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Original Article

Pharyngeal Airway Space Changes after Single Mandibular and Two-Jaw Surgery in Patients with Skeletal Class II Malocclusion

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Main Points

- The results of single-jaw mandibular advancement surgery and double-jaw surgery have demonstrated a positive impact on the increase of oropharyngeal and hypopharyngeal airway size.
- In patients with severe skeletal Class II malocclusion and hyperdivergent, a reduction in nasopharyngeal airway dimensions has been observed following the implementation of preferred double-jaw surgery.
- The reduction in the nasopharyngeal airway following double-jaw surgery can be attributed to maxillary impaction.
- In addition to the anterior displacement of the hyoid bone observed following single-jaw mandibular advancement surgery, superior displacement of the hyoid bone was also observed following double-jaw surgery.

ABSTRACT

Objective: To retrospectively evaluate the effects of single mandibular advancement (MA) and two-jaw surgery (2J-S) on the pharyngeal airway space (PAS) and hyoid position for the correction of skeletal Class II malocclusion.

Methods: Eleven adult patients who underwent only MA surgery and twelve adult patients who underwent Le Fort I maxillary impaction-MA surgery (2-JS) were included in the retrospective study. A total of 46 cephalometric recordings obtained before (T1) and after treatment (T2) were examined. Craniofacial changes, area, and linear measurements of the pharyngeal airway and hyoid bone position were obtained in both groups. The Wilcoxon signed-rank test was used to evaluate time-dependent changes within groups. The Mann-Whitney U test was used to compare differences between groups.

Results: Hyoid-Vert values increased significantly in both groups (MA, $p<0.01$; 2J-S, $p<0.05$); however, Hyoid-Hor values decreased significantly only in the 2J-S group ($p<0.01$). The anteroposterior dimensions of the airway increased in both groups, except for the PNS-P and PPS groups ($p<0.01$). Although a significant increase was observed in the nasopharyngeal area (A1) in the MA group ($p<0.05$), the decrease was found to be statistically significant in 2JG ($p<0.01$). Significant increases were found in the oropharyngeal (A2) and hypopharyngeal areas (A3) in both groups ($p<0.01$, $p<0.05$).

Conclusion: Both surgical procedures for the correction of Class II malocclusion resulted in increased hypopharyngeal, oropharyngeal, and total airway measurements.

Keywords: Class II treatment, orthognathic surgery, mandibular advancement, pharyngeal airway, non-growing patients, skeletal malocclusion

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INTRODUCTION

Sixty percent of individuals with Class II division 1 malocclusion have posterior positioning of the mandible, and a smaller percentage have anterior positioning of the maxilla.[1] Muto et al.[2] reported that patients with Class II malocclusion had pharyngeal dimensions that specifically decreased in the anteroposterior direction in the retroglossal region of the oropharynx. Therefore, a direct relationship was observed between the sagittal position of the mandible and the pharyngeal airway space (PAS) dimensions.

Lateral cephalograms are reproducible diagnostic tools that can effectively examine the PAS and hyoid bone position.[3,4] PAS measurements made on lateral cephalometric recordings were highly correlated in terms of predictability when compared with measurements made on three-dimensional (3D) imaging methods.[5] It has also been stated that it is used for diagnostic purposes and staging of pharyngeal airway obstruction in obstructive sleep apnea symptoms (OSAS) patients.[6]

Orthognathic surgical inevitably affects not only the hard tissues but also all soft tissues associated with the maxilla and mandible. The most affected areas are the PAS, which has many vital functions, such as breathing and swallowing. It was detected that the morphology of many complex structures was affected and respiratory efficiency changed after orthognathic surgery.[7,8] Moreover, it is known that in Class II individuals due to mandibular retrognathia, PAS dimensions are increased as a result of moving the mandible forward, and as a result, sleep breathing disorders such as snoring and OSAS can be reduced.[6]

The aim of our study was to assess pharyngeal airway changes after mandibular advancement (MA), combined with LeFort I maxillary impaction and MA [two-jaw surgery (2J-S)], and compare the results for each surgical procedure; our study also included postoperative evaluation of the hyoid bone.

METHODS

This retrospective study was conducted using data obtained from patients at Ankara University Faculty of Dentistry, Department of Orthodontics and Maxillofacial Surgery. The study was approved by the Ankara University Faculty of Dentistry Clinical Research Ethics Committee (approval no.: 36290600/70, date: 07.07.2017).

Study Design and Subject Selection

Sample size was determined via power analysis (G*Power, Ver. 3.1.9.2, Franz Faul; Universitat Kiel, Germany), concluding that a maximum of 10 subjects per group was sufficient. The calculation of the sample size based on the study of Jiang et al.[4] indicated that 20 patients would be sufficient for each group with a power greater than 80%, an alpha error of 0.05, a beta error of 0.20, and an effect size of 0.9. Therefore, the analysis included the radiographs of 23 adult patients: 11 patients with severe skeletal Class II malocclusion underwent single MA surgery (mean age: 25.29±7.70 y; six females, five males) and 12 patients with severe skeletal Class II malocclusion underwent 2J-S (mean age: 23.18±3.98 y, eleven females, one male). All patients included in the study were in the Ru stage according to hand-wrist radiographs and had completed 100% of their development.

When selecting patients for the groups, pre- and post-treatment radiographs were evaluated, and those who met the following criteria were included: Non-syndromic, skeletal Class II adult patients who underwent MA only and combined Lefort I maxillary impaction and MA surgery, and completed postsurgical orthodontic treatment. The exclusion criteria were previous orthognathic surgery, genioplasty, OSA, stained and poor-quality radiographs, and craniofacial anomalies.

Fixed orthodontic treatment was applied to each patient for decompensation before orthognathic surgery. After surgical treatment was completed, orthodontic treatment was continued for a certain period to achieve ideal occlusion. The mean treatment duration was 1.72 years in the MA group and 2.10 years in the 2-JS. While combined maxillary impaction and MA surgery was performed in the 2-JS group, single MA surgery was performed in the MA group.

Cephalometric Method and Data Acquisition

Lateral cephalometric radiographs obtained before (T1) and after treatment (T2) were included in the study. Measurements were performed using a computer software (Dolphin Imaging 11.95, Dolphin Imaging & Management Solutions, Chatsworth, CA, USA). As in previous studies, a horizontal plane (Hor) angled +7° clockwise to the SN line passing through Sella and a vertical plane (Vert) passing through Sella and perpendicular to this line were used as reference planes in this study (Figure 1).[4,9] Similar to the study of Ono et al.[10] and Tsuiki et al.[11], PAS reference points were used. Six linear and three area measurements were performed to determine changes in the PAS (Figures 2 and 3). Moreover, the PAS was divided into 3 regions and the area changes in PAS were evaluated.[11] A digital planimeter (Ushikata X plan380dll/460dll, Tokyo, Japan) was used for area measurements. In order to minimize the error rate, each determined area was measured 3 times and the average of the 3 measurements was obtained.

Statistical Analysis

The data obtained in this study were evaluated using the SPSS 11.5 package. The Shapiro–Wilk test was used to test the normality of parameter distribution. The Wilcoxon signed-rank test was used to evaluate changes in skeletal, dental, and pharyngeal airway parameters from T1 to T2 in the study group. The Mann–Whitney U test was used to compare the changes obtained in T2-T1 between groups and for comparisons between groups at T1. In the parametric evaluation of the changes from T1 to T2 in all patients, the paired sample t-test was used for data with normal distribution, and the Wilcoxon signed-rank test was used for data not conforming to normal distribution. Significance was predetermined at $P<0.05$.

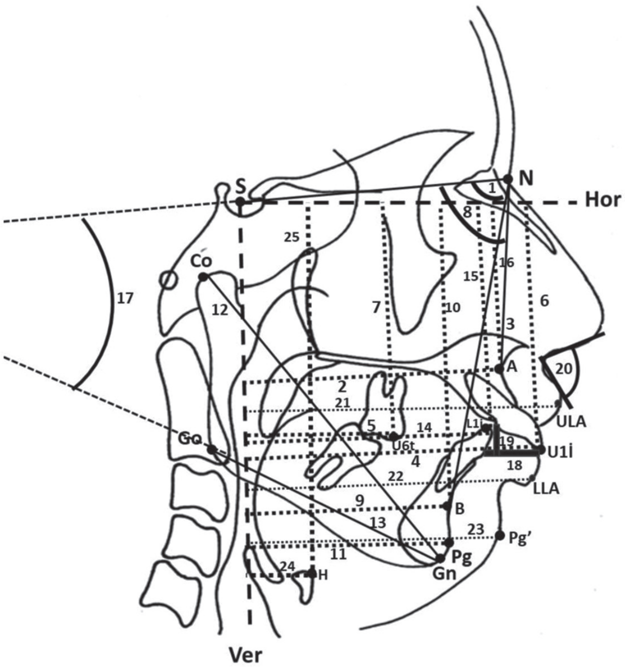

Figure 1. Cephalometric measurements. Maxillary skeletal and dental measurements: (1) SNA; (2) A-Vert; (3) A-Hor; (4) U1i-Vert; (5) U6t-Vert; (6) U1i-Hor; and (7) U6t-Hor. Mandibular skeletal and dental measurements: (8) SNB; (9) B-Vert; (10) B-Hor; (11) Pg-Vert; (12) Co-Gn; (13) Go-Gn; (14) L1i-Vert; and (15) L1i-Hor. Maxillo-mandibular skeletal and dental measurements: (16) ANB; (17) GoGn/SN; (18) Overjet; (19) Overbite. Soft Tissue Measurements: (20) Nasolabial angle; (21) ULA-Vert; (22) LLA-Vert; and (23) Pg'-Vert. Hyoidal measurements: (24) Hyoid-Vert; (25) Hyoid-Hor

RESULTS

In this study, all measurements made in a total of 20 lateral cephalometric records taken at the beginning and end of the treatment of 10 randomly selected individuals included in the treatment group were repeated 4 weeks later. The intraclass correlation value between the first and second measurements was found to be between 0.68 and 1.00 with confidence intervals, and it was observed that all measurements were reproducible.

Cephalometric Measurements

Comparisons of the values obtained in T1 for MA and 2-JS are presented in Table 1. Among the parameters in the T1 period, ANB, GoGn/SN, and B-Hor values were significantly higher in 2-JS ($P<0.05$), whereas Pg-Vert ($P<0.05$) and overbite ($P<0.01$) values were higher in MA. Apart from this, all values were found to be similar in the comparison between groups at T1 ($P>0.05$) (Table 1).

Changes in the craniofacial and hyoid position and PAS measurements from T1 to T2 in MA are presented in Table 2. Significant increases were observed in all measurements of mandibular skeletal, dental, and soft tissue measurements ($P<0.01$). In maxillo-mandibular skeletal measurements, there was a significant decrease in the ANB value (-3.27°) and a significant increase in the GoGn/SN (2.31°) ($P<0.01$). Significant decreases in overjet (-5.11 mm; $P<0.01$) and overbite (-3.43 mm; $P<0.05$) values were detected. A significant increase was observed in the Hyoid Region (4.02 mm; $P<0.01$). Significant

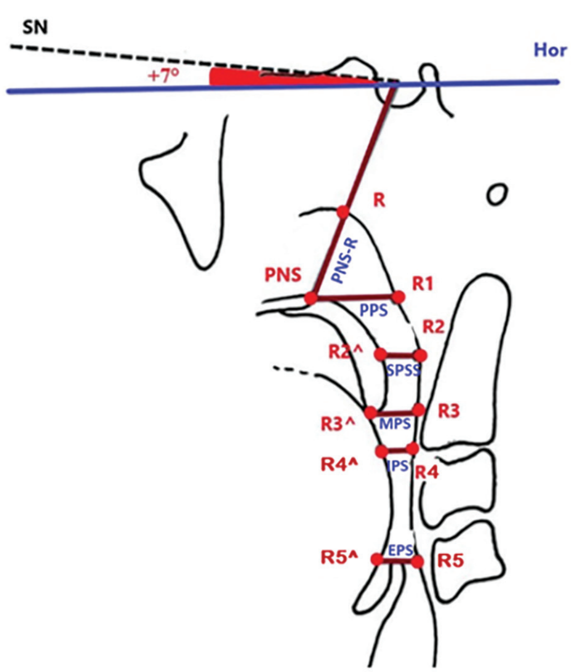

Figure 2. Pharyngeal Linear Measurements: PNS-R: distance between PNS and R points; PPS (PNS-R1): distance between PNS and R1 points (Palatal pharyngeal region). SPSS (R2-R2^): Superior posterior pharyngeal region MPS (R3-R3^): Middle pharyngeal region, IPS(R4-R4^): Inferior pharyngeal region, EPS (R5-R5^): Epiglottic pharyngeal region

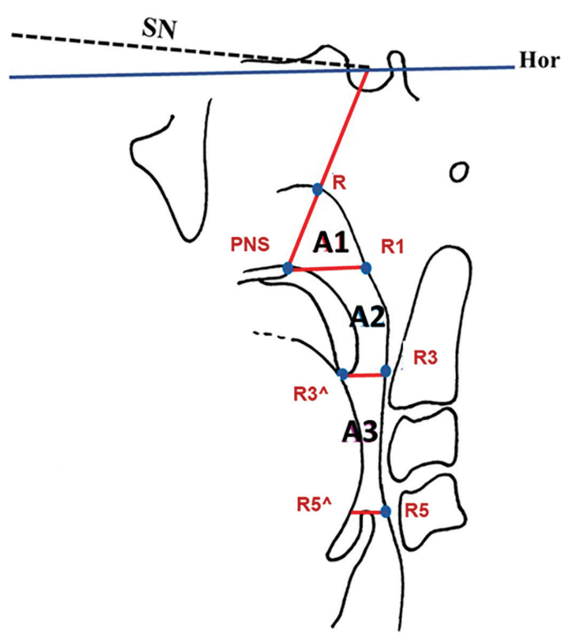

Figure 3. Pharyngeal Area Measurements: AREA 1 (A1): Nasopharyngeal Area; region bounded by the anterior and posterior pharyngeal walls between the PNS-R and PPS planes. AREA 2 (A2): Oropharyngeal area; region bounded by the anterior and posterior pharyngeal walls between the PPS and MPS planes. AREA 3 (A3): Hypopharyngeal Area; region bounded by the anterior and posterior pharyngeal walls between the MPS and EPS planes

Table 1. Comparison of the cephalometric measurements in pre-treatment (T1) periods between groups

Parameters	MA Group T1					2-JS Group T1					P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Maxillary skeletal measurements											
SNA	77.46	3.74	79.50	70.4	81.2	78.58	3.78	77.95	73.8	87.1	0.887
A-Ver	61.17	5.25	61.50	52.3	68.7	60.63	4.90	61.40	52.2	68.7	0.815
A-Hor	51.43	2.98	52.00	44.7	55.3	51.72	3.12	52.05	45.8	58.1	0.962
Maxillary dental measurements											
U1i-Ver	63.88	5.24	64.90	55.8	69.6	61.83	5.48	61.45	53.9	72.0	0.289
U6t-Ver	33.86	5.10	33.70	23.0	40.9	33.29	4.92	33.25	24.6	39.8	0.873
U1i-Hor	73.88	5.28	74.70	60.8	81.1	75.16	4.22	75.00	68.4	82.0	0.131
U6t-Hor	65.19	4.36	64.60	56.1	71.7	66.87	3.48	67.15	61.5	72.8	0.441
Mandibular skeletal measurements											
SNB	70.30	3.77	71.50	64.6	75.8	69.11	3.19	68.35	65.2	76.5	0.203
B-Ver	45.68	7.64	47.70	33.4	57.9	39.90	7.13	38.15	31.0	53.0	0.055
B-Hor	86.59	7.17	85.40	73.1	99.7	91.20	4.19	90.50	86.0	99.5	0.032*
Pg-Ver	46.86	8.32	48.90	34.5	61.1	38.68	7.26	36.00	29.0	51.5	0.019*
Co-Gn	101.98	7.49	103.40	91.4	116.5	101.49	8.82	101.55	88.1	115.1	0.984
Go-Gn	66.39	3.68	64.80	61.4	72.7	64.20	6.05	65.65	53.0	72.3	0.872
Mandibular dental measurements											
L1i-Ver	55.88	5.68	56.60	47.6	63.5	53.97	7.51	52.8	42.7	67.0	0.257
L1i – Hor	67.81	6.68	67.70	54.6	79.9	70.13	7.19	71.05	50.4	78.4	0.138
Maxillo-mandibular skeletal measurements											
ANB	7.15	1.57	7.10	4.8	9.1	9.29	2.38	9.00	5.6	14.1	0.013*
GoGn/SN	34.52	7.57	34.30	22.8	45.5	41.94	6.87	43.10	27.1	50.8	0.032*
Maxillo-mandibular dental measurements											
Overjet	8.42	2.73	8.90	2.7	11.5	8.34	3.59	8.45	3.6	13.8	0.891
Overbite	6.10	3.44	6.90	-3.2	9.3	2.72	4.14	4.25	-9.1	5.6	0.003**
Soft tissue measurements											
Nasolabial angle	97.29	8.58	98.30	75.9	108.2	102.47	10.03	101.00	89.1	119.3	0.364
ULA-Ver	76.34	4.23	76.20	70.6	81.7	74.50	5.48	74.75	66.6	82.7	0.439
LLA-Ver	67.14	6.00	68.70	60.1	75.9	64.62	6.11	63.40	55.8	76.6	0.537
Pg′-Ver	59.64	8.59	63.10	48.5	74.0	53.01	6.85	52.50	43.5	65.3	0.086
Hyoidal measurements											
Hyoid-Ver	2.75	7.38	2.30	-10.7	14.4	-0.81	7.46	-0.80	-10.6	13.0	0.054
Hyoid-Hor	101.23	11.50	98.50	82.5	124.0	98.73	8.17	97.60	86.5	113.5	0.102
PAS linear measurements											
PNS-P	18.15	2.73	18.20	13.1	24.2	18.79	2.02	19.35	14.5	21.6	0.858
PPS	25.05	2.33	25.40	21.9	29.0	24.77	2.86	25.35	18.9	28.8	0.861
SPSS	9.30	3.41	8.90	3.3	14.8	11.10	2.47	11.95	6.0	13.7	0.476
MPS	9.96	2.70	10.10	5.4	14.2	9.55	1.55	9.75	7.0	12.0	0.983
IPS	8.67	2.96	7.90	4.1	13.7	9.28	3.67	9.75	2.9	14.0	0.791
EPS	9.22	2.57	9.10	4.8	13.4	11.72	3.00	10.90	7.2	17.0	0.279
PAS area measurements											
Area 1	306.20	65.10	291.05	202.51	430.17	350.43	68.15	349.97	236.55	440.12	0.052
Area 2	284.84	86.77	260.71	181.98	448.05	281.27	65.63	291.43	155.50	381.76	0.764
Area 3	208.46	34.80	216.14	148.96	277.03	238.46	98.87	206.07	112.33	427.20	0.173

SD indicates standard deviation; min., minimum value; and max., maximum value.
Mann-Whitney U test; P≤0.05*, P≤0.01**, P≤0.001***.
MA, mandibular advancement group; 2-JS, two-jaw surgery group; Ver, vertical reference plane; Hor, horizontal reference plane; Co, condylion; U1i, upper central incisor; U6t, upper first molar; L1i, lower central incisor; ULA, upper lip anterior; LLA, lower lip anterior; H, Hyoidale; PAS, pharyngeal airway space

Table 2. Pre- (T1) and post-treatment (T2) changes in cephalometric variables in the single-jaw mandibular advancement group

MA Group																
Parameters	T1					T2					T2-T1					P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Maxillary skeletal measurements																
SNA	77.46	3.74	79.50	70.4	81.2	77.53	3.78	79.90	70.0	81.5	0.07	0.45	0.20	-0.50	0.90	0.289[a]
A-Ver	61.17	5.25	61.50	52.3	68.7	62.07	6.51	63.40	53.5	76.3	0.90	2.79	1.00	-3.20	7.60	0.920
A-Hor	51.43	2.98	52.00	44.7	55.3	51.67	4.26	53.00	41.7	56.4	0.24	2.85	0.70	-7.10	5.40	0.635
Maxillary dental measurements																
U1i – Ver	63.88	5.24	64.90	55.8	69.6	64.58	7.05	67.00	54.4	79.2	0.70	3.65	0.20	-3.70	9.70	0.667
U6t-Ver	33.86	5.10	33.70	23.0	40.9	35.70	5.38	35.10	28.1	47.4	1.84	2.67	1.40	-2.00	6.50	0.299
U1i-Hor	73.88	5.28	74.70	60.8	81.1	75.70	5.60	74.50	62.7	81.9	1.81	2.61	1.60	-1.20	8.90	0.028*
U6t-Hor	65.19	4.36	64.60	56.1	71.7	66.20	4.93	65.50	56.1	73.3	1.01	2.21	0.50	-1.70	7.20	0.416
Mandibular skeletal measurements																
SNB	70.30	3.77	71.50	64.6	75.8	73.88	3.64	74.00	68.2	79.2	3.57	1.08	3.60	1.90	5.30	0.008**
B-Ver	45.68	7.64	47.70	33.4	57.9	51.42	8.09	52.00	42.4	66.7	5.74	4.52	4.40	0.80	14.90	0.004**
B-Hor	86.59	7.17	85.40	73.1	99.7	91.36	7.73	91.40	76.1	104.5	4.77	3.78	4.20	0.60	15.20	0.003**
Pg-Ver	46.86	8.32	48.90	34.5	61.1	52.19	9.49	52.70	41.2	67.8	5.32	4.59	3.80	-0.10	13.90	0.004**
Co-Gn	101.98	7.49	103.40	91.4	116.5	108.69	9.49	108.80	93.2	121.5	7.71	6.12	5.50	1.80	5.00	0.003**
Go-Gn	66.39	3.68	64.80	61.4	72.7	70.92	5.44	71.00	62.0	80.1	4.53	2.52	5.30	-0.60	7.40	0.007**
Mandibular dental measurements																
L1i-Ver	55.88	5.68	56.60	47.6	63.5	61.74	7.00	63.60	52.2	76.5	5.86	4.03	4.60	1.30	15.30	0.002**
L1i-Hor	67.81	6.68	67.70	54.6	79.9	72.89	5.64	74.40	59.8	79.4	5.08	3.43	-0.40	-9.2	13.9	0.006**
Maxillo-mandibular skeletal measurements																
ANB	7.15	1.57	7.10	4.8	9.1	3.61	2.18	3.90	-0.8	6.5	-3.27	1.47	3.50	-5.50	-2.50	0.002**
GoGn/SN	34.52	7.57	34.30	22.8	45.5	36.88	7.78	36.80	25.0	45.9	2.31	1.56	2.00	0.50	4.50	0.009**
Maxillo-mandibular dental measurements																
Overjet	8.42	2.73	8.90	2.7	11.5	3.31	0.92	0.92	3.50	2.0	-5.11	2.72	-5.40	-8.90	0.20	0.003**
Overbite	6.10	3.44	6.90	-3.2	9.3	2.67	1.03	1.03	2.50	0.6	-3.43	3.39	-4.60	-6.80	4.70	0.011*
Soft tissue measurements																
Nasolabial angle	97.29	8.58	98.30	75.9	108.2	97.73	9.49	99.70	85.3	111.8	0.44	9.11	0.8	-13.8	12.0	0.082[a]
ULA-Ver	76.34	4.23	76.20	70.6	81.7	78.01	7.15	79.70	68.0	94.4	1.67	4.38	0.3	-2.6	12.7	0.093
LLA-Ver	67.14	6.00	68.70	60.1	75.9	72.63	7.76	73.50	62.4	88.0	5.49	4.41	3.9	1.2	15.0	0.007**
Pg′-Ver	59.64	8.59	63.10	48.5	74.0	65.86	9.20	66.20	54.7	80.8	6.21	4.93	4.2	0.7	15.3	0.006**

Table 2. Continued

MA Group															
Parameters	T1					T2					T2-T1				P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Hyoidal measurements															
Hyoid-Ver	2.75	7.38	2.30	-10.7	14.4	6.78	6.93	6.60	-2.3	21.6	4.02	3.45	4.60	-2.3	9.9	0.005**
Hyoid-Hor	101.23	11.50	98.50	82.5	124.0	101.73	11.25	95.50	88.0	119.9	0.50	5.26	0.80	-9.6	9.8	0.645
PAS linear measurements															
PNS-P	18.15	2.73	18.20	13.1	24.2	18.38	2.96	17.70	13.1	24.4	0.22	1.07	0.20	-1.60	2.20	0.843
PPS	25.05	2.33	25.40	21.9	29.0	25.85	2.85	26.00	21.7	31.1	0.80	1.27	0.80	-1.00	2.10	0.786
SPSS	9.30	3.41	8.90	3.3	14.8	12.32	3.04	11.90	7.4	17.9	3.01	1.85	2.60	0.60	6.50	0.008**
MPS	9.96	2.70	10.10	5.4	14.2	13.50	2.10	13.90	9.7	16.6	3.53	1.90	3.80	0.40	6.70	0.009**
IPS	8.67	2.96	7.90	4.1	13.7	11.46	2.07	12.30	6.8	14.1	2.79	2.09	2.00	0.40	7.20	0.006**
EPS	9.22	2.57	9.10	4.8	13.4	12.59	2.13	13.60	8.6	14.9	3.36	1.66	3.50	0.90	6.20	0.007**
PAS area measurements															
Area 1	306.20	65.10	291.05	202.51	430.17	317.67	67.90	308.42	222.70	428.73	11.46	2.73	2.88	-27.88	77.63	0.028*
Area 2	284.84	86.77	260.71	181.98	448.05	367.09	97.21	314.18	265.29	556.92	82.24	52.41	67.89	36.21	226.55	0.004**
Area 3	208.46	34.80	216.14	148.96	277.03	276.28	54.16	278.65	162.65	394.48	67.81	42.55	66.93	8.19	168.04	0.006**

SD indicates standard deviation; min., minimum value; and max., maximum value. P≤0.05*, P≤0.01**, P≤0.001***

Paired t-tests were performed to compare the changes in posttreatment (T2) and pretreatment (T1), with the exception of a, which showed the results of the Wilcoxon signed-rank test

MA, mandibular advancement group; Ver, vertical reference plane; Hor, horizontal reference plane; Co, Condylion; U1i, upper central incisor; U6t, upper first molar; L1i, lower central incisor; ULA, upper lip anterior; LLA, lower lip anterior; H, hyoidale; PAS, pharyngeal airway space

increases were found in all linear measurements of the oropharyngeal and hypopharyngeal airway (P<0.01). A significant increase was found in all pharyngeal airway area measurements (A1, P<0.05; A2, P<0.01; A3, P<0.01) (Table 2).

Changes in the craniofacial and hyoid position and PAS measurements from T1 to T2 in 2-JS are presented in Table 3. A significant decrease was observed in A-Hor and U6t-Hor (P<0.01); however, the decrease in GoGn/SN value was not significant (P>0.05). Significant increases were detected in all measurements, including sagittal mandibular skeletal, dental, and soft tissue changes (P<0.01; P<0.05). Significant decreases were found in ANB (-2.13°) and overjet (-4.91 mm) values (P<0.01). A significant increase was found in the Hyoid Vertex (3.55 mm; P<0.05), whereas a significant decrease was detected in Hyoid-Hor (-4.43 mm; P<0.01). A significant decrease (P<0.01) was observed in PNS-P, one of the linear measurements of PAS, whereas significant increases were observed in all other linear measurements (P<0.01; P<0.05). A significant decrease was found in A1 (-52.25 mm^2; P<0.01), whereas significant increases were found in A2 (81.58 mm^2; P<0.01) and A3 (54.30 mm^2; P<0.05) (Table 3).

The comparison of differences from T1 to T2 between groups is presented in Table 4. The increase in A-Hor (P<0.01), U1i-Hor (P<0.05), U6t-Hor (P<0.001), B-Hor (P<0.001), L1i-Hor (P<0.001) and GoGn/SN (P<0.01), which are the parameters used in the vertical direction evaluation, increased in the MA group and the decrease in the 2-JS group was found to be significant in the comparison between groups. On the contrary, the decrease in the overbite value in the MA group and the increase in the 2-JS group were statistically significant compared with the time-dependent comparison of the groups (P<0.01). Increases in Hyoid-Hor (P<0.05) in MA and decreases in 2-JS showed significant differences between groups. In addition, the increase in PNS-P and A1 values from T1 to T2 in the MA group (P<0.01) and the decrease in the 2-JS group (P<0.001) were statistically significant in the comparison between groups (Table 4).

DISCUSSION

Although orthognathic surgery is known to improve the quality of life of patients with severe skeletal Class II malocclusion, there are still concerns regarding its treatment.[12] In addition to complaints of pain in the orofacial region, these patients had the highest rates of functional problems and a

Table 3. Pre- (T1) and post-treatment (T2) changes in cephalometric variables in the two-jaw surgery group.

2-JS Group																
Parameters	T1					T2					T2-T1					P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Maxillary skeletal measurements																
SNA	78.58	3.78	77.95	73.8	87.1	79.22	3.81	78.70	74.9	88.0	0.64	0.30	0.60	0.20	1.10	0.009**
A-Ver	60.63	4.90	61.40	52.2	68.7	61.69	5.45	61.00	53.5	76.3	1.19	1.25	1.30	-1.00	3.30	0.028*
A-Hor	51.72	3.12	52.05	45.8	58.1	49.84	2.65	49.70	45.4	54.3	-1.88	1.43	-1.25	-4.50	-0.40	0.003[a]**
Maxillary dental measurements																
U1i-Ver	61.83	5.48	61.45	53.9	72.0	61.79	6.35	60.80	52.0	71.6	-0.04	3.01	-0.30	-6.50	4.10	0.454
U6t-Ver	33.29	4.92	33.25	24.6	39.8	35.05	4.94	34.50	27.0	41.4	1.76	3.18	2.05	-3.50	9.00	0.536
U1i-Hor	75.16	4.22	75.00	68.4	82.0	74.22	3.44	73.55	68.1	79.0	-0.94	2.06	-0.60	-4.50	2.30	0.513
U6t-Hor	66.87	3.48	67.15	61.5	72.8	64.05	3.75	64.85	56.5	70.1	-2.82	1.46	-3.00	-5.00	-0.50	0.008**
Mandibular skeletal measurements																
SNB	69.11	3.19	68.35	65.2	76.5	72.06	3.04	71.05	68.9	79.8	2.95	0.72	2.95	1.9	4.2	0.002**
B-Ver	39.90	7.13	38.15	31.0	53.0	45.16	6.08	43.60	38.0	55.5	5.26	2.09	6.25	1.50	7.20	0.002**
B-Hor	91.20	4.19	90.50	86.0	99.5	90.05	3.17	89.80	84.5	97.6	-1.14	2.76	-0.50	-6.60	3.30	0.762
Pg-Ver	38.68	7.26	36.00	29.0	51.5	44.76	6.95	42.85	36.5	56.0	6.08	3.18	6.80	0.50	11.90	0.002**
Co-Gn	101.49	8.82	101.55	88.1	115.1	104.90	8.26	105.40	89.6	120.8	3.54	3.21	2.50	-1.00	9.00	0.004**
Go-Gn	64.20	6.05	65.65	53.0	72.3	66.47	6.58	67.25	52.7	75.9	2.27	1.90	1.75	-0.30	5.40	0.003**
Mandibular dental measurements																
L1i-Ver	53.97	7.51	52.8	42.7	67	58.86	6.41	57.80	50.0	70.0	4.89	3.21	4.20	0.30	10.70	0.002**
L1i-Hor	70.13	7.19	71.05	50.4	78.4	69.78	6.68	70.50	51.4	77.4	-0.35	1.86	-1.20	-2.40	3.5	0.051[a]
Maxillo-mandibular skeletal measurements																
ANB	9.37	2.38	9.00	5.6	14.1	7.15	2.09	7.10	4.2	11.8	-2.13	0.80	-2.1	-3.4	-0.9	0.009**
GoGn/SN	41.94	6.87	43.10	27.1	50.8	40.90	7.59	40.35	28.1	55.1	-1.04	2.90	-1.35	-5.20	5.80	0.970
Maxillo-mandibular dental measurements																
Overjet	8.34	3.59	8.45	3.6	13.8	3.42	1.41	3.25	1.2	6.0	-4.91	3.23	-4.60	-10.20	0.30	0.004**
Overbite	2.72	4.14	4.25	-9.1	5.6	3.00	1.03	3.00	1.0	5.1	0.28	3.52	-1.50	-2.20	10.10	0.270[a]
Soft tissue measurements																
Nasolabial angle	102.47	10.03	101.00	89.1	119.3	103.70	8.79	104.25	90.7	123.3	1.23	11.31	4.65	-14.1	14.7	0.092
ULA-Ver	74.50	5.48	66.6	82.7	75.90	75.90	5.47	74.10	70.0	85.2	1.40	4.60	0.35	-3.8	11.6	0.993
LLA-Ver	64.62	6.11	63.40	55.8	76.6	67.46	5.32	66.60	59.0	78.0	2.84	4.37	3.50	-4.40	8.00	0.016*
Pg′-Ver	53.01	6.85	52.50	43.5	65.3	58.91	7.32	57.80	49.0	69.6	5.90	3.09	5.80	0.50	11.70	0.007**

Table 3. Continued

2-JS Group	T1					T2					T2-T1					
Parameters	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	P value
Hyoidal measurements																
Hyoid-Ver	-0.81	7.46	-0.80	-10.6	13.0	2.74	7.44	3.30	-7.0	19.5	3.55	3.94	3.80	-4.60	11.50	0.021*
Hyoid-Hor	98.73	8.17	97.60	86.5	113.5	94.30	8.51	94.55	80.6	110.0	-4.43	4.43	-3.55	-13.80	0.00	0.006**
PAS linear measurements																
PNS-P	18.79	2.02	19.35	14.5	21.6	16.95	2.88	17.60	11.1	21.6	-1.83	1.97	-1.60	-5.10	1.90	0.009**
PPS	24.77	2.86	25.35	18.9	28.8	26.13	3.19	26.50	20.5	31.8	1.35	1.66	1.20	-0.60	5.10	0.014*
SPSS	11.10	2.47	11.95	6.0	13.7	13.59	2.70	12.85	9.0	18.8	2.48	2.12	2.50	-1.10	6.20	0.008[a]***
MPS	9.55	1.55	9.75	7.0	12.0	12.00	2.68	11.75	8.0	16.9	2.44	1.65	1.95	0.00	5.60	0.006**
IPS	9.28	3.67	9.75	2.9	14.0	12.55	3.69	12.75	6.5	20.0	3.26	2.39	3.40	0.00	6.90	0.006**
EPS	11.72	3.00	10.90	7.2	17.0	14.23	2.91	15.10	9.0	18.0	2.50	2.04	2.35	-0.20	5.70	0.005[a]***
PAS area measurements																
Area 1	350.43	68.15	349.97	236.55	440.12	298.18	86.10	300.18	149.70	414.43	-52.25	33.59	-49.31	-126.33	-8.34	0.036**
Area 2	281.27	65.63	291.43	155.50	381.76	362.85	79.54	361.56	232.11	494.41	81.58	59.03	64.24	-26.00	188.70	0.003**
Area 3	238.46	98.87	206.07	112.33	427.20	292.76	117.83	299.06	128.92	494.22	54.30	65.85	28.48	-48.01	176.33	0.014*

SD indicates standard deviation; min, minimum value; and max, maximum value. P≤0.05*, P≤0.01**, P≤0.001***
Paired t-tests were performed to compare the changes in post-treatment (T2) and pre-treatment (T1), with the exception of [a], which showed the results of the Wilcoxon signed-rank test.
2-JS, Two-jaw surgery group; Ver, Vertical Reference Plane; Hor, Horizontal Reference Plane; Co, Condylion; U1i, Upper central incisor; L1i, Lower central incisor; U6t, Upper first molar; ULA, Upper lip anterior; LLA, Lower lip anterior; H, Hyoidale; PAS, Pharyngeal airway space

history of TMD compared with other types of malocclusion.[13,14] Therefore, the expectations of these patients regarding treatment are quite high. Although patients with severe skeletal Class III malocclusion require orthognathic surgery due to aesthetic complaints, this demand may not be valid for individuals with skeletal Class II malocclusion.[15]

Although 3D computed tomography imaging is considered the gold standard for the evaluation of PAS, it is not ethical to obtain multiple tomography images from patients. For this reason, two-dimensional (2D) lateral cephalometric radiographs were used in our study. Moreover, in this study, in which we examined the changes that occur as a result of the treatment of skeletal Class II malocclusion with orthognathic surgery, we decided to evaluate the area of the pharyngeal airway. For this purpose, as in previous studies, digital planimeter was used.[16,17]

Establishing cranial base references and coordinate systems is of great importance in the evaluation of changes in the maxillofacial system. The Sella-Nasion (SN) plane is often used as a reference for lateral cephalometric radiograph analysis. However, using the S-N reference plane may cause some measurement errors. Proffit et al.[18] introduced the horizontal reference plane, which is the horizontal plane below the SN plane and drawn at an angulation of 6° with the SN plane. At the same time, a plane perpendicular to the horizontal reference plane was drawn from the Sella Point, and this plane was accepted as the vertical reference plane. In this study, as in previous studies, the horizontal reference plane obtained at an angulation of 7° with the SN plane and the vertical reference plane drawn perpendicularly to the horizontal reference plane from the Sella point were created.[17,19]

According to this study, the 2-JS group had increased vertical dimensions (GoGn/SN, 41.94°; B-Hor, 91.20 mm) and more severe skeletal Class II malocclusion (ANB, 9.29°) than the MA group in T1. The combination of orthodontic treatment and bimaxillary orthognathic surgery is usually indicated for the treatment of adults with high-angle skeletal Class II malocclusion.[20] Maxillary impaction with Le Fort I osteotomy provides good skeletal stability in high angle patients with skeletal open bite. Therefore, intrusion of the maxilla with Lef Fort I osteotomy and counterclockwise rotation of the mandible in patients with Class II skeletal malocclusion who have increased facial height is expected to be advantageous in terms of treatment.[21,22] In summary, it can be said that the main difference between groups is due to

Table 4. Comparison of T2–T1 changes in cephalometric variables between groups

Parameters	MA Group T2-T1		2-JS Group T2-T1		P value
	Mean	±SD	Mean	±SD	
Maxillary skeletal measurements					
SNA	0.07	0.45	0.64	0.30	0.003**
A-Ver	0.90	2.79	1.19	1.25	0.405
A-Hor	0.24	2.85	-1.88	1.43	0.004**
Maxillary dental measurements					
U1i-Ver	0.70	3.65	-0.04	3.01	0.054
U6t-Ver	1.84	2.67	1.76	3.18	0.901
U1i-Hor	1.81	2.61	-0.94	2.06	0.011*
U6t-Hor	1.01	2.21	-2.82	1.46	0.000***
Mandibular skeletal measurements					
SNB	3.57	1.08	2.95	0.72	0.513
B-Ver	5.74	4.52	5.26	2.09	0.736
B-Hor	4,77	3,78	-1,14	2,76	0.000***
Pg-Ver	5.32	4.59	6.08	3.18	0.133
Co-Gn	7.71	6.12	3.54	3.21	0.064
Go-Gn	4.53	2.52	2.27	1.90	0.023*
Mandibular dental measurements					
L1i-Ver	5.86	4.03	4.89	3.21	0.204
L1i-Hor	5.08	3.43	-0.35	1.86	0.007**
Maxillo-mandibular skeletal measurements					
ANB	-3.27	1.47	-2.13	0.80	0.748
GoGn/SN	2.31	1.56	-1.04	2.90	0.002**
Maxillo-mandibular dental measurements					
Overjet	-5.11	2.72	-4.91	3.23	0.559
Overbite	-3.43	3.39	0.28	3.52	0.004**
Soft tissue measurements					
Nasolabial angle	0.44	9.11	1.23	11.31	0.788
ULA-Ver	1.67	4.38	1.40	4.60	0.958
LLA-Ver	5.49	4.41	2.84	4.37	0.116
Pg′-Ver	6.21	4.93	5.90	3.09	0.766
Hyoidal measurements					
Hyoid-Ver	4.02	3.45	3.55	3.94	0.763
Hyoid-Hor	0.50	5.26	-4.43	4.43	0.013*
PAS linear measurements					
PNS-P	0.22	1.07	-1.83	1.97	0.004**
PPS	0.80	1.27	1.35	1.66	0.673
SPSS	3.01	1.85	2.48	2.12	0.741
MPS	3.53	1.90	2.44	1.65	0.702
IPS	2.79	2.09	3.26	2.39	0.574
EPS	3.36	1.66	2.50	2.04	0.559
PAS area measurements					
Area 1	11.46	25.73	-52.25	33.59	0.000***
Area 2	82.24	52.41	81.58	59.03	0.833
Area 3	67.81	42.55	54.30	65.85	0.353

Data presented as mean ± standard deviation, P≤0.05*, P≤0.01**, P≤0.001*** Mann Whitney-U test
MA, Mandibular advancement group; 2-JS, Two-jaw surgery group; Ver, Vertical Reference Plane; Hor, Horizontal Reference Plane; Co, Condylion; U1i, Upper central incisor; U6t, Upper first molar; L1i, Lower central incisor; ULA, Upper lip anterior; LLA, Lower lip anterior; H, Hyoidale; PAS, Pharyngeal airway space

the inclusion of a vertical component in addition to sagittal malocclusion in the 2-JS group.

In the current study, due to MA, the hyoid bone moved significantly anteriorly by approximately 4.02 mm, and this finding was similar to previous study results.[23-26] At the same time, as in a previous study, significant increases were observed in all linear measurements below the level of the soft palate in the MA group.[27] These increases can be associated with anterior movement of the mandible and hyoid bone and anterior stretching of the muscles forming the anterior pharyngeal wall and posterior tongue muscles. Similar to the findings of many studies after MA, increases were observed in all areas, including the nasopharyngeal airway area.[26,28] Although there was no maxillary surgery, the risk of upper airway collapse was reduced with anterior movement of the tongue as a result of the surgery.

In the 2-JS group, after Le Fort I maxillary impaction and MA surgery, the hyoid bone was displaced anteriorly and superiorly following the movement of the mandible in the anterior and superior directions, similar to previous studies.[4,29] Additionally, statistically significant increases were observed in the oropharyngeal and hypopharyngeal areas as well as all dimensional measurements below the PNS in the 2-JS group.[27,29] Therefore, it should not be forgotten that the mandible and hyoid bone are not structures independent of the pharyngeal airway. Thus, it can be concluded that these increases are related to the anterior movement of the mandible and hyoid bones and their associated muscles. Moreover, decreases in the PNS-P value and nasopharyngeal area were also detected due to maxillary impaction surgery, similar to the finding of Vijayakumar Jain et al.[30] The reason for the decrease in nasopharyngeal area as a result of maxillary impaction can be explained by the impaction of the posterior region of the maxilla onto the upper and posterior parts of the pharyngeal walls, resulting in a more limited area in PAS, as well as the decrease in A-Hor.

In the comparison of the T2-T1 periods between groups, significant differences occurred due to the decrease in A-Hor, B-Hor, GoGn-SN, which are skeletal parameters, and U1-iHor, U6t-Hor, and L1i-Hor values, which are dental measurements, as a result of the superior movement of the maxilla and the anterior rotation of the mandible after the maxillary impaction surgery performed in the 2-JS group. In addition, the significant difference in the H-Hor value in the time-dependent comparison between the groups can be interpreted as the counterclockwise rotation of the mandible as a result of the impaction of the maxilla in the 2-JS group and, accordingly, superior follow-up of the hyoid bone.[4,29] In the comparison of the changes in the T2-T1 periods of both surgical approaches, a significant difference was found between the groups as a result of the decrease in the PNS-P value and nasopharyngeal area due to the superior movement of the maxilla after maxillary impaction surgery in 2-JS.[30]

Study Limitations

One of the main shortcomings of this study was the absence of a control group. The second limitation was the lack of long-term follow-up of the study groups. More studies, including a control group and long-term follow-up, are needed to examine the airway with 3D imaging. However, for ethical reasons, we preferred 2D analysis in this study.

CONCLUSION

Our findings indicated that single MA and combined Le Fort I maxillary impaction and MA surgery were viable options for widening the oropharyngeal and hypopharyngeal airway spaces in Class II skeletal patients. However, the decrease in linear and area measurements of the nasopharyngeal airway after 2J-S was noteworthy, which is generally preferred in patients with increased facial height and more severe skeletal Class II malocclusion. Although the hyoid bone was clearly displaced forward in both groups, the hyoid bone was positioned superiorly in the 2J-S group.

Ethics

Ethics Committee Approval: The study was approved by the Ankara University Faculty of Dentistry Clinical Research Ethics Committee (approval no.: 36290600/70, date: 07.07.2017).

Informed Consent: This retrospective study was conducted using data obtained from patients at Ankara University Faculty of Dentistry, Department of Orthodontics and Maxillofacial Surgery.

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