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Original Article

Evaluation of Postural Balance, Cervical Lordosis and Neck Disability after Orthognathic Surgery

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Main Points

- Bimaxillary orthognathic surgical correction for skeletal Class III malocclusion did not result in a significant change in cervical lordosis.
- Neck pain and disability did not significantly change due to their multifactorial nature.
- Skeletal correction primarily based on maxillary advancement did not significantly impact the postural balance or mandibular proprioception.

ABSTRACT

Objective: The present study aimed to investigate changes in cervical lordosis, neck disability, and postural balance through static and dynamic tests in patients with skeletal Class III malocclusion who were treated with bimaxillary orthognathic surgery.

Methods: In this prospective observational study, 18 patients (mean age 23.3±5.4 years) with maxillary retrusion and mandibular prognathia were treated by bimaxillary orthognathic surgery. Static and dynamic balance tests were recorded with the Kinesthetic Ability Trainer preoperatively (T1) and at least 2 months postoperatively (T2). Cervical lordosis angle (C2-C7) was evaluated with the posterior tangent method on the lateral cephalometric films taken at T1 and T2. Neck disability and pain were assessed through questionnaires at both time points.

Results: The median follow-up time was 5.8 months. The mean maxillary advancement was 4.0 mm at point A (p=0.001). The mean mandibular setback was 2.4 mm at point B (p=0.166). An 8.4 mm maxillomandibular correction was observed according to the Wits appraisal (p=0.001). Static and dynamic balance tests, cervical lordosis angle, neck disability, and pain revealed no significant change between T1 and T2. No statistically significant correlation was observed between surgical movements and changes in the cervical lordosis angle.

Conclusion: Orthognathic surgical correction of skeletal Class III malocclusion, —primarily through maxillary advancement with less mandibular setback— did not lead to significant changes in cervical lordosis, neck disability, or postural balance as assessed through static and dynamic tests.

Keywords: Cervical lordosis, neck pain, maxillofacial orthognathic surgery, postural balance

INTRODUCTION

Maxillomandibular deformity is defined as an incorrect relationship of the maxilla and mandible leading to malocclusions.[1] Skeletal deformities within the maxillo-mandibular complex have been associated with altered head and neck posture. Patients diagnosed with skeletal Class III malocclusion, have been observed to exhibit

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a posteriorly positioned and flexed head, accompanied by a diminished cervical lordosis when compared to patients exhibiting skeletal Class I or Class II malocclusion.[2] In addition to sagittal malocclusions, vertical discrepancies in the maxillo-mandibular complex have been reported to be associated with neck posture. The conclusion that the reduction of facial height, as observed following orthognathic surgery, results in a change in neck posture has been determined by measuring a significant change in craniocervical angulation.[3] Orthognathic surgery is performed to improve the malocclusion, and facial aesthetics by repositioning the structures of the maxilla and mandible.

The loss of cervical lordosis has been identified as a contributing factor to chronic neck pain. Patients exhibiting loss of cervical lordosis may present with symptoms analogous to those observed in individuals experiencing nonspecific neck pain. Since skeletal Class III patients have been found to have straighter cervical columns compared to Class I patients, the relationship between Class III malocclusion and neck disability requires further investigation.[4] The Neck Disability Index (NDI) is a self-rated and reliable scale that has been developed for assessing disability in patients presenting neck pain.[5]

Postural control is defined as the capacity to sustain, achieve, and reestablish a given state of balance during any posture or activity. This is achieved by integrating signals from the visual, vestibular, and proprioceptive systems.[6] The stomatognathic system has ligamentous and muscular connections in the cervical region forming a craniocervical-mandibular complex, which may affect body balance. Research examining the relationship between posture and malocclusion highlights the potential role of jaw positions in maintaining postural control.[7-10] Paya-Argoud et al.[11] showed that head orientation and postural stabilization in a static situation were improved by providing orofacial muscular harmonization in the 10th week after orthognathic surgery. They suggested that mandibular proprioception was improved by establishing a novel reference frame and will lead to the head orienting in space by enhancing postural stabilization. However, there is no study analyzing the consequences of orthognathic surgery on postural stabilization under dynamic tests. Therefore, this study was aimed at investigating changes in cervical lordosis, neck disability, and postural balance through static and dynamic tests in patients with skeletal Class III deformity and being treated with orthognathic surgery.

METHODS

This prospective study was approved by Başkent University Medical and Health Sciences Research Board (approval no.: D-KA19/26-19/85 date: 11.09.2019). The study was conducted in accordance with the provisions of the Declaration of Helsinki. All participants were informed about the study protocol and the consent form. A total of 18 patients with skeletal Class III malocclusion, ranging in age from 18 to 40 years and with an indication for orthognathic surgery, participated in the study. Patients with symptoms of temporomandibular joint disorder, a history of dentofacial surgery, neurologic disorders, musculoskeletal diseases, and immune deficiency as well as those presenting a shift or discrepancy between centric relation and centric occlusion, were excluded from the study.

The patients received presurgical orthodontic treatment to establish a proper occlusion following orthognathic surgery and to eliminate anteroposterior or lateral shifts due to occlusal interferences. They lacked anterior guidance due to negative overjet during the preoperative period. Maxillary advancement was achieved with the Le Fort 1 osteotomy, and mandibular setback was performed by bilateral sagittal split ramus osteotomy in the surgical procedure. The occlusion following the surgical correction of the skeletal problem was achieved through canine guidance in some patients, while group function was established for others. Since it has been reported that both canine-guided and group function occlusions are acceptable functional occlusion schemes, no specific occlusal scheme was chosen.[12] Additionally, all patients had anterior guidance after surgery, which led to obtaining proper overjet and overbite values.

G* Power (Heinrich Heine Universität, Dusseldorf, Germany) 3.1.9.2 software was employed to estimate the sample size. The static balance of patients with skeletal Class III deformity was used as a parameter for calculation of the sample size, using a study in the literature as a reference.[11] The power analysis revealed that 18 patients were required to detect 85% power at a significance level of 0.05.

Cephalometric Measurements

All lateral cephalometric radiographs were captured using the same X-ray machine (Morita Veraviewepocs, Kyoto, Japan). A slight modification was incorporated into the lateral cephalometric radiographs to encompass all structures from the Nasion-Sella line to the seventh cervical vertebra, as outlined in the study by de Oliveira Andriola et al.[8] Cephalometric analysis of all patients was performed using *Dolphin 11.9 Software* by an orthodontist. Sagittal and vertical movements following orthognathic surgery in both the maxilla and mandible were measured.

The cervical lordosis angle formed between the second and seventh cervical vertebrae of the patients was calculated using the posterior tangent technique preoperatively (T1), and at least 8 weeks after the operation (T2) by the same researcher (Figure 1). One researcher identified the landmarks and conducted all measurements twice. The mean values of the two measurements were calculated and evaluated in the statistical analysis.

A subsample of 30% of the radiographs was re-measured 4 weeks after the initial measurements. The intraclass correlation coefficients for these measurements were found to be greater than 0.912, indicating excellent intra-rater reliability.

Neck Disability and Pain Perception

Patients were examined at T1 and T2. The modified NDI-Turkish questionnaire was administered to patients during the T1 and T2 periods to assess how neck pain affected their ability to perform daily living activities, since it has been determined to be a valid and reliable tool.[5] In addition, a 10-mm visual analogue scale (VAS) was employed to evaluate the patients' pain perception of neck pain preoperatively and postoperatively.

Balance Index

The balance index is a quantitative metric of an individual's capacity to maintain balance, with a low index suggesting a favorable aptitude for balance-related tasks. The balance index was determined using the Kinesthetic Ability Trainer (KAT) 3000 (KAT 3000, Breg, Vista, CA) device. The KAT 3000 is a device consisting of a movable platform supported by a small pivot at its central point.

The device is composed of a platform and a base engineered as a circular pneumatic cushion. The stability of the platform is modulated by the varying pressure of the cushion. At the forefront of the platform is a tilt sensor, which is connected to the computer. The computer records the deviation of the platform from the reference situation 18.2 times per second. In each record, the distance from the center of the platform to the reference position is measured. The calculation of the Balance Index score is the sum of these distances. The objective of the static test involves overlaying the cross, which corresponds to the center of the platform, onto the cursor. In dynamic tests, the cursor moves at a constant speed, completing a full circle on the computer screen every 10 seconds. Participants are asked to superimpose the cross on the moving cursor. The device under consideration is composed of two components: a movable platform and a tilt sensor connected to a computer.

Evaluation of Static Balance

The patients were requested to stand on the platform and maintain body balance for 30 seconds to measure double-leg static balance. During the test, the patients were also requested to keep their gaze on the red X symbol, which was situated in the middle of the computer screen.

Evaluation of Dynamic Balance

The patients were requested to follow the moving target point that appeared on the monitor for 30 seconds. During the test, the patients constantly followed the mark on the monitor showing the displacement of their center of gravity, relative to the target point. The lowest value, indicating the most achieved balanced position, was considered the final score, as it helps limit inherent variability in the assessment.

Statistical Analysis

Statistical analyses were conducted using SPSS version 25.0 (Statistical Package for the Social Sciences, USA). The Shapiro-Wilk test was employed for the assessment of the normality of the variables. Descriptive statistics included the mean, standard deviation, median, minimum, and maximum values. The paired t-test and Wilcoxon signed-rank test were performed to evaluate the mean differences between the periods (T2-T1). Spearman's rho analysis was employed to correlate surgical movements with changes in the cervical lordosis angle. A p-value of less than 0.05 was deemed statistically significant.

RESULTS

Sample Characteristics

Initially, the study comprised 30 patients; however, 12 patients were excluded from the analysis due to nonattendance at the follow-up appointments. Consequently, the present study encompassed 18 patients (7 female, 11 male) who were treated with bimaxillary orthognathic surgery and attended subsequent follow-up controls. The mean age of patients was 23.3±5.44 years and the mean body mass index was 24.50±4 kg/m^2. The median follow-up time was 5.7 months (2-22 months) (Table 1).

Maxillary and Mandibular Movement

The mean maxillary advancement was 4.0±3.2 mm at point A (p=0.001). The mean mandibular setback was 2.4±7.0 mm at point B (p=0.166). The Wits appraisal revealed an 8.4±4.0 mm maxillomandibular correction based on the occlusal plane (p=0.001). Additionally, a mean upward displacement of 3.1±6.3 mm in the mandible was observed (p=0.049). The study did not reveal a statistically significant mandibular rotation, as determined by the sum of posterior angles (p=0.616) (Table 2).

Changes in the Lordosis Angle (C2-C7)

The mean C2-C7 angles were 19.7±8.4 degrees preoperatively and 18.2±9.3 postoperatively (p=0.312) (Table 1). No

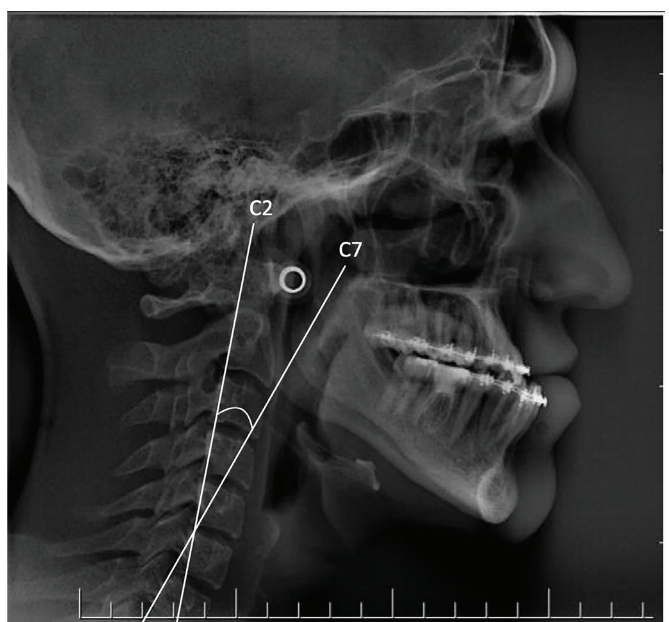

Figure 1. The cervical lordosis angle measured by the posterior tangent technique between C2 and C7

statistically significant correlation was observed between surgical movements and changes in the cervical lordosis angle.

Static Balance

The discrepancy between the preoperative and postoperative values (336.2 and 356.3, respectively) did not demonstrate statistical significance (p=0.913) (Table 1).

Dynamic Balance

The difference between preoperative and postoperative values (1673.3 and 1799.9, respectively) was not statistically significant (p=0.386) (Table 1).

NDI

The mean preoperative NDI score for the patients was 1.8, and the mean postoperative NDI score was 2.9, indicating that no significant change occurred after orthognathic surgery (p=0.341) (Table 1).

Table 1. Descriptive characteristics of the patients at preoperative (T1) and postoperative (T2) periods

				95% Confidence interval of the difference		
	Parameters	Mean±SD	Median (Min.-Max.)	Lower	Upper	p-value
Demographic characteristics	Age (years)	23.3±5.4	21.5 (17-36)	20.3	25.7	
	Follow-up (months)	6.8±5.1	5.8 (2-22)	4.3	9.4	
	Body mass index	24.5±4.0	24 (18-32)	22.5	26.5	
Pain	VAS (T1)	1.2±2.2	0 (0-6)	0.1	2.2	0.288‡
	VAS (T2)	1.7±2.7	0 (0-8)	0.3	3.0	
Balance measurements	Static balance (T1)	336.2±298.0	172.5 (112.0-1228.0)	188.0	484.4	0.913‡
	Static balance (T2)	356.3±457.2	238.0 (76.0-2119.0)	129.0	583.7	
	Dynamic balance (T1)	1673.4±732.4	1448.5 (207.0-3434.0)	1309.2	2037.6	0.386
	Dynamic balance (T2)	1799.9±625.9	1630.0 (775.0-3115.0)	1488.7	2111.2	
Neck disability	Neck disability index (T1)	1.8±1.9	1 (0-6)	0.9	2.8	0.341‡
	Neck disability index (T2)	2.9±3.5	2 (0-11)	1.2	4.6	
Cervical lordosis	Cervical lordosis angle (T1)	19.7±8.4	20.1 (4.3-32.3)	15.6	23.9	0.246
	Cervical lordosis angle (T2)	18.2±9.3	18.5 (1-38.5)	13.6	22.9	
Cephalometric measurements	SNA (°) (T1)	77.1±5.3	78.0 (60.8-85.4)	74.4	79.7	**<0.001‡**
	SNA (°) (T2)	82.7±5.0	83.2 (70.4-94.0)	80.2	85.2	
	SNB (°) (T1)	81.3±4.8	81.0 (68.3-88.6)	79.0	83.7	0.312
	SNB (°) (T2)	80.8±4.4	80.6 (68.7-90.4)	78.6	83.0	
	ANB (°) (T1)	-4.3±2.5	-4.1 (-8--0.7)	-5.5	-3.0	**<0.001***
	ANB (°) (T2)	1.9±1.3	2.6 (-0.5-3.6)	1.3	2.5	
	Wits (mm) (T1)	-11.2±5.00	-10.5 (-21-1.6)	-13.6	-8.7	**<0.001‡**
	Wits (mm) (T2)	-2.8±3.7	-3.1 (-7.3-8.8)	-4.7	-0.9	
	A-FH (mm) (T1)	30.6±3.3	30.3 (25.6-36.5)	29.0	32.3	0.421
	A-FH (mm) (T2)	29.9±3.0	29.9 (24.8-35.9)	28.4	31.4	
	A-N perp (mm) (T1)	-4.6±5.3	-4.2 (-19.1-5.5)	-7.2	-2.0	**0.001‡**
	A-N perp (mm) (T2)	-0.6±4.6	0.5 (-10.8-8.1)	-2.9	1.6	
	B-FH (mm) (T1)	72.8±5.9	71.4 (65.0-84.7)	69.9	75.7	**0.049***
	B-FH (mm) (T2)	69.7±5.9	68.1 (61.7-81.4)	66.7	72.6	
	B-N perp (mm) (T1)	-1.6±9.1	-1.7 (-18.2-13)	-6.2	2.9	0.166
	B-N perp (mm) (T2)	-4.0±6.6	-2.7 (-20.6-6.6)	-7.3	-0.8	
	Sum of posterior angles (°) (T1)	394.7±5.8	392.9 (387.0-408.0)	391.9	397.6	0.616‡
	Sum of posterior angles (°) (T2)	394.1±5.2	393.8 (385.0-403.0)	391.6	396.7	

*p<0.05, Paired t-test was used; ‡p<0.05, Wilcoxon signed-ranks test was used.
SD, standard deviation; VAS, visual analogue scale; FH, Frankfort horizontal plane; Min.-Max., minimum-maximum.

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Table 2. Descriptive statistics regarding orthognathic surgical movements measured by the cephalometric analysis

Orthognathic surgical movements	Parameters	Mean±SD	Median (Min.-Max.)	95% Confidence interval of the difference		p-value
				Lower	Upper	
Maxillary sagittal movements	SNA (°)	5.6±2.5	5.4 (0.8-9.6)	4.4	6.9	**<0.001‡**
	A-N perp (mm)	4.0±3.3	3.5 (-2.9-13.7)	2.3	5.6	**0.001‡**
Mandibular sagittal movements	SNB (°)	-0.6±2.2	0.0 (-4.2-3.1)	-1.7	0.6	0.312
	B-N perp (mm)	-2.4±7.0	-1.7 (- 14.0-9.0)	-5.9	1.1	0.166
Maxillomandibular sagittal movements	ANB (°)	6.2±2.3	5.8 (2.7-10.5)	5.0	7.3	**<0.001***
	Wits (mm)	8.4±4.0	7.6 (1.7-16.8)	6.4	10.3	**<0.001‡**
Maxillary vertical movement	A-FH (mm)	-0.7±3.7	-1.0 (-6.6-7.0)	-2.6	1.1	0.332
Mandibular vertical movement	B-FH (mm)	-3.1±6.3	-3.3 (-15.1-6.7)	-6.3	0	**0.049***
Mandibular rotation	Björk sum (°)	-0.6±3.7	0.4 (-10.7-4.5)	-2.4	1.2	0.616‡

*p<0.05, Paired t-test was used; ‡p<0.05, Wilcoxon signed-ranks test was used.
SD, standard deviation; VAS, visual analogue scale; FH, Frankfort horizontal plane; Min.-Max., minimum-maximum.

DISCUSSION

Cervical lordosis has been suggested to be associated with the overjet, and the mandibular position, length, and divergence.[7] Individuals with Class III malocclusion are supposed to exhibit a flexed head posture, reduced cervical lordosis, and a tendency towards posteriorization.[13,14] Since body posture and balance are closely related, the postural balance of individuals who undergo orthognathic surgery may be affected.[10] As far as we know, this is the first study to prospectively evaluate cervical lordosis, neck pain, and postural balance through static and dynamic tests using an objective measurement device such as the KAT in patients who have all undergone orthognathic surgery for the correction of skeletal Class III.

The KAT is a valid and reliable computerized balance test and training device used to assess static and dynamic balance abilities and to provide information about postural stability. It has been reported to be user-friendly and relatively affordable.[15]

The 'normal' or 'ideal' position of the cervical spine is generally considered to be a lordotic curve. Still, the exact values are uncertain depending on the measurement methods.[16] Cervical lordosis angle has been described as being within the normal range between 16-40° with the posterior tangent measurement method.[17-19] The impact of orthognathic surgery on cervical vertebrae posture was investigated in several studies.[8-10,20] In the present study, the preoperative cervical lordosis angle was 19.7°, which fell within the normal limits described in the literature and did not demonstrate a significant change following orthognathic surgery. In this case, the study population had a different lordotic structure preoperatively than that described in the broader literature for Class III patients, which may help explain the lack of significant change after surgery. Similarly, Sinko et al.[20] found no significant differences in spinal posture of Class III patients before and after orthognathic surgery. They also reported that the mouth-breathing patterns could play a more important role in head and body posture than the occlusal relationships alone. Indeed, mouth-breathing was observed to be strongly associated with the forward head posture and cervical extension.[21,22] On the other hand, de Oliveira Andriola et al.[8] found an increase in cervical lordosis angle indicating the extension of the cervical column, which might be related to compensate the deficiency in airway size following mandibular setback surgery. A compensatory increase in the craniocervical angle has also been reported in the long-term follow-up after mandibular setback surgery.[23] The differences of the findings in the present study may be attributed to the severity of the skeletal malocclusion and number of the surgical movements in the study sample.

Several factors have been identified for neck pain in adults. These include female sex, older age, a history of smoking low back pain, or previous neck pain, and the presence of other musculoskeletal disorders or psychosocial factors.[24] Since skeletal Class III patients have a flattened cervical curvature, the effect of double jaw orthognathic surgery on neck disability and pain was also examined in this study; however, no significant change was found. Even in the preoperative period, the patients' NDI scores and VAS pain scores were observed to be less than expected. The multifactorial nature of neck disability and neck pain may provide a possible explanation for these findings. Moreover, a strong relationship between temporomandibular dysfunction and neck disability has been reported in the literature.[25,26] It points to the relationship between the temporomandibular joint and neck muscles rather than the classification of skeletal malocclusion.

Balance has been defined as the ability to maintain the body's center of gravity over the base of support, which is closely related to the functioning of postural control.[6] The center of gravity in Class III patients prior to orthognathic surgery has been found to displace anteriorly. Additionally, some postural misalignments throughout the whole body have been identified in these patients, which affect the agonist and antagonist muscles and cause muscle imbalances and pain.[27] However, Paya-Argoud et al.[11] have found no significant change in the position of the center of foot pressure following orthognathic surgery. Additionally, they explained the effect of surgical correction of skeletal malocclusion on postural control using a neurophysiological theory. According to this theory, surgical improvement harmonizes the orofacial muscles and improves postural stabilization by changing mandibular proprioception and head orientation. On the other hand, Kulczynski et al.[9] identified an increased tension on the suprahyoid muscles in Class III patients generated by the reverse overjet. They have reported that orthognathic surgery can change the neck and head position by moving the chin back and decreasing the tension in the suprahyoid muscles. Correcting the occlusion from Class III to Class I can also significantly affect the adjustment of spinal posture.[9] However, the findings in this study did not show any statistically significant change in static or dynamic balance. A possible explanation for this is that the mean mandibular setback in this study was 2.4 mm, and the vertical reduction was 3.1 mm. The observed skeletal correction was primarily due to the 4 mm maxillary advancement. From a clinical perspective, the authors stated that the amount of mandibular setback was limited during surgical planning to avoid airway obstruction and to reduce the risk of soft tissue sagging under the chin. However, this approach is associated with the failure to observe significant reorganization of head and neck muscles or changes in mandibular proprioception.

Study Limitations

Limitations of this study may include the lack of assessment of the entire vertebral column and lack of assessment of the center of gravity. Additionally, the small sample size and 40% patient dropout rate from initial recruitment may have limited the generalizability of the findings, and may have failed to eliminate the high individual variability of the investigated parameters. Lastly, the lack of a nonsurgical Class III or Class I control group makes it difficult to definitively attribute the observed findings solely to surgery or to other time-dependent factors. Moreover, long-term studies are required to evaluate balance and cervical spine changes following orthognathic surgery.

CONCLUSION

Within the limitations of this study, orthognathic surgery for skeletal Class III malocclusion did not lead to significant changes in cervical lordosis, neck disability, or postural balance, as assessed through static and dynamic tests. Despite the known association between malocclusion and postural changes, the moderate surgical interventions, particularly maxillary advancement, may not have been sufficient to produce observable effects on postural alignment. These findings highlight the need for further research with larger sample sizes and more extensive surgical approaches to better understand the impact of orthognathic surgery on cervical posture and balance. Additionally, evaluating the full spinal alignment and center of gravity shifts may provide a more comprehensive insight into postural changes following such procedures.

Ethics

Ethics Committee Approval: This prospective study was approved by Başkent University Medical and Health Sciences Research Board (approval no.: D-KA19/26-19/85 date: 11.09.2019).

Informed Consent: All participants were informed about the study protocol and the consent form.

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Footnotes

Author Contributions: Surgical and Medical Practices - B.B., S.Ç.; Concept - S.İ.-B., S.Ç., O.Ü.Y.; Design - S.Ç.; Data Collection and/or Processing - E.B.; Analysis and/or Interpretation - S.İ.-B., E.B.; Literature Search - S.Ç., S.İ.-B.; Writing - S.İ.-B., S.Ç., O.Ü.Y.

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