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U-Shaped Osseous Release for Le Fort 1 Osteotomy: Potential Application to Superior Repositioning

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Abstract: This study was performed to investigate the utility of U-shaped osseous release (USOR) for Le Fort 1 osteotomy as a novel surgical technique for superior repositioning. Thirty-six patients with jaw deformities were divided into 2 groups based on whether or not USOR was adopted (18 in the non-adoption group and 18 in the adoption group). Maxillary surgical time, blood loss, and discrepancy from the planned amount of movement (anterior-posterior and superior-inferior directions) were compared between the 2 groups. Correlations between these items and the planned amount of superior-inferior movement were also examined. There were no significant differences in mean age, preset displacement, surgical time, blood loss, body mass index, or preset displacement error. However, a significant positive correlation was observed between the planned and actual amount of vertical movement only in the adoption group ($P = 0.0018$). In addition, there was a tendency for the error (downward) to increase as the amount of upward movement increased in the non-adoption group, but not the adoption group. These findings suggest that USOR may be a useful technique because it can safely and conveniently remove bony interference and can enable guidance to a more precise position, especially in cases with substantial superior movement.

Key Words: Le Fort osteotomy, orthognathic surgery, superior repositioning, U-shaped osseous release

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The range of applications of Le Fort 1 osteotomy has significantly expanded because of recent advancements in orthognathic surgery. One of the major contributing factors is the increased adoption of posterior and/or superior repositioning of the maxillary bone. In patients with jaw deformities of vertical excess of the maxilla accompanied by open bite, gummy smile, or maxillary protrusion, the posterior and/or superior movement of the maxilla through the Le Fort 1 osteotomy can provide good occlusion and esthetic improvements.[1–6] However, because of the difficulty of trimming interference from the pterygoid processes and the bones surrounding the descending palatine artery (DPA), this procedure was challenging and was not actively adopted in the past.[7,8]

The last decade has seen the development of ultrasonic bone-cutting devices that enable delicate cutting and shaping of bone without damaging the surrounding soft tissues. These devices are now widely used in oral and maxillofacial surgery. Consequently, several surgical techniques have been proposed to remove bony interference around the DPA using ultrasonic bone-cutting devices.[9–13]

When injury to the DPA occurs during bony interference removal, it can lead to unexpected hemorrhage and an increased

risk of aseptic necrosis of the maxilla related to a lack of blood supply.[7,14] Therefore, a simple and safe procedure for superior/posterior repositioning of the maxilla is required to ensure the removal of bony interference around the DPA without complications.

The U-shaped osteotomy (USO) is a technique that can quickly, safely, and reliably remove posterior bony interference. The osteotomy is performed around the DPA to the nasal floor, maxillary sinus, and maxillary tuberosity, and a bone fragment containing the DPA[15,16] is mobilized (Fig. 1A). The technique now used in our department is a U-shaped osseous release (USOR), which further divides and completely removes the mobilized bone around the DPA after performing USO (Fig. 1B-E).

In this retrospective study, the surgical time, blood loss, and movement accuracy of Le Fort 1 osteotomy, with and without the adoption of USOR, is compared with clarify the efficiency of USOR in posterior and/or superior movement of the maxilla.

MATERIALS AND METHODS

Study Design

This was a retrospective self-controlled clinical study based on the Dental and Maxillofacial Center database at Kyushu University Hospital between January 2014 and December 2022. The study was designed in accordance with the Declaration of Helsinki for research. Ethics approval was obtained from the Institutional Review Board of the Center for Clinical and Translational Research of Kyushu University Hospital (IRB serial number: 23138-00), and informed consent was signed by the patients. This study followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guideline.

Study Participants

This study included 36 patients with jaw deformities (25 females and 11 males, mean age ± standard deviation (SD): 26.4 ± 9.4 years) who underwent Le Fort 1 osteotomy with posterior and/or superior repositioning of the maxilla between January 2014 and December 2022 in the Department of Oral and Maxillofacial Surgery at Kyushu University Hospital, a tertiary care center. Surgeries were performed under general anesthesia by a senior surgeon (M.M.). All patients underwent conventional Le Fort 1 osteotomy and bilateral sagittal split osteotomy. Patients who underwent procedures involving maxillary anterior-inferior movement were excluded from this study. Since 2018, the procedure has been used the Le Fort 1 osteotomy with USOR, requiring posterior and/or superior repositioning of the maxilla. The patients with complete preoperative and postoperative cephalometric radiographs and intraoperative findings were divided into 2 groups: the non-adoption group (trimming (Tm) group: 18 patients, 6 men, and 12 women; mean age ± SD: 27.6 ± 7.6 years) and the adoption group (USOR group: 18 patients, 5 men, and 13 women; mean age ± SD: 25.2 ± 11.0 years). Supplementary tables 1, Supplemental Digital Content 1, http://links.lww.com/SCS/H105 and 2 Supplemental Digital Content 2, http://links.lww.com/SCS/H106 show the clinical findings in both groups.

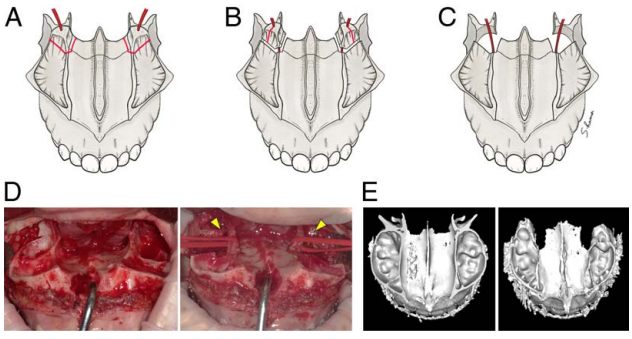

FIGURE 1. Schematic diagram of the U-shaped osseous release (USOR) technique. (A) Bilateral U-shaped osteotomy for mobilizing the bone fragment containing the descending palatine artery (DPA). (B) Mobilized bone around the DPA with vertical incisions made with ultrasonic cutting tools. (C) The mobilized bone around the DPA is divided and completely removed. (D) Intraoperative photographs after USOR. Yellow arrowheads indicate DPA. (E) Three-dimensional computed tomography image. Left: before USOR. Right: after USOR.

Data Collection Methods

Standardized lateral cephalometric radiographs were obtained using a cephalostat (Shimadzu Corp.) before the surgery and 6 months postoperatively. The cephalometric reference points were PNS. The Frankfort horizontal plane was defined as the *x*-axis, and the vertical line perpendicular to the *x*-axis passing through the nasion was defined as the *y*-axis. Using this coordinate system, the right side in the *x*-axis and the upper side in the *y*-axis were designated as being in the positive direction. Vertical and horizontal changes in the PNS were measured before and after the surgery.

Statistical Analysis

All statistical analyses were performed using GraphPad Prism 9 (GraphPad Software). Student *t* test, the Mann-Whitney *U* test, and Fisher exact test were used for comparison of independent groups. Pearson correlation coefficient was used for linear correlation between 2 sets of data. A P-value of < 0.05 was considered statistically significant. The correlation coefficient (r) can range from negative (−1) to positive (+1). A positive correlation is measured on a scale from 0 to 1.0: a "weak positive correlation" ranges from 0.2 to 0.4, a "moderate positive correlation" ranges from 0.4 to 0.6, and a "strong positive correlation" is between 0.6 and 1.0. Conversely, a negative correlation is measured on a scale from 0 to −1.0: a "weak negative correlation" ranges from −0.2 to −0.4, a "moderate negative correlation" from −0.4 to −0.6, and a "strong negative correlation" from −0.6 to −1.0.

RESULTS

Comparison of Clinical Findings Between the Tm and USOR Group

The demographic characteristics of each group are shown in Supplementary table 3, Supplemental Digital Content 3, http://links.lww.com/SCS/H107. There was no significant difference in age, sex, surgical time (until the completion of maxillary sutures), blood loss, body mass index (BMI), the planned amount of maxillary movement (*x*-axis and *y*-axis), or maxillary repositioning errors (*x*-axis and *y*-axis) in the PNS between each group. No cases of DPA injury after maxillary postoperative necrosis were observed.

Relationship Between Clinical Findings and Maxillary Repositioning Errors in the Tm Group

In the Tm group, there was no significant correlation between the planned amount of maxillary horizontal movement (*x*-axis) in the PNS and surgical time or blood loss (Fig. 2A, B), whereas there was a weak positive correlation with actual

amount of horizontal movement ($r = 0.23$, $P < 0.05$) (Fig. 2C) and a weak negative correlation with horizontal repositioning errors ($r = -0.28$, $P < 0.05$) (Fig. 2D).

For the planned amount of maxillary vertical movement (y-axis) in the PNS, there were no significant correlations with surgical time, blood loss, or the actual amount of vertical movement (Fig. 3A-C), whereas there was a weak negative correlation with vertical repositioning errors ($r = 0.35$, $P < 0.05$) (Fig. 3D).

Relationship Between Clinical Findings and Maxillary Repositioning Errors in the USOR Group

In the USOR group, there was no significant correlation between the planned amount of maxillary horizontal movement (x-axis) in the PNS and surgical time or blood loss (Fig. 4A, B), whereas there was a strong positive correlation with the actual amount of vertical movement ($r = 0.93$, $P < 0.01$) (Fig. 4C) and a week positive correlation with horizontal repositioning errors ($r = 0.30$, $P < 0.05$) (Fig. 4D).

For the planned amount of maxillary vertical movement (y-axis) in the PNS, there were no significant correlations with surgical time, blood loss, or vertical repositioning errors (Fig. 5A, B, D), whereas there was a moderate positive correlation with the actual amount of vertical movement ($r = 0.47$, $P < 0.01$) (Fig. 5C).

Effects of Vertical Movement on Clinical Findings in the Tm and USOR Groups

The patients were divided into 2 groups according to their planned vertical movement: one group with upward movement <4 mm (Tm, 10 patients; USOR, 11 patients) and another group with more than 4 mm (Tm, 8 patients; USOR, 7 patients). Regardless of the planned vertical movement, there were no significant differences with surgical time or blood loss between the Tm and USOR groups (Fig. 6A, B). In contrast, only when the upward movement was more than 4 mm, the downward errors in the Tm group were significantly larger than those in the USOR group (Fig. 6C).

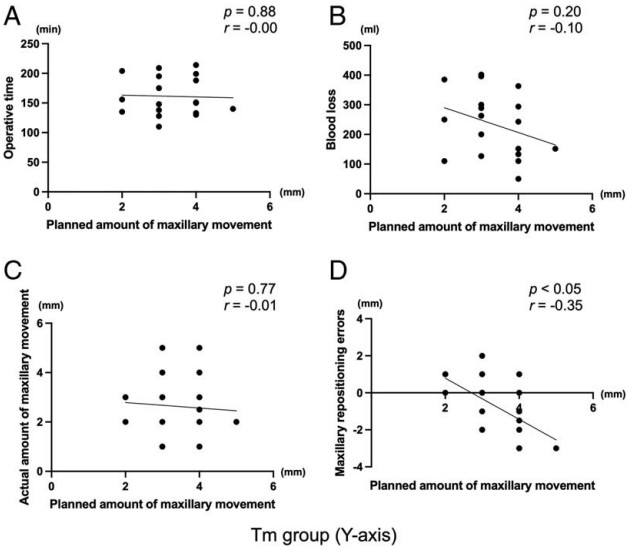

FIGURE 3. Relationship between clinical findings and vertical maxillary repositioning errors (y-axis) in the Tm group. Planned amount of vertical maxillary movement in the PNS and operation time (A), blood loss (B), the actual amount of vertical movement (C), and vertical repositioning errors (D). Significant differences between the groups were determined by Pearson's correlation coefficient. Tm indicates trimming.

DISCUSSION

Posterior and/or superior repositioning of the maxilla by Le Fort 1 osteotomy is a highly complex procedure compared with anterior and inferior repositioning because of the increased risk of DPA injury by removing the interference of the periprosthetic

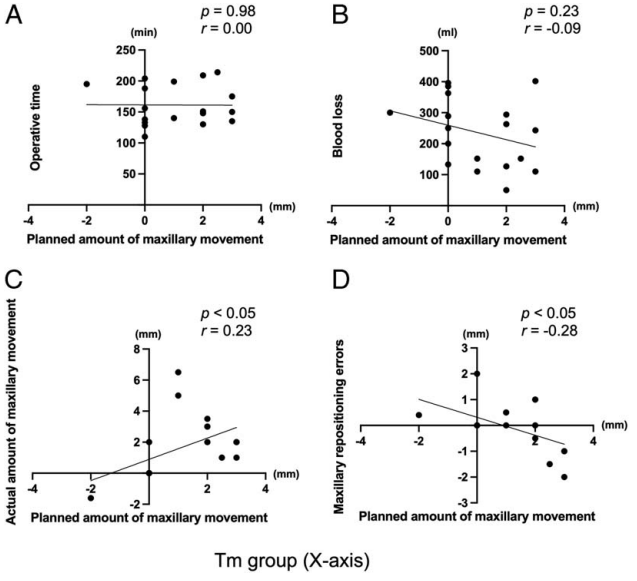

FIGURE 2. Relationship between clinical findings and horizontal maxillary repositioning errors (x-axis) in the trimming (Tm) group. The planned amount of horizontal maxillary movement in the PNS and operation time (A), blood loss (B), the actual amount of horizontal movement (C), and horizontal repositioning errors (D). Significant differences between the groups were determined by Pearson correlation coefficient.

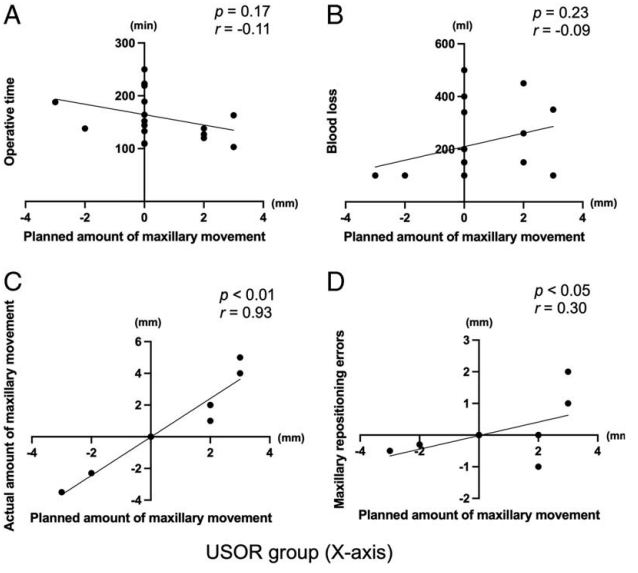

FIGURE 4. Relationship between clinical findings and horizontal maxillary repositioning errors (x-axis) in the U-shaped osseous release (USOR) group. Planned amount of horizontal maxillary movement in the PNS and operation time (A), blood loss (B), the actual amount of horizontal movement (C), and horizontal repositioning errors (D). Significant differences between the groups were determined by Pearson's correlation coefficient.

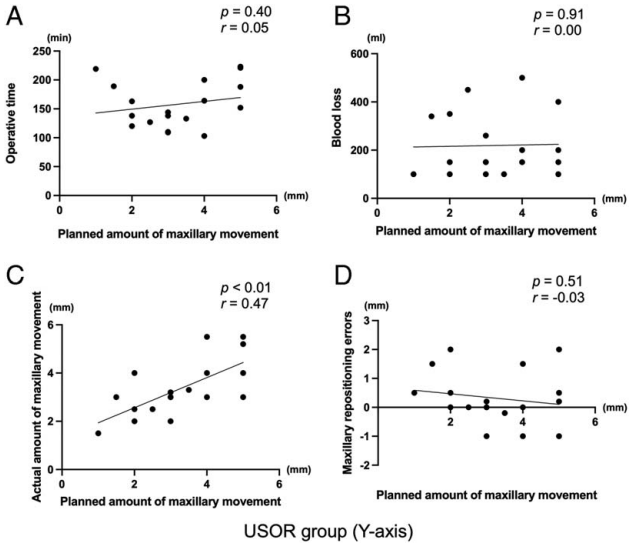

FIGURE 5. Relationship between clinical findings and vertical maxillary repositioning errors (*y*-axis) in the USOR group. Planned amount of vertical maxillary movement in the PNS and surgical time (A), blood loss (B), the actual amount of vertical movement (C), and vertical repositioning errors (D). Significant differences between the groups were determined by Pearson's correlation coefficient. USOR indicates U-shaped osseous release.

bone of the DPA.[17] Consequently, treatment strategies frequently circumvented posterior/superior movement as much as possible. However, in recent years, the introduction of ultrasonic cutting tools has made it possible to remove bone interference relatively safely.[10,18] In addition, several surgical procedures including horseshoe osteotomy,[19–21] USO,[16] and pyramidal and posterior osseous release (PPOR)[22] have been reported to remove bone interference around the DPA more safely.

Horseshoe osteotomy combined with Le Fort 1 osteotomy involves the separation of the down-fractured maxilla into dentoalveolar and palatal components while preserving the DPA. By trimming the anterior edge of the palatal component, the dentoalveolar component can be repositioned posteriorly.[20]

PPOR is a unique procedure that involves sectioning a pyramidal portion of bone from the posterior medial antrum and the posterior lateral nasal floor/wall by creating 2 osseous grooves in a triangular pattern using an ultrasonic bone-cutting device. The pyramidal-shaped segment is then freed due to identify DPA bundle. Finally, the posterior bone segment was removed by making a horizontal cutting groove, including the palatal bone.[22]

These techniques are useful for posterior/superior movement of the maxilla, but are time-consuming because of the extensive bone interference and the many steps involved. For these reasons, our department has adopted USO as a more simple and convenient technique for moving the maxilla backward and upward. However, in cases of significant posterior/superior movement, the mobilized bone itself around the DPA can cause interference, so that in some cases the planned amount of movement is not achieved. Therefore, as shown in Fig. 1, the USOR technique was devised to remove the mobilized bone around the DPA by making vertical incisions with ultrasonic cutting tools. In this study, no major complications were observed in the USOR group. Although 3 cases demonstrated injury to the DPA bundle during USOR procedure, none of these cases resulted in significant blood loss (see Supplementary table 2, Supplemental Digital Content 2, http://links.lww.com/SCS/H106).

Although no significant differences were observed in surgical time, blood loss, or maxillary repositioning errors in the PNS between the Tm and USOR group (Supplementary table 3, Supplemental Digital Content 3, http://links.lww.com/SCS/H107), the characteristics of the 2 groups become clear in cases with substantial superior movement. In the Tm group, as the amount of upward movement of the maxilla increases, the downward error also increases (Fig. 3D), whereas the USOR group did not exhibit a significant correlation between the planned amount and repositioning errors in horizontal movement (Fig. 5D). Interestingly, in cases planning upward movements of more than 4mm, the Tm group showed significantly greater downward errors compared with the USOR group (Fig. 6). In addition, The USOR group achieved the planned vertical movement more accurately than the Tm group (Figs. 3C and 5C). These results suggest that in cases with substantial upward movement, USOR is a useful technique for effectively reducing downward errors.

However, upward movement of the maxillary bone, even with the application of USOR, can lead to significant issues such as instability, poor treatment outcomes, and failure if the surgeon does not recognize bony interference.[23] Therefore, meticulous attention is required for the positioning of the maxilla.

It is a matter of great regret that this study was conducted using only a single lateral cephalometric reference point (PNS), and could not perform the 3-dimensional analysis with multiple reference points. Moreover, regarding with horizontal movement, the number of cases with posterior movement in both groups was so small that the correlation with clinical findings

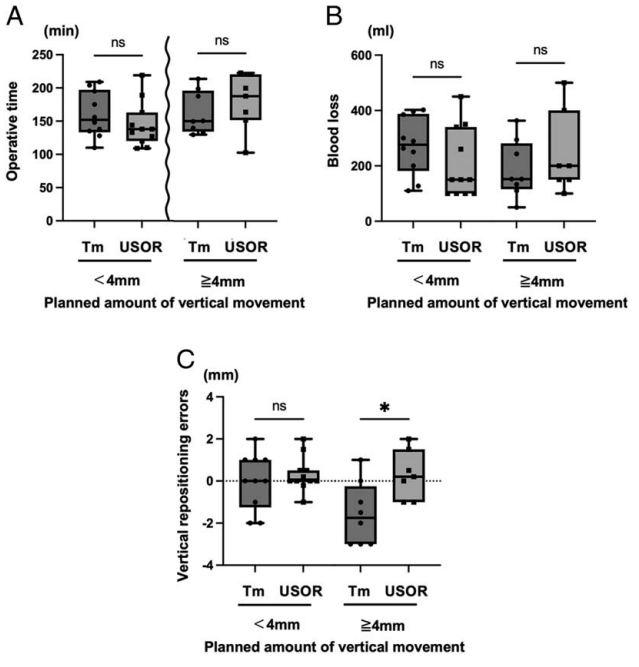

FIGURE 6. Comparison of clinical findings including surgical time (A), blood loss (B), and vertical repositioning errors (C) between the Tm and USOR groups. The patients were categorized into 2 groups based on the planned amount of vertical movement: one group with <4 mm (Tm, n = 10; USOR, n = 11) and another with more than 4 mm (Tm, n = 8; USOR, n = 7). Data are shown as box plots. Each box represents the upper and lower interquartile range. Lines inside the boxes represent the median. Symbols represent individual subjects. * $P < 0.05$ by Mann-Whitney *U* test. ns indicates not significant; Tm, trimming; USOR, U-shaped osseous release.

could not be adequately examined (Figs. 2 and 4). The comparative analysis in this study was retrospective in design, underscoring the necessity of verifying the utility of the USOR technique with a multicenter randomized controlled trial in the future.

CONCLUSION

USOR is proposed as a beneficial technique because of its ability to extract the mobilized bone around the DPA safely and efficiently, resulting in more accurate repositioning, particularly in cases with substantial superior movement.

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Supplementary table 1. Clinical findings for patients in the trimming group.

No.	Age	Sex	BMI	Skeletal class	Operative time* (min)	Blood loss* (ml)	Planned amount of movement in PNS	
							Horizontal	Vertical
1	29	M	18.6	III	214	152	2.5	4.0
2	37	F	21.6	III	138	396	0.0	3.0
3	39	F	22.2	III	280	152	1.0	5.0
4	17	F	22.4	III	209	263	2.0	3.0
5	45	F	20.6	III	151	294	2.0	4.0
6	28	F	17.2	III	148	127	2.0	3.0
7	35	M	21.1	III	150	243	3.0	4.0
8	20	M	19.0	III	175	402	3.0	3.0
9	24	M	26.1	III	156	385	0.0	2.0
10	25	F	19.7	III	128	289	0.0	3.0
11	24	F	21.2	III	135	110	3.0	2.0
12	21	F	25.1	III	133	133	0.0	4.0
13	25	F	15.1	II	110	200	0.0	3.0
14	25	F	19.5	II	130	50	2.0	4.0
15	35	F	18.1	III	188	363	0.0	4.0
16	22	M	19.0	III	199	110	1.0	4.0
17	21	F	20.7	III	204	250	0.0	2.0
18	24	M	18.4	III	195	300	-2.0	3.0

*Time to finish the maxillary suture. BMI, body mass index.

Supplementary table 2. Clinical findings for patients in the USOR group.

No.	Age	Sex	BMI	Skeletal class	Operative time* (min)	Blood loss* (ml)	Planned amount of movement in PNS	
							Horizontal	Vertical
1	17	F	20.0	III	173	400	0.0	5.0
2	18	F	24.3	III	103	500	0.0	4.0
3	20	F	21.6	III	221	150	0.0	5.0
4	18	F	18.1	III	219	100	3.0	1.0
5	21	M	20.5	III	163	350	3.0	2.0
6	21	M	20.6	III	138	260	2.0	3.0
7	63	F	21.1	II	127	450	2.0	2.5
8	24	F	17.6	II	120	150	2.0	2.0
9	27	M	20.1	III	109	150	0.0	3.0
10	25	M	27.2	III	188	100	-3.0	5.0
11	19	F	20.3	III	144	150	0.0	3.0
12	21	F	19.7	III	152	200	0.0	5.0
13	30	F	18.3	III	133	100	0.0	3.5
14	18	F	24.6	III	164	200	0.0	4.0
15	22	F	16.7	III	110	100	0.0	3.0
16	27	F	18.7	II	138	100	-2.0	2.0
17	22	M	23.2	III	189	340	0.0	1.5
18	40	F	20.8	III	200	150	0.0	4.0

*Time to finish the maxillary suture. BMI, body mass index.

Supplementary table 3. Demographic characteristics between the Tm and USOR group.

	Total	**Tm group**	**USOR group**	***P*-value**
Patients (n)	36	18	18	
Age (years)	26.4 ± 9.4	27.6 ± 7.6	25.2 ± 11.0	0.45*
Gender				
Female	25	12	13	
Male	11	6	5	1.00§
BMI (kg/m^2)	20.5 ± 2.6	20.3 ± 2.7	20.7 ± 2.7	0.62*
Operative time (min)	162.1 ± 39.8	169.1 ± 42.4	155.1 ± 37.0	0.78*
Blood loss (ml)	226.9 ± 119.9	234.4 ± 110.3	219.4 ± 131.5	0.71*
Planned amount of maxillary movement (mm)				
Horizontal	0.74 ± 1.50	1.08 ± 1.42	0.39 ± 1.54	0.15†
Vertical	3.29 ± 1.06	3.33 ± 0.84	3.25 ± 1.27	0.80†
Maxillary repositioning errors (mm)				
Horizontal	-0.05 ± 0.70	-0.06 ± 0.93	-0.04 ± 0.37	0.98†
Vertical	-0.19 ± 1.38	-0.69 ± 1.58	0.32 ± 0.93	0.14†

Mean value ± standard deviation. Significant differences between the groups were determined by *Student's *t* test, §Fisher's exact test, and †Mann–Whitney *U* test.