100.0	57	100.0
No	70	61.4	32	56.1	38	66.7
Yes	44	38.6	25	43.9	19	33.3
Extraction of upper left third molar						
Total	114	100.0	57	100.0	57	100.0
No	67	58.8	31	54.4	36	63.2
Yes	47	41.2	26	45.6	21	36.8

PMJ, at the pterygomaxillary junction.
[a]Maxillary tuberosity/sinus: in front of the PMJ, at the maxillary tuberosity and posterior wall of maxillary sinus.
[b]Pterygoid plate: behind the PMJ, at the pterygoid plate.

because intermediate variables of the causal chain such as bone trimming (OR 0.02; $P < 0.001$) and the removal of upper third molars (OR 0.17; $P < 0.001$) were sufficiently relevant to explain the probability of success (Table 3). In fact, the bone trimming rate in the control group was two-fold higher than that in the test group. Similarly, bone trimming was significantly more required when the extraction of upper third molars was not performed immediately prior to maxillary down-fracture ($P < 0.001$).

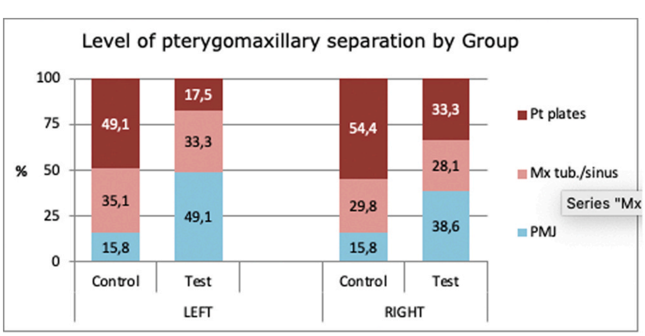

Fig. 5. Level of pterygomaxillary separation by group.

Discussion

The study results demonstrated that performing a transmucosal PMJ osteotomy using a piezoelectric hand-piece device in the context of the minimally invasive twist technique, enhanced the accuracy of the PMJ disarticulation path, increasing the percentage of patients in whom an ideal separation at the PMJ level was obtained, while decreasing those occurring in the pterygoid plate (from 51.8% in the control group to 25.4% in the test group). This approach therefore improves the overall safety of the technique, since separations arising in the pterygoid plate are more often related to potential neurovascular complications.[9,10,14,15] In this context, it was proven that a clean cut through the PMJ also involved less bone trimming around the pedicles after the down-fracture (OR 0.02; $P < 0.001$) for appropriate maxillary mobilization, and potential damage to the neurovascular bundle is consequently reduced. Besides, the transmucosal PMJ osteotomy decreases the resistance during down-fracture and, consequently, may reduce unfavourable fracture propagation to the surrounding bones of the skull base. Although it could not be proven

Table 2. Association between success (yes/no) and independent variables: simple binary logistic regression models for the probability of separation at the PMJ. Non-adjusted odds ratio (OR) and 95% confidence interval (95% CI).

	Category	OR	95% CI	*P*-value
Total sample				
Group	Control	1		
	Test	4.17	2.02–8.60	< 0.001 * **
Age		0.99	0.95–1.02	0.413
Sex	Male	1		
	Female	1.26	0.60–2.68	0.543
Third molar extraction	No	1		
	Yes	0.83	0.43–1.59	0.828
Bone trimming	No	1		
	Yes	0.04	0.01–0.11	< 0.001 * **
Right side				
Group	Control	1		
	Test	3.35	1.38–8.16	0.008 * *
Age		0.98	0.93–1.02	0.267
Sex	Male	1		
	Female	1.31	0.52–3.32	0.567
Third molar 18 extraction	No	1		
	Yes	0.69	0.29–1.64	0.397
Bone trimming	No	1		
	Yes	0.02	0.00–0.15	< 0.001 * **
Left side				
Group	Control	1		
	Test	5.15	2.13–12.4	< 0.001 * **
Age		0.99	0.96–1.03	0.736
Sex	Male	1		
	Female	1.22	0.51–2.92	0.651
Third molar 28 extraction	No	1		
	Yes	0.96	0.43–2.13	0.918
Bone trimming	No	1		
	Yes	0.06	0.02 – 0.21	< 0.001 * **

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

objectively, the main surgeon (F.H.A.) found that during the maxillary down-fracture, the strength required was considerably decreased in all cases in which the new technique was performed.

This manoeuvre for PMJ separation preserves the minimally invasive concept, since the incision in the labiobuccal sulcus is not enlarged or torn to reach the PMJ through a direct approach. With the same purpose, Susarla et al.[26] in 2020 described a similar technique with transmucosal pterygomaxillary separation, but they used a sharp osteotome with an acute curve, and the osteotomy was performed over the maxillary tuberosity along the attached gingiva.

It is widely accepted that PMJ separation is a technically demanding manoeuvre because of its blind approach. Additionally, anatomical variants can occur at the base of the skull, such as bony defects or incomplete ossification, or abnormally thick posterior walls of the maxilla and pterygoid plates.[9,27] This is especially manifest in patients with craniofacial deformities or syndromes, since their regional PMJ anatomy differs from that of the general population. Chin et al.[13] reported that cleft patients had a higher incidence of pterygoid plate fracture. It is at this point where imaging techniques and virtual planning gain relevance. Anatomical aspects of the PMJ have been very well evaluated by Dadwal et al.,[28] who found the mean width of the PMJ to be 7.8 ± 1.5 mm, the mean distance of the greater palatine canal from the PMJ to be 7.4 ± 1.6 mm, and the mean length of fusion of the PMJ to be 8.0 ± 1.9 mm. However, all transmucosal PMJ osteotomies should be virtually planned and tailored to the patient, and the authors also recommend using a customized cutting guide to start with, until the learning curve has been assimilated.

Regarding the overall rates of successful separation exactly at the PMJ level, the study results are in line with those found in the literature.[11,16,28,29] According to the reviewed literature, the placement mostly depends on the PMJ disjunction technique and instrumentation used, as well as on patient anatomical factors. On the one hand, Ueki et al.[11] reported ideal PMJ separation in 24.3% of a sample of 37 Japanese patients with mandibular prognathism and asymmetry, and using an anterior approach with separators for maxillary down-fracture. On the other hand, Precious et al.[5] demonstrated that fracture of the pterygoid plates took place in 87% of the cases in which a pterygoid chisel was used, versus in 82% of the cases in which PMJ separation was accomplished without a chisel. Dadwal et al.[28] noted that pterygoid plate fractures occurred in patients in whom the thickness of the pterygomaxillary junction was < 3.6 mm preoperatively, while Kanazawa et al.[30] identified a significant risk when the maxillary tuberosity length was more than 11.5 mm. In any case, in the context of the minimally invasive twist technique, the additional transmucosal PMJ osteotomy described increases the accuracy in exact disarticulation of the PMJ, increasing the overall success rate nearly three-fold, while preserving the minimally invasive approach.

The need for bone trimming around the pedicle was inversely correlated with the occurrence of PMJ disarticulation at the suture level ($P < 0.001$), which means that

Table 3. Association between success (yes/no) and independent variables: multiple binary logistic regression models for the probability of separation at the PMJ. Adjusted odds ratio (OR) and 95% confidence interval (95% CI).

	Category	OR	95% CI	*P*-value
Total sample				
Group	Control	1		
	Test	1.40	0.59–3.37	0.448
Age		1.00	0.96–1.05	0.848
Sex	Male	1		
	Female	0.91	0.37–2.24	0.841
Third molar extraction	No	1		
	Yes	0.17	0.07–0.43	< 0.001 * **
Bone trimming	No	1		
	Yes	0.02	0.01–0.05	< 0.001 * **
Right side				
Group	Control	1		
	Test	0.47	0.12–1.90	0.289
Age		0.99	0.94–1.06	0.967
Sex	Male	1		
	Female	0.74	0.19–2.85	0.662
Third molar 18 extraction	No	1		
	Yes	0.07	0.02–0.29	< 0.001 * **
Bone trimming	No	1		
	Yes	0.01	0.00–0.04	< 0.001 * **
Left side				
Group	Control	1		
	Test	2.53	0.90–7.06	0.077
Age		1.01	0.96–1.06	0.704
Sex	Male	1		
	Female	0.94	0.31–2.85	0.939
Third molar 28 extraction	No	1		
	Yes	0.27	0.09–0.82	0.021 *
Bone trimming	No	1		
	Yes	0.04	0.01–0.16	< 0.001 * **

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

maxillary mobilization is easier in this proper scenario, and therefore no more surgical time is wasted on bone trimming. Although the incidence of pedicle damage was not reported, since this manoeuvre reduces the need for bone trimming around the pedicle, it consequently could be reduced. In the same way, the probability of bone trimming was also directly correlated with the presence of the upper third molars ($P < 0.001$). This was not unexpected, since the prior removal of upper third molars in conjunction with Le Fort I osteotomy located at the vertical osteotomy line appears to have favourable effects, due to lessened bone reduction and a clear field for maxillary repositioning – thus also reducing the risk of bleeding due to surgical manipulation.[31]

The current study results revealed a greater efficacy of the additional osteotomy on the left side of the patients, which could be related to the fact that the main surgeon (F.H.A.) is right-handed. However, this was probably a chance finding, since the occurrence of a clean cut showed an equal distribution on the two sides in the control group. This technique has the associated additional cost of using the piezoelectric device; however, nowadays the piezoelectric device is part of the standard armamentarium for orthognathic surgery. It is considered essential in performing several osteotomies, such as interdental, subspinal, and lingual osteotomies.[32–34]

This study has some limitations, such as the retrospective cohort and the single-centre design, with the inherent biases involved. Furthermore, only one right-handed surgeon was evaluated, always using an anterior approach for PMJ disjunction (the twist technique). Moreover, the need for pedicle cauterization due to its damage during bone trimming around the structure or for maxillary extensive movements was not reported, but could have added relevant information. Thus, although the reported outcomes are promising, further multicentre randomized trials are needed in order to obtain firm evidence.

In conclusion, compared with the originally described twist technique, the addition of the transmucosal PMJ osteotomy performed using a piezoelectric device was found to increase the accuracy of the Le Fort I osteotomy at the level of the PMJ, while decreasing separations occurring in the pterygoid plate. As a result, there is a decrease in resistance during down-fracture, less bone trimming is necessary, and moreover the minimally invasive concept is preserved.

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None.

Competing interests

None.

Ethical approval

Ethical approval was obtained from the Ethics Committee of Teknon Medical Center, Barcelona, Spain (Ref. PtMxDys).

Patient consent

Patient written consent was obtained to access the CBCT database.

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