Effects of vertical movement of the anterior nasal spine on the maxillary stability after LeFort I osteotomy for pitch correction

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Abstract

Few reports have so far evaluated the maxillary stability after LeFort I osteotomy (L-1) for pitch correction. In the present study, we assessed the SN-PP in order to evaluate the skeletal stability after osteotomy with clockwise or counter-clockwise rotation and investigated the effects of ANS and PNS movement on the stability of the SN-PP.

The SN-PP and the positions of ANS, PNS and point A were measured on lateral cephalograms before surgery (T1), immediately after surgery (T2) and more than one year after surgery (T3).

All measured angle and points were stable in four cases of counter-clockwise rotation. In the 16 cases of clockwise rotation, T3-T2 of SN-PP, ANS and point A was -2.05 degrees, -2.56 mm and -1.64 mm, when the SN-PP increased more than four degrees after osteotomy. When the ANS moved downward more than 3 mm, the ANS and point A relapsed significantly by 2.75 mm and 2.31 mm, while the SN-PP relapsed 1.61 degrees more than one year after surgery.

When the SN-PP increased by more than four degrees or the ANS moved downward by more than three mm, we suggest shifting the PNS upward instead of moving the ANS downward.

Introduction

LeFort I osteotomy (L-1) is a common strategy for correcting the maxilla in patients with jaw deformities. The segments are fixed loosely with a wire or rigidly with plates and screws after L-1[1], and an admissible skeletal stability of the segment is acquired in both osteosynthesis procedures. However, according to the segmental movement pattern after osteotomy, the segment is more stable with rigid fixation than with wire fixation.[1] Therefore, the use of rigid fixation between bone segments is now the standard strategy after L-1.

Many reports have assessed the skeletal stability of the bone segment with rigid fixation after L-1, and most researchers agree that skeletal stability of the segment can be completely obtained when the segment is moved upward.[1, 2] Moreover, Proffit et al.[2-4] evaluated the segmental stability in the anterior-posterior direction after L-1 and showed good stability in both directions. According to these previous reports, segments treated with rigid fixation after L-1 are stable when the segments move in parallel. However, few studies have evaluated the stability when the maxilla is moved to correct the pitch, cant and/or yaw, although these corrections of the maxilla are required in many cases (Fig. 1).

Since pitch correction is predominant among cases involving pitch, cant and yaw, we herein evaluated the skeletal stability of the maxilla after L-1 with clockwise or counter-clockwise rotation to correct the pitch. There are insufficient reports referring to the maxillary stability after L-1 with clockwise or counter-clockwise rotation for pitch correction. Furthermore, almost all previous studies have investigated changes in the angles between the Sella-Nasion plane (SN), Frankfort horizontal plane (FH) and occlusal plane (OP).[5, 6] However, these parameters bias the results since the SN-OP and

FH-OP includes both skeletal and dental factors. In this study, we also assessed the SN-PP in order to evaluate the definitive skeletal stability. The SP-PP is the angle between the SN and the palatal plane (PP), which consists of the anterior nasal spine (ANS) and posterior nasal spine (PNS). Meanwhile, the value of SP-PP does not reflect positional changes in ANS or PNS. Since there are no reports referring to the effects of vertical movement of the ANS or PNS on the maxillary stability after pitch correction, the movement of the ANS and PNS was also evaluated in this study. The results of this study will contribute to acquiring more precise outcomes of maxilla correction in the orthognathic surgical treatment of patients with clockwise or counter-clockwise rotation.

Materials and Methods

Patients: Thirty-four patients who underwent conventional L-1 of their maxillae due to a jaw deformity at the Oral and Maxillofacial Surgery Clinic of the Nagasaki University Hospital and Dentistry and Oral Surgery Clinic at the University of Fukui Hospital between 2006 and 2012 were included in this study. No patients had undergone prior orthognathic surgery. No critical complications or trouble with the osteosynthesis materials were observed during or after surgery.

Surgical procedure: Standard one-piece L-1 with down-fracture was performed in all maxillae. The segments were rigidly fixed using four titanium plates with five titanium screws in each plate at the bilateral para-nasal aperture and root of the zygoma after moving the segment to the planned position with a splint.

Lateral cephalometric measurement (Fig. 2): Lateral cephalograms were obtained before surgery (T1), immediately after surgery (T2) and at more than one year of follow-up (T3). The aim of this study was to assess the maxillary stability after L-1 with clockwise or counter-clockwise rotation for correcting the pitch. For this purpose, the SN-PP (the angle between the SN and PP) was measured. Furthermore, the positions of the ANS and PNS were measured to assess the effects of their vertical movement on maxillary stability. A horizontal reference line was constructed at seven degrees clockwise rotation from the SN through the Sella (S) according to a previous report.[7] The perpendicular distances from the horizontal line to the ANS, PNS and point A were measured to evaluate the vertical movement of these parameters. The level of the horizontal line was described as 0; negative values increased as the underlying position from the horizontal line increased.

Clockwise or counter-clockwise rotation: Reyneke et al.[5] decided if the angle of

occlusal plane increased more than 2 degrees, that movement was clockwise rotation. According to their report, counter-clockwise (Group 1) or clockwise rotation (Group 2) was defined as an increase or decrease in the SN-PP of more than two degrees, respectively. Bone transplantation was performed in two cases in which the ANS moved downward by more than 4 mm.

Group 1: Counter-clockwise rotation of the segment after Le Fort I osteotomy. SN-PP decreased more than 2 mm. T2-T1 of SN-PP < -2 degrees.

Group 2: Clockwise rotation of the segment after Le Fort I osteotomy. SN-PP increased more than 2 mm. 2 degrees < T2-T1 of SN-PP.

Statistical analysis: Student's *t*-test was used to compare the average cephalometric measurements in order to evaluate the changes at different time points. A p-value of < 0.05 was considered to be statistically significant.

Results

Maxillary stability after counter-clockwise rotation

In four of the 34 cases, the segment was rotated counter-clockwise after L-1. The data for these four cases are listed in Table 1. The SN-PP decreased 4.30 ±0.99 (3.21-5.31) degrees from T1 to T2. All measured points were completely stable in cases 1, 2 and 3. In case 4, the ANS and PNS decreased 0.45 mm and 0.72 mm from T2 to T3, respectively, which resulted in relapse of the SN-PP of 1.82 degrees.

Maxillary stability after clockwise rotation

In 16 of the 34 cases, the segment was rotated clockwise with L-1. Among all cases, the SN-PP increased 4.33 ±0.63 degrees from T1 to T2 and T3-T2 of SN-PP, ANS, PNS and point A was each less than 1.0 mm (Table 2). Since T2-T1 of SN-PP had wide range (2.2-11.58 degrees), Group 2 was divided into following four groups to assess that the relationship between the rotation amount of the segment and relapse after L-1 (Table 3). For this purpose, the skeletal stability was assessed when T2-T1 of SN-PP was lower than 3 or 4 degrees.

Group 2-a: 2 degrees < T2-T1 of SN-PP $\leqq$ 3 degrees

Group 2-b: 3 degrees < T2-T1 of SN-PP

Group 2-c: 2 degrees < T2-T1 of SN-PP $\leqq$ 4 degrees

Group 2-d: 4 degrees < T2-T1 of SN-PP

The patients were divided into two groups according to the degree of change in the SN-PP, and the stability was evaluated separately in each group. T3-T2 of SN-PP was 0.18 degrees, while the T3-T2 of ANS, PNS and point A were each less than 1.0 mm in Group 2-a. T3-T2 of SN-PP changed 0.77 degrees, while T3-T2 of ANS, PNS and point A remained less than 1.0 mm in Group 2-b. However, T3-T2 of SN-PP was 0.08 degrees

(2.60%), while that of ANS, PNS or point A was each less than 0.25 mm in Group 2-c. In Group 2-d, T3-T2 of SN-PP was -2.05 degrees (28.59%) and T3-T2 of point A was 1.64 mm (47.81%), although the differences were not significant. T3-T2 of ANS was 2.56 mm (64.97%) with a significant difference. In contrast, T3-T2 of PNS was small (0.69 mm) (Table 3).

Effects of ANS movement on maxillary stability after clockwise rotation

SN-PP, ANS, PNS and point A were measured when ANS moved upward or downward in order to assess the influence of vertical movement of ANS on the maxillary stability (Table 4). All measured degrees and points were stable when the ANS moved upward (1.77 ±1.25 mm). On the other hand, T3-T2 of ANS was 1.23 mm (42.27%), with a statistically significant difference, when the ANS moved downward (2.91 ±1.79 mm). Although the value was small (0.73 mm), the PNS also changed, with a statistically significant difference. The range of downward shift in ANS was 0.12-7.21 mm after L-1. Thus, the relationship between the amount of ANS movement downward and relapse after L-1 with clockwise rotation was assessed as followed (Table 4). According to Ueki et al,[8] there was more than 3mm gap between bone segments after L-1, the bone healing was delayed, the samples was divided into the two groups whether T2-T1 of ANS was more than 3 mm or not.

Group 2-e: T2-T1 of ANS $\leqq$ 3 mm

Group 2-f: 3 mm < T2-T1 of ANS

All measured degrees and points were stable in Group 2-e (Table 5). In Group 2-f, both the ANS and point A relapsed significantly by 2.75 mm (64.55%) and 2.31 mm (60.16%), respectively. The PNS was moved upward by 1.11 mm, however, the difference was not significant. Two patients exhibited more than four degrees of

clockwise rotation, both of whom underwent bone transplantation into the gap of the anterior wall of the maxillary sinus. However, T3-T2 of ANS was 4.54 mm and 1.85 mm and the relapse rate was 62.97% and 38.2%, respectively.

Effects of PNS movement on maxillary stability after clockwise rotation

The SN-PP, ANS, PNS and point A were evaluated when the PNS moved upward (3.17 ±1.51 mm) or downward (0.41 ±0.58 mm) in order to assess the effects of vertical movement of the PNS on the maxillary stability after L-1 (Table 6). In both cases, all measured degrees and points exhibited relatively good stability.

The range of upward movement of the PNS was wide (1.30-5.99 mm) after osteotomy. Thus, Group 2 was divided into following four groups to assess that the relationship between the rotation amount of PNS movement and relapse after L-1 (Table 7). The sample was divided whether T2-T1 of PNS was more than 3 mm or not same as ANS. Since the skeletal stability was not obtained, the sample was divided whether T2-T1 of PNS was more than 4 mm or not.

Group 2-g: T2-T1 of PNS $\leqq$ 3 mm

Group 2-h: 3 mm < T2-T1 of PNS

Group 2-i: T2-T1 of PNS $\leqq$ 4 mm

Group 2-j: 4 mm < T2-T1 of PNS

All measured degrees and points were stable in Group 2-h (Table 7). In contrast, the SN-PP and ANS tended to relapse by 1.35 degrees (30.61%) and 1.28 mm (70.72%), respectively in Group 2-g. The PNS remained completely stable when the PNS moved upward by less than 3 mm.

T3-T2 of ANS was 1.38 mm (52.08%) and the PNS was stable in Group 2-i (Table 7). In contrast, in Group 2-j, the ANS was stable, while the PNS relapsed by 1.23 mm

(24.21%) without statistically significant.

Discussion

In the patients with counter-clockwise rotation, although the sample size was small, the segments after surgery showed similar behavior in each case. Therefore, it was considered that the skeletal stability of segment was obtained in counter clockwise rotation after L-1 (Tables 1). In this group, the PNS did not shift significantly, and the upward movement of the ANS contributed to pitch correction of the maxillae, resulting in a wide contact area between the bone segments in both the anterior and posterior regions of the maxillae after L-1. Therefore, good skeletal stability was achieved. Proffit et al.[2] reported that good maxillary stability was obtained in a case of maxillary parallel impaction. In addition, Chemello et al.[9] also showed good stability of point A and FH-OP after L-1 associated with a decrease in the FH-OP of 8.8 degrees (counter-clockwise rotation). According to these results, the maxillary stability is reliable after L-1 in patients with counter-clockwise rotation. It is, of course, necessary to accumulate more cases in order to draw any definitive conclusions.

In the patients with clockwise rotation, the SN-PP exhibited good stability at the one-year follow-up when the SN-PP increased by less than four degrees with L-1. Among the cases in which the SN-PP increased by more than four degrees with L-1, the SN-PP relapsed by 2.05 degrees (28.59%) (Table 3). Moreover, the ANS significantly relapsed by 2.56 mm (64.97%) and point A relapsed by 1.64 mm (47.81%). On the other hand, the PNS remained completely stable. Considering these results, if the SN-PP changes by more than four degrees after surgery, the maxillary stability is not considered to be reliable due to relapse of the ANS.

Maxillary stability was acquired after L-1 in the patients with clockwise rotation when the ANS moved upward or downward by less than 3 mm. On the other hand, when the

ANS moved downward by more than 3 mm, the ANS and Point A were not stable, resulting in relapse of the SN-PP (Table 5). This result is consistent with the findings of Jakobsone et al.[10] who showed that the ANS stability is untrustworthy if the ANS moves downward by more than 4 mm after L-1 in patients with parallel or clockwise rotation. Ueki et al.[8] concluded that bone healing is delayed and not completed within one year if the gap between the bone segment is greater than 3 mm after L-1. According to these results, the maxillary stability is not considered to be reliable when the ANS moves downward by more than 3 mm.

Considering the instability of the ANS and the stability of the PNS when the SN-PP increased by more than four degrees (Table 3), vertical movement of the ANS is considered to affect the maxillary stability after L-1 in patients with clockwise rotation. In the present study, the ANS moved downward in most cases of clockwise rotation, resulting in a lack of bone contact between bone segments. Santos et al.[11] evaluated the segmental stability when the ANS moves downward by 1.19–10.20 mm and concluded that the level of segmental stability was unreliable without bone transplantation when the ANS moves downward. In the present study, bone transplantation was performed into the gap of the anterior wall of the maxillary sinus after osteotomy in two cases in which the ANS moved downward by 7.21 mm and 4.83 mm, respectively. However, in these cases, the ANS relapsed by 4.54 mm (62.97%) and 1.85 mm (38.3%) and the SN-PP rotated clockwise by 11.58 and 8.32 degrees, respectively. Therefore, it is considered that the thrust force of the anterior teeth was large enough to induce relapse during occlusion.

The PNS was stable regardless of the amount and direction of movement (Table 7) and remained completely stable when the SN-PP increased by more than four degrees after

L-1 (Table 3). The PNS stayed in position or moved upward slightly in most cases of clockwise rotation. This means that the degree of bone contact around the PNS remained stables after L-1 in the patients with clockwise rotation. Chemello et al.[8] reported that both skeletal and dental stability was obtained after L-1 by increasing the FH-OP by 5.6 degrees (clockwise rotation). However, point A did not move vertically after surgery, and the ANS and PNS values were not measured. Considering the fixation of point A, the PNS can move upward to increase the FH-OP. Therefore, the degree of bone contact should remain stable in both the ANS and PNS regions, resulting in good stability of the maxillae after L-1 in patients with clockwise rotation. This finding is consistent with our results.

In conclusion, the degree of maxillary stability is reliable after L-1 in patients with counter-clockwise rotation or less than four degrees of clockwise rotation in the SN-PP. On the other hand, large degrees of relapse were observed in the patients with clockwise rotation of more than four degrees in the SN-PP and/or a downward shift in the ANS of more than 3 mm. PNS was not seemed effect on the segmental stability a lot. We suggest moving the PNS upward instead of shifting the ANS downward in order to obtain a wide area of bone contact and not alter the ANS by more than 3 mm for postoperative stability after L-1 osteotomy in such cases.

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Figure legends

Figure 1. Segmental movement pattern.

Figure 2. Measurement angle and points on a lateral cephalogram.

ANS: anterior nasal spine, N: nasion, PNS: posterior nasal spine, S: sella.

The horizontal plane was rotated seven degrees from the SN plane through S.

The angle between the SN plane and the palatal plane was measured (SN-PP).

The distances from the horizontal plane to the ANS, PNS and point A were measured.

Figure 1.

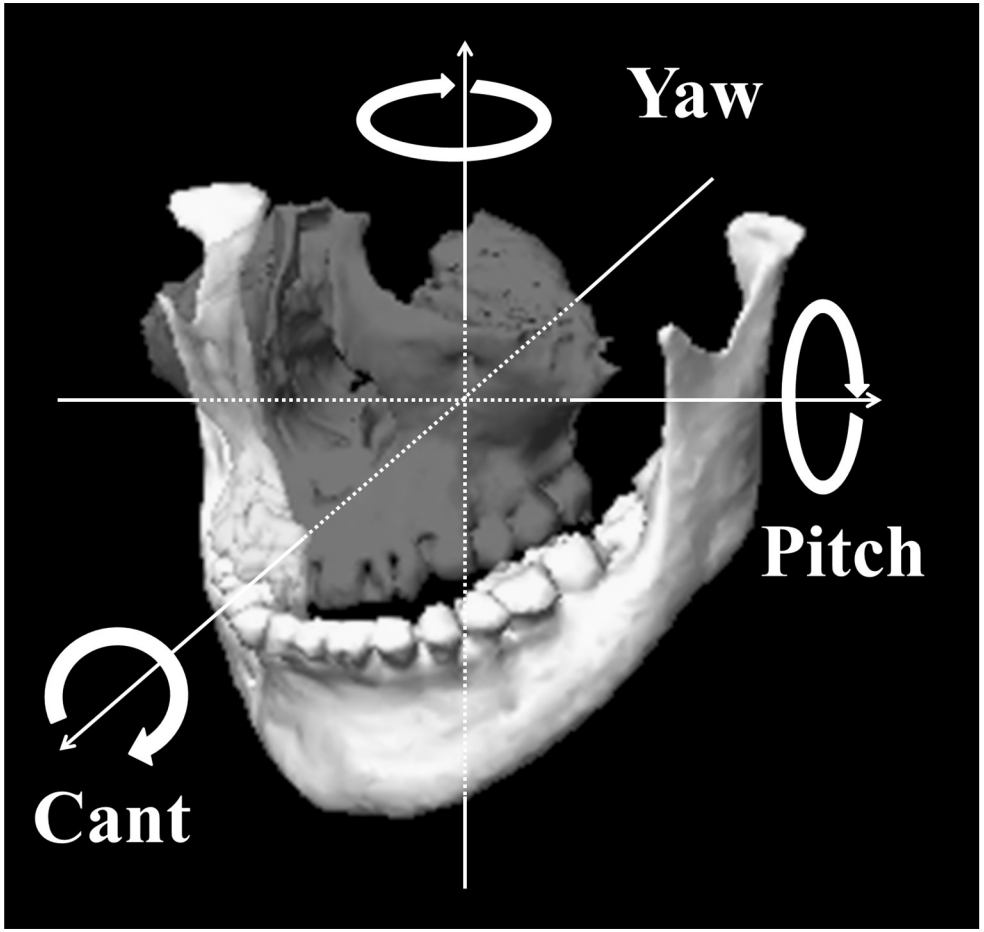

Figure 2.

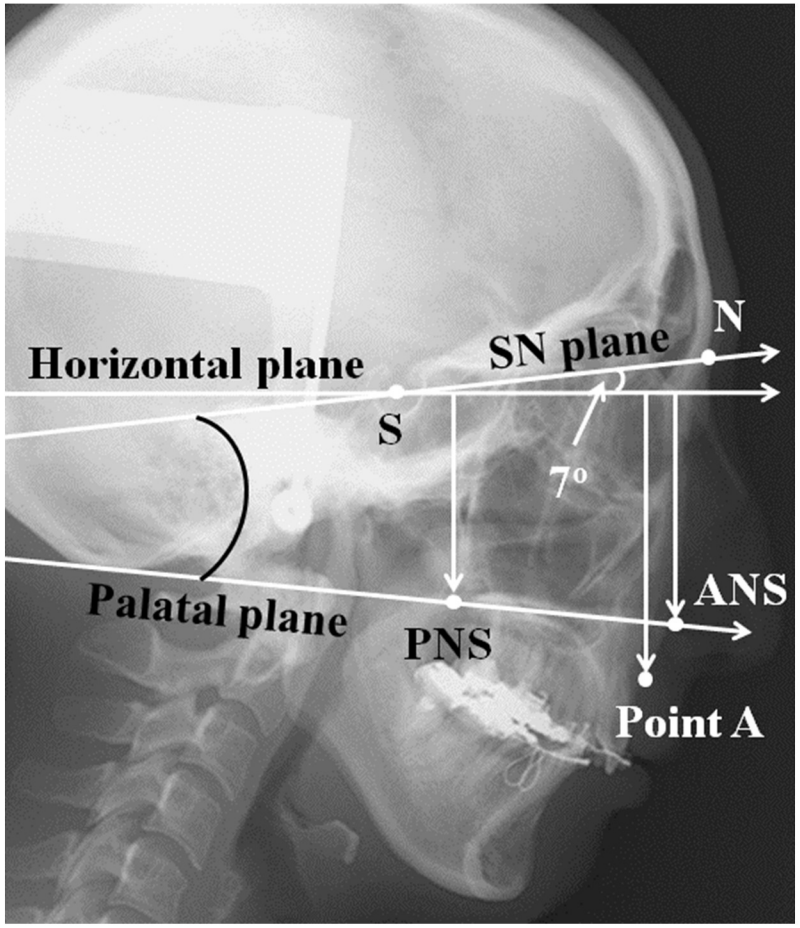

Table 1. The maxillary stability after counter-clockwise rotation (Group 1).

	SN-PP		ANS		PNS		Point A	
	T2-T1	**T3-T1**	**T2-T1**	**T3-T1**	**T2-T1**	**T3-T1**	**T2-T1**	**T3-T1**
Case 1	-4.8	-4.8	4.79	4.79	0.30	0.30	3.25	3.25
Case 2	-5.41	-5.41	2.54	2.54	1.71	1.71	2.40	2.40
Case 3	-3.21	-3.21	3.03	3.03	0.00	0.00	2.88	2.88
Case 4	-3.76	-1.94	1.95	1.50	0.74	0.02	0.22	1.34

Table 2. The maxillary stability among all cases after clockwise rotation (Group 2).

Total (n=16)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	4.33 ±0.63	3.75 ±3.57	0.2300	-0.58
ANS (mm)	-1.74 ±2.66	-0.92 ±1.94	0.0891	0.82
PNS (mm)	2.05 ±.013	2.37 ±1.62	0.3115	0.32
Point A (mm)	-1.73 ±2.54	-1.06 ±2.41	0.0922	0.67

Table 3. Effects of changes in the SN-PP on maxillary stability after clockwise rotation (Group 2). The SN-PP increased by less (a) or more (b) than three degrees, less (c) or more (d) than four degrees after L-1.

a) SN-PP<3 (n=5)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	2.60 ±0.30	2.42 ±1.17	0.6806	-0.18
ANS (mm)	-2.06 ±1.45	-1.32 ±1.37	0.1865	0.74
PNS (mm)	0.02 ±1.29	0.71 ±0.94	0.2243	0.69
Point A (mm)	-2.17 ±1.67	-1.28 ±1.62	0.5060	0.89
b) 3<SN-PP (n=11)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	5.12 ±2.73	4.35 ±2.42	0.2711	-0.77
ANS (mm)	-1.60 ±3.11	-0.74 ±2.18	0.2071	0.86
PNS (mm)	2.98 ±1.77	3.12 ±1.26	0.7151	0.14
Point A (mm)	-1.41 ±.282	-0.73 ±2.62	0.1361	0.68
c) SN-PP<4 (n=11)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	3.04 ±0.50	3.12 ±1.52	0.8333	0.08
ANS (mm)	-0.74 ±2.28	-0.72 ±1.95	0.9365	0.02
PNS (mm)	1.81 ±2.45	1.96 ±1.58	0.7219	0.15
Point A (mm)	-0.96 ±2.25	-0.72 ±2.10	0.4753	0.24
d) 4<SN-PP (n=5)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	7.17 ±2.97	5.12 ±3.17	0.1174	-2.05
ANS (mm)	-3.94 ±2.16	-1.38 ±2.04	0.0362*	2.56
PNS (mm)	2.58 ±0.95	3.27 ±1.45	0.1794	0.69
Point A (mm)	-3.43 ±2.50	-1.79 ±3.11	0.1383	1.64

Table 4. Effects of the direction of ANS movement on maxillary stability after clockwise rotation (Group 2).

upward (n=4)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	3.31 ±0.41	2.73 ±1.09	0.3150	-0.58
ANS (mm)	1.77 ±1.25	1.34 ±1.44	0.3910	0.43
PNS (mm)	4.39 ±1.67	3.42 ±1.00	0.1837	0.97
Point A (mm)	1.28 ±1.73	1.25 ±1.74	0.3910	0.03
downward (n=12)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	4.68 ±2.87	4.09 ±2.48	0.3586	-0.59
ANS (mm)	-2.91 ±1.79	-1.68 ±1.43	0.0422*	-1.23
PNS (mm)	1.29 ±1.70	2.02 ±1.67	0.0228*	0.73
Point A (mm)	-2.74 ±1.89	-1.82 ±2.12	0.0884	-0.92

*$p<0.05$: a statistical difference between the amount of T2-T1 and T3-T1.

Table 5. Effects of ANS vertical movement on maxillary stability after clockwise rotation. The ANS moved downward by more or less than 3 mm (Group 2).

e) ANS<3 (n=7)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	3.45 ±0.86	3.81 ±1.5	0.4737	0.36
ANS (mm)	-1.95 ±1.04	-1.80 ±1.40	0.7543	0.15
PNS (mm)	1.32 ±1.38	1.77 ±1.52	0.2198	0.45
Point A (mm)	-1.95 ±1.11	-2.00 ±1.86	0.8319	-0.05
f) 3<ANS (n=5)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	6.03 ±3.60	4.42 ±3.26	0.1600	-1.61
ANS (mm)	-4.26 ±1.81	-1.51 ±1.63	0.0161*	2.75
PNS (mm)	1.24 ±2.25	2.35 ±1.98	0.0706	1.11
Point A (mm)	-3.84 ±2.31	-1.53 ±2.64	0.0223*	2.31

*$p<0.05$: a statistical difference between the amount of T2-T1 and T3-T1.

Table 6. Effects of the direction of PNS movement on maxillary stability after clockwise rotation (Group 2).

upward (n=11)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	5.09 ±2.75	4.15 ±2.45	0.1571	-0.94
ANS (mm)	-1.31 ±3.12	-0.46 ±2.09	0.2134	0.85
PNS (mm)	3.17 ±1.51	3.15 ±1.23	0.9482	-0.02
Point A (mm)	-1.27 ±2.91	-0.53 ±2.65	0.1365	0.74
downward (n=5)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	2.67 ±0.31	2.86 ±1.66	0.7574	0.19
ANS (mm)	-2.70 ±0.63	-1.94 ±1.14	0.1688	0.76
PNS (mm)	-0.41 ±0.58	0.65 ±0.83	0.0967	1.06
Point A (mm)	-2.74 ±1.01	-2.22 ±1.31	0.5060	0.52

Table 7. Effects of the amount of PNS vertical movement on maxillary stability after clockwise rotation. The PNS moved downward by more or less than 3 mm (Group 2).

g) PNS<3 (n=5)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	4.41 ±1.64	3.06 ±1.25	0.3082	-1.35
ANS (mm)	-1.81 ±1.37	-0.53 ±1.70	0.2022	1.28
PNS (mm)	1.88 ±0.58	2.20 ±0.96	0.3739	0.32
Point A (mm)	-1.46 ±1.51	-0.91 ±2.94	0.5251	0.55
h) 3<PNS (n=5)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	5.66 ±3.48	5.06 ±2.94	0.4094	-0.6
ANS (mm)	-0.89 ±4.19	-0.41 ±2.53	0.6423	0.48
PNS (mm)	4.25 ±1.10	3.94 ±0.79	0.6130	-0.31
Point A (mm)	-1.11 ±3.88	-0.21 ±2.62	0.1815	-0.9
i) PNS<4 (n=8)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	5.96 ±3.04	4.69 ±2.62	0.2687	-1.27
ANS (mm)	-2.65 ±2.48	-1.27 ±1.67	0.1216	1.38
PNS (mm)	2.45 ±0.91	2.88 ±1.33	0.1719	0.43
Point A (mm)	-2.35 ±2.48	-1.32 ±2.51	0.1325	1.03
j) 4<PNS (n=3)	**T2-T1**	**T3-T1**	**p**	**T3-T2**
SN-PP (degree)	3.25 ±0.27	2.71 ±2	0.3410	-0.54
ANS (mm)	2.27 ±0.93	1.69 ±1.53	0.4226	0.58
PNS (mm)	5.08 ±0.95	3.85 ±0.60	0.1860	-1.23
Point A (mm)	1.61 ±1.96	1.56 ±1.97	0.4226	-0.05