

## Original Article

# Short-term and long-term alterations of condylar position after bilateral sagittal split ramus osteotomy for mandibular setback: A preliminary before-after clinical trial

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## ABSTRACT

**Background:** Because of the importance of the condyle, it is crucial to document all changes in its position after orthognathic surgery. Since previous studies in this regard are mostly controversial and limited by two-dimensional radiography technique, this study was conducted.

**Materials and Methods:** This prospective clinical trial was performed on 102 measurements (17 patients, 2 condyles each, and 3 time points). Cone-beam computerized tomography imaging was done for 17 skeletal Class-III patients (10 females and 7 males, mean age,  $24.05 \pm 4.78$  years) undergoing fixed orthodontic treatment, at three time points T0 (before surgery), T1 (immediately after surgery), and T2 (8 months after surgery). Condylar positions were measured. Position changes were evaluated during the course of the study. They were also compared between right/left sides and between men and women. Tests in use were repeated-measures one- and two-way analysis of variance and paired *t*-tests ( $\alpha = 0.05$ ,  $\alpha = 0.017$ ).

**Results:** Alterations in various anatomical condyle parameters over the 8-month course of the study did not reach the level of significance ( $P \geq 0.078$ ). At all intervals, mean anterior-posterior index (API) remained between  $-12$  and  $+12$  (indicative of central position of the condyle in the glenoid fossa). Between men and women, left superior joint space, left anterior joint space, and left API differed ( $P \leq 0.05$ ). Left condyle mean superior joint space and anterior joint space were greater in men compared to women in all the three intervals; left condyle mean API was greater in women compared to men (more posterior in men,  $P \leq 0.05$ ).

**Conclusion:** Condyles might not change significantly after 8 months post-surgery. However, small changes might be observed, and these changes might differ between the left and right sides and between males and females.

**Key Words:** Mandibular condyle, orthognathic surgical procedures, sagittal split ramus osteotomy

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## INTRODUCTION

Different orthodontic processes are used to improve the patient's beauty in addition to correcting mandibular and maxillary occlusion.<sup>[1]</sup> However, severe malocclusions might not be corrected by orthodontic treatments alone; they would also need orthopedic treatments for children and orthognathic surgery for adults.<sup>[2]</sup> One of the most common methods in the management of excessive mandibular prognathism is mandibular setback using bilateral sagittal split ramus osteotomy (BSSRO), which has many advantages including a wide contact area between segments facilitating healing as well as convenient relocation of the distal segment; it also has certain complications including condylar displacement and a rather high rate of relapse.<sup>[1-5]</sup> In BSSRO, the mandible is divided into distal and proximal segments to enable their displacement.<sup>[4,6]</sup> In such cases, it is of significant value to maintain the initial positions of the condylar heads.<sup>[4,6]</sup> because it can help prevent post-BSSRO relapse.<sup>[4,7,8]</sup> Postsurgical condylar displacements are multifactorial and associated with numerous factors such as age, the course of bone displacement, surgeon's expertise, soft-tissue and muscular traction, quality of orthodontic treatment, the anatomic form of the proximal segment, direction and amount of displacement of the proximal from the distal segments on the surgical plan, fixation method, and postorthodontic treatment maintenance.<sup>[2,4,7,8]</sup>

In many cases, the position of condylar head changes unexpectedly during surgery and fixation, due to various reasons such as relaxation of masticatory muscles due to anesthesia, joint edema, bone ligaments malalignment, patients' posture, methods used for positioning the condyle, and fixing it.<sup>[4,6,9-11]</sup>

Mandibular condyles play a crucial role in a healthy occlusal function.<sup>[12]</sup> Furthermore, their mispositioning might cause relapse, temporomandibular and occlusal disorders, morphologic condylar alterations.<sup>[4,9,13-18]</sup> Hence, the assessment of BSSRO on condylar position in long term is of importance. However, effects (especially long-term effects) of orthognathic surgery on the condylar position are assessed in a few controversial studies,<sup>[9,19,20]</sup> and it is not yet clarified how condylar positions change after orthognathic surgery and whether these changes are significant or not.<sup>[9,18]</sup> A reason might be the methodology of assessment. Plain radiographs might not properly show condylar position, due to their

limitations such as distortions and overlaps. Whereas, three-dimensional (3D) imaging methods (such as cone-beam computerized tomography [CBCT]) allow the detection of even minor changes in the position of condyle with high accuracies.<sup>[4,9,21-23]</sup>

This study was conducted given the importance of the subject and the controversial results, the small number of studies using 3D imaging methods, and due to a lack of ample studies on comparison of changes in left/right condyles or in women versus men, and since no studies had examined the short- or long-term changes happening after mandibular set-back using BSSRO surgery in an Iranian population. Its aim was to document the positional changes in condylar head position up to 8 months after the surgery, using CBCT.

## MATERIALS AND METHODS

This study was approved by research and ethics code: IR.MAZUMS.REC.95.2295. In this prospective before-after clinical trial, 102 measurements (17 patients, 2 condyles each, 3 time points) were assed. A total of 17 fixed orthodontic patients (10 females and 7 males, mean age:  $24.05 \pm 4.78$  years) who had skeletal Class III occlusion (with prognathic mandible) with moderate discrepancy and were under treatment with preadjusted MBT brackets with slot 22' were included. Other inclusion criteria were a lack of any problems of temporomandibular joint, needing mandibular setback surgery using BSSRO (for a minimum of 4 mm, a maximum of 6 mm, and a mean of 5 mm), and a successful surgery resulting in normal overjet and occlusion.

The average reverse jet before orthodontic treatment in all patients was 2–3 mm; all patients entered the preorthodontic phase without extraction of any maxillary teeth and prepared for mandibular setback surgery. None of the patients had skeletal deviation. All patients underwent only mandibular setback, and no maxillary surgery was performed. To release the muscles during the surgery, in the distal segment, the surgeon released the muscles by his finger, and in the proximal segment, a J retractor was used to release the muscles.

The period of orthodontic treatment until the time of surgery was about 1–1.5 years. For all patients, before surgery, 21' × 25' stabilizer wires were placed. The sample size was predetermined by an epidemiologist based on previous studies, in order to obtain test powers above 80%.

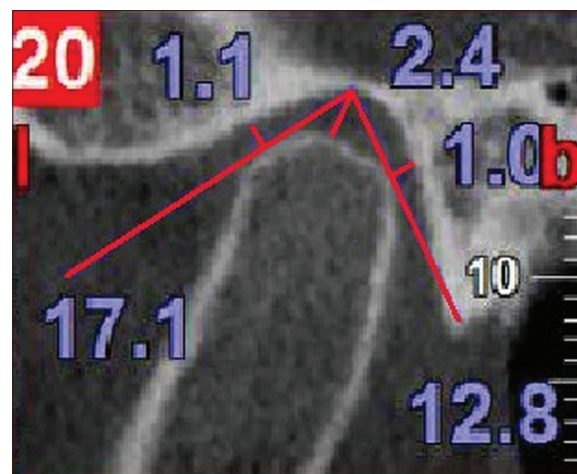
Patients' CBCTs were taken right before surgery (T0), immediately after surgery (T1), and 8 months after surgery (T2), using a CBCT unit (NewTom, Verona, Italy; Kv: 110 exposure time: 3.6 seconds, field of view: 12 × 8, Axial condylar view, 110 kvp, 2.77 mAs). During radiography, patients were in maximum intercuspation. Acrylic splint wafers 2.5 mm thin were fabricated for each patient using the conventional method on a hinge-axis articulator. CBCTs after the surgery were taken with these splint wafers in mouth. Due to their thinness, they might not affect the condylar position considerably. The taken volumes could be re-oriented in order for the Frankfurt plane to become completely horizontal. The T2 duration was chosen as 8 months, because postsurgical orthodontic treatment of all patients lasted for maximum 8 months, and the authors wanted to take the final CBCT after finishing the orthodontic treatment.

First, a section with the largest anterior-posterior diameter of the condyle was identified,<sup>[24]</sup> then the condyle distance from the temporal fossa was measured in the anterior joint space (AJS), posterior joint space (PJS), and superior joint space (SJS). The space between the condyle and glenoid fossa was calculated by Pullinger and Hollender methods. In this method, some landmarks are defined and their distances are measured. These landmarks are: (a) the uppermost point in the glenoid fossa; (b) the uppermost point on the condyle; (c) tangent to the anterior surface of the condyle from Point A; (d) tangent to the posterior surface of the condyle from Point A; (e) perpendicular to line A-C from point C to anterior slope of glenoid fossa; and (f) perpendicular to line A-D from Point D to the posterior slope of glenoid fossa. AJS: The distance between Points C and E. PJS: The distance between Points D and F. SJS: The distance between Points A and B [Figure 1].<sup>[15,24,25]</sup>

The anterior-posterior index (API) was used to determine the condyle position in the temporal fossa:  $API = (PJS - AJS) / (PJS + AJS) \times 100$ . APIs between the values "+12 and -12" indicate central condyle position. APIs >+12 was considered as anterior position and those smaller than -12 were regarded as posterior position. API was used to assess the changes in condylar position in CBCTs between T0, T1, and T2. It was classified as unchanged, backward, and forward displacement.<sup>[15]</sup>

### Statistical analysis

Descriptive statistics and 95% confidence intervals (CI) were evaluated. Normality of data



**Figure 1:** An example of condylar space measurements.

was confirmed using Kolmogorov–Smirnov test. Repeated-measures analysis of variance (ANOVA), repeated-measures two-way ANOVA, and paired *t*-test were used to analyze the data. The software in use was SPSS version 25 (IBM, Armonk, NY, USA). The level of significance was set at 0.05 for ANOVA. It was adjusted to 0.017 for paired *t*-test, using the Bonferroni method.

## RESULTS

Descriptive statistics and 95% CIs are reported in Table 1. Almost all assessed mean spaces first showed a slight increase immediately after treatment that after 8 months returned back to about baseline levels [Table 1]. The only mean space that showed a different pattern was PJS which increased at each interval [Table 1]. None of the three spaces on the right or left condyles showed any significant change over the 8-month course of the study (all 6 ANOVA  $P \geq 0.18$ ).

The mean API on both sides remained between the range of “-12 and 12,” and the CI showed that despite slight deviations toward outside the normal range, they never completely passed this “-12 – 12” range of central condylar position [Table 1]. The mean API on the right side was negative before and after surgery but it had a considerable increase and became positive 8 months after the surgery [Table 1]. These alterations were marginally significant (repeated-measures ANOVA,  $P = 0.078$ ). On the left side, the mean API remained negative throughout the study period and decreased considerably between T1 and T2. However, its changes did not reach the level of significance ( $P = 0.159$ ). The repeated-measures

**Table 1: Statistics of all the variables (n=17 for each row). Units of measurement for all variables were mm, except for the anterior-posterior index which was unitless**

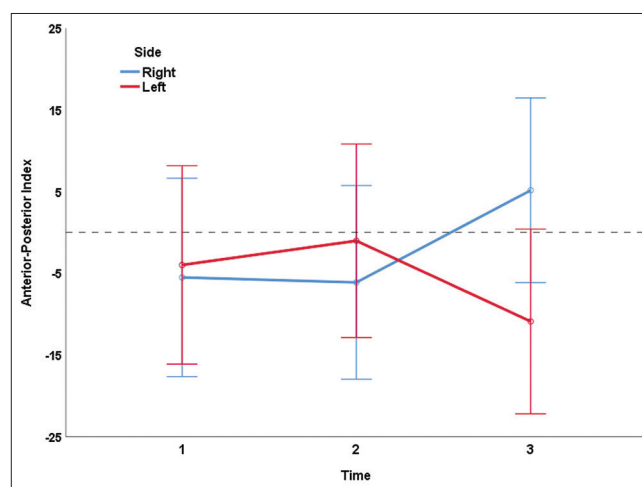
Time	Side	Parameter	Mean±SD	Minimum	Maximum	Percentiles			95% CI
						25 <sup>th</sup>	Median	75 <sup>th</sup>	
T0	Right	SJS	2.01±0.65	1.20	3.00	1.50	1.70	2.75	1.67-2.34
T0	Left	SJS	2.41±1.01	0.90	4.40	1.55	2.40	3.30	1.89-2.93
T0	Right	AJS	1.69±0.74	0.50	3.80	1.20	1.60	2.05	1.31-2.07
T0	Left	AJS	1.64±0.67	0.90	3.60	1.05	1.50	1.95	1.30-1.99
T0	Right	PJS	1.44±0.42	1.00	2.30	1.05	1.50	1.65	1.22-1.65
T0	Left	PJS	1.54±0.65	0.50	2.80	1.05	1.40	2.00	1.20-1.87
T0	Right	API	-5.50±26.94	-55.10	50.00	-28.59	-3.45	15.59	-19.35-8.35
T0	Left	API	-3.97±21.96	-50.00	33.33	-21.54	2.44	12.25	-15.26-7.32
T1	Right	SJS	2.08±0.91	0.90	3.60	1.40	1.90	2.95	1.61-2.54
T1	Left	SJS	2.50±1.03	1.20	4.50	1.55	2.30	3.40	1.97-3.03
T1	Right	AJS	1.75±0.70	1.20	3.90	1.30	1.60	1.85	1.40-2.11
T1	Left	AJS	1.79±0.95	1.10	4.50	1.25	1.50	1.80	1.31-2.28
T1	Right	PJS	1.54±0.53	0.80	2.50	1.15	1.40	1.95	1.27-1.81
T1	Left	PJS	1.73±0.74	0.90	3.70	1.10	1.50	2.25	1.35-2.11
T1	Right	API	-6.10±23.31	-47.17	25.00	-23.20	-3.70	14.55	-18.09-5.88
T1	Left	API	-1.01±24.64	-58.33	48.00	-21.40	4.35	16.48	-13.68-11.66
T2	Right	SJS	1.92±0.66	1.00	3.30	1.30	1.90	2.60	1.58-2.26
T2	Left	SJS	2.42±0.93	1.20	4.40	1.65	2.30	3.10	1.95-2.90
T2	Right	AJS	1.49±0.55	0.80	3.00	1.20	1.40	1.55	1.21-1.77
T2	Left	AJS	1.76±0.79	1.10	3.70	1.30	1.40	1.85	1.36-2.17
T2	Right	PJS	1.63±0.43	0.90	2.40	1.30	1.70	2.00	1.41-1.85
T2	Left	PJS	1.36±0.42	0.80	2.00	1.00	1.30	1.75	1.14-1.57
T2	Right	API	5.17±22.08	-35.71	42.86	-16.48	7.69	20.90	-6.19-16.52
T2	Left	API	-10.88±23.64	-57.45	22.58	-28.29	-6.25	10.73	-23.03-1.28

SD: Standard deviation; CI: Confidence interval; T0: Baseline; T1: Immediately after surgery; T2: 8 months after surgery; AJS: Anterior joint space; PJS: Posterior joint space; SJS: Superior joint space; API: Anterior-posterior index

two-way ANOVA showed that API values were not different significantly on the right and left sides ( $P = 0.660$ ); yet, a significant interaction of the variables “time and side” was observed ( $P = 0.031$ ), meaning that trends of change in API over time differed between the right and left sides [Figure 2].

Pairwise comparisons between intervals showed that none of the changes in the condyle parameters between T0 and T1 was significant [Table 2]. The only significant pairwise comparisons between T1 and T2 were seen in the right AJS and API as well as the left PJS and API [Table 2]. According to the significant API values on the right and left sides, the left condyle had a posterior displacement after 8 months, while the right one had an anterior repositioning after 8 months [Table 2].

Comparing women with men using repeated-measures two-way ANOVA, it was shown that the genders differed significantly in terms of changes occurred to the three measurements: “left SJS, left AJS, and left API” ( $P \leq 0.05$ ). Left condyle mean SJS and AJS were greater in men compared to women in all the



**Figure 2:** Trends of mean (95% confidence interval) change in the anterior-posterior index of right and left condyles. Negative anterior-posterior indexes indicate posterior inclination while positive ones indicate anterior inclinations.

three intervals [Table 3]. The left condyle mean API was greater in women compared to men: In men, the left condyle mean API was negative and at about 12 in the baseline and immediately after the surgery, which decreased to about -26 after 8 months; all of

**Table 2: Pairwise comparisons between different time points, using paired t-test, with a level of significance=0.017. Units of measurement for all variables were mm, except for the anterior-posterior index which was unitless**

Parameter	Time	n	Mean±SD	P
ΔSJS right	T1-T0	17	0.07±0.41	0.49
	T2-T0	17	-0.08±0.30	0.25
	T2-T1	17	-0.15±0.44	0.16
ΔSJS left	T1-T0	17	0.08±0.42	0.4
	T2-T0	17	0.11±0.35	0.89
	T2-T1	17	-0.07±0.38	0.42
ΔAJS right	T1-T0	17	0.05±0.70	0.73
	T2-T0	17	-0.20±0.70	0.24
	T2-T1	17	-0.26±0.29	0.002
ΔAJS left	T1-T0	17	0.15±0.62	0.33
	T2-T0	17	0.12±0.44	0.27
	T2-T1	17	-0.02±0.33	0.71
ΔPJS right	T1-T0	17	0.10±0.49	0.38
	T2-T0	17	0.19±0.40	0.06
	T2-T1	17	0.08±0.37	0.34
ΔPJS left	T1-T0	17	0.19±0.74	0.3
	T2-T0	17	-0.17±0.60	0.24
	T2-T1	17	-0.37±0.51	0.009
ΔAPI right	T1-T0	17	-0.10±2.56	0.92
	T2-T0	17	10.6±2.26	0.07
	T2-T1	17	11.2±1.32	0.003
ΔAPI left	T1-T0	17	2.95±2.30	0.6
	T2-T0	17	-6.91±2.49	0.27
	T2-T1	17	-9.86±0.90	<0.001

AJS: Anterior joint space; PJS: Posterior joint space; SJS: Superior joint space; API: Anterior-posterior index; T0: Baseline; T1: Immediately after surgery; T2: 8 months after surgery; SD: Standard deviation

these negative and considerable API values imply a posterior position of the left condyle in men [Table 3]. Whereas, this variable in women was close to zero in the baseline, and it increased to about + 7 immediately after the surgery and returned back to about zero after 8 months; it implied a symmetric anteroposterior position of the left condyle in women [Table 3].

## DISCUSSION

Keeping the condylar position at its former location after orthognathic surgery is important to reduce the likelihood of relapse and temporomandibular joint disease.<sup>[26-29]</sup> In this study, the condylar position was mainly in the central area, which was consistent with some other studies.<sup>[15]</sup> The review article of Costa et al.<sup>[11]</sup> as well confirms this finding that slight changes can be observed. Other studies have shown downward displacement of condyles immediately after surgery, following the return of condyles to the original form after the recovery period.<sup>[8,13,24]</sup> Changes

**Table 3: Comparing the statistics of condylar parameters of men and women, using repeated-measures two-way analysis of variance. Units of measurement for all variables were mm, except for the anterior-posterior index which was unitless**

Side	Parameter	Time	Mean±SD		P
			Females (n=10)	Males (n=7)	
Right	SJS	T0	1.83±0.63	2.25±0.61	0.27
		T1	1.91±0.89	2.31±0.93	
		T2	1.77±0.71	2.12±0.55	
Left	SJS	T0	1.87±0.64	3.18±0.96	0.01
		T1	2.11±0.85	3.05±1.06	
		T2	2.00±0.71	3.02±0.90	
Right	AJS	T0	1.50±0.46	1.97±0.98	0.11
		T1	1.54±0.27	2.05±0.99	
		T2	1.35±0.27	1.68±0.77	
Left	AJS	T0	1.36±0.36	2.04±0.82	0.01
		T1	1.42±0.24	2.32±1.31	
		T2	1.38±0.21	2.31±0.99	
Right	PJS	T0	1.47±0.47	1.38±0.33	0.53
		T1	1.66±0.61	1.37±0.34	
		T2	1.63±0.48	1.62±0.37	
Left	PJS	T0	1.44±0.60	1.67±0.72	0.98
		T1	1.77±0.80	1.67±0.68	
		T2	1.42±0.46	1.27±0.34	
Right	API	T0	-0.43±2.69	-12.73±2.72	0.24
		T1	1.08±2.23	-16.37±2.21	
		T2	8.11±2.21	0.94±2.32	
Left	API	T0	1.10±1.85	-11.20±2.58	0.052
		T1	7.24±1.99	-12.80±2.73	
		T2	-0.51±2.05	-25.68±2.05	

AJS: Anterior joint space; PJS: Posterior joint space; SJS: Superior joint space; API: Anterior-posterior index; T0: Baseline; T1: Immediately after surgery; T2: 8 months after surgery; SD: Standard deviation

were observed in this study in the position of condyle, but they were mostly small or not generalizable. This was consistent with some other studies who showed that the changes were not noticeable.<sup>[4,8,9,25,30]</sup> Furthermore, Wang et al.<sup>[31]</sup> showed that the condylar position might return to its original position after a 6-month recovery period. Yet, we observed that the lack of overall significance might be mostly due to the lack of changes between T0 and T1, as T2 positions would differ with T1 in some cases. On the other hand, other studies have reported a wide range of controversial changes following orthognathic surgery in condylar head position in most directions including forward, backward, downward dislocation as well as inward or outward rotations as well as rotations on coronal plane.<sup>[3,4,7,8,32-41]</sup> This can be due to the surgical procedure as well as other risk factors including patient posture, masticatory muscle tension, the approach for locating the proximal

segment, and fixation methods.<sup>[4,42]</sup> Furthermore, severity of asymmetry might contribute to the extent of condylar displacement following surgery.<sup>[4,43]</sup> Moreover, the condylar position alterations might differ between different persons depending on various factors mentioned above (e.g., surgeon's expertise, surgical procedures, etc.).<sup>[9,10,18,20,44,45]</sup> Since the ongoing orthodontic treatment after surgery is mostly performed to stabilize surgical results besides small occlusal corrections, it seems unlikely to affect the condylar position in the glenoid fossa considerably.

Interestingly, we observed different long-term repositioning directions of the condylar head on the left and right sides, while the left condyle was posteriorly repositioned, the right one was displaced to the anterior side. Still, condyles remained mostly in the central position, especially in women of the current sample, which was in line with some previous studies<sup>[9,24]</sup> but not with some others.<sup>[46]</sup> And what was observed in left condyles of men in this study suggested posterior position. The controversy might root in some methodological differences including surgical procedures and expertise of surgeons, as well as the duration after which the condylar position was evaluated.<sup>[9]</sup> Longer recovery periods may allow a greater extent of physiologic adaptive bone remodeling (probably induced by masticatory functional recovery), causing a greater change in the position of the condyle.<sup>[9,47]</sup> In most cases, condyles might return back to their original position; Ueki *et al.*<sup>[48]</sup> reviewed the literature and suggested that it is possible for the optimum condylar position to differ before and after the surgery, yet it might not change considerably, except in the cases of asymmetry or temporomandibular defects.<sup>[48]</sup> Kim *et al.*<sup>[25]</sup> added that such slight changes can be compensated through natural adaptation.<sup>[25]</sup>

In the present study, the mean left SJS and left AJS were greater in men compared to women, which might be due to a lower and more anterior condylar position in men compared to women, as well as the overall larger size of mandible and skeleton in men compared to women. This finding was consistent with other studies reporting a greater SJS in men compared to women.<sup>[49]</sup> The left condyles were positioned posteriorly in men compared to women who had mostly central left condyles. We could not find more studies comparing women and men.

## CONCLUSION

The findings of this before-after clinical trial suggest that condylar heads might not show much changes after 8 months postsurgery. However, small changes might be observed, and these changes might differ between the left and right sides and between males and females.

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## Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

## REFERENCES

- Choi BJ, Choi YH, Lee BS, Kwon YD, Choo YJ, Ohe JY. A CBCT study on positional change in mandibular condyle according to metallic anchorage methods in skeletal class III patients after orthognathic surgery. *J Craniomaxillofac Surg* 2014;42:1617-22.
- Lake SL, McNeill RW, Little RM, West RA. Surgical mandibular advancement: A cephalometric analysis of treatment response. *Am J Orthod* 1981;80:376-94.
- Nishimura A, Sakurada S, Iwase M, Nagumo M. Positional changes in the mandibular condyle and amount of mouth opening after sagittal split ramus osteotomy with rigid or nonrigid osteosynthesis. *J Oral Maxillofac Surg* 1997;55:672-6.
- Choi BJ, Kim BS, Lim JM, Jung J, Lee JW, Ohe JY. Positional change in mandibular condyle in facial asymmetric patients after orthognathic surgery: Cone-beam computed tomography study. *Maxillofac Plast Reconstr Surg* 2018;40:13.
- Hwang DS, Kim YI, Lee KM. Effect of intended manual condylar positioning on skeletal and dental changes in Skeletal Class III deformities: CBCT-generated half-cephalograms. *J Craniomaxillofac Surg* 2014;42:7-12.
- Ellis E 3<sup>rd</sup>. A method to passively align the sagittal ramus osteotomy segments. *J Oral Maxillofac Surg* 2007;65:2125-30.
- Hackney FL, Van Sickels JE, Nummikoski PV. Condylar displacement and temporomandibular joint dysfunction following bilateral sagittal split osteotomy and rigid fixation. *J Oral Maxillofac Surg* 1989;47:223-7.
- Lee W, Park JU. Three-dimensional evaluation of positional change of the condyle after mandibular setback by means of bilateral sagittal split ramus osteotomy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002;94:305-9.
- Holzinger D, Willinger K, Millesi G, Schicho K, Breuss E, Wagner F, *et al.* Changes of temporomandibular joint position after surgery first orthognathic treatment concept. *Sci Rep* 2019;9:2206.
- Ellis E 3<sup>rd</sup>. Condylar positioning devices for orthognathic surgery: Are they necessary? *J Oral Maxillofac Surg* 1994;52:536-52.
- Costa F, Robiony M, Toro C, Sembronio S, Polini F, Politi M.

- Condylar positioning devices for orthognathic surgery: A literature review. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;106:179-90.
12. Arieta-Miranda JM, Silva-Valencia M, Flores-Mir C, Paredes-Sampen NA, Arriola-Guillen LE. Spatial analysis of condyle position according to sagittal skeletal relationship, assessed by cone beam computed tomography. *Prog Orthod* 2013;14:36.
  13. Oh MH, Hwang HS, Lee KM, Cho JH. Cone-beam computed tomography evaluation on the condylar displacement following sagittal split ramus osteotomy in asymmetric setback patients: Comparison between conventional approach and surgery-first approach. *Angle Orthod* 2017;87:733-8.
  14. Kim MI, Kim JH, Jung S, Park HJ, Oh HK, Ryu SY, et al. Condylar positioning changes following unilateral sagittal split ramus osteotomy in patients with mandibular prognathism. *Maxillofac Plast Reconstr Surg* 2015;37:36.
  15. Zafar H, Choi DS, Jang I, Cha BK, Park YW. Positional change of the condyle after orthodontic-orthognathic surgical treatment: Is there a relationship to skeletal relapse? *J Korean Assoc Oral Maxillofac Surg* 2014;40:160-8.
  16. Arnett GW. A redefinition of bilateral sagittal osteotomy (BSO) advancement relapse. *Am J Orthod Dentofacial Orthop* 1993;104:506-15.
  17. Goncalves JR, Wolford LM, Cassano DS, da Porciuncula G, Paniagua B, Cevidanes LH. Temporomandibular joint condylar changes following maxillomandibular advancement and articular disc repositioning. *J Oral Maxillofac Surg* 2013;71:15.e1-15.
  18. Ueki K, Moroi A, Sotobori M, Ishihara Y, Marukawa K, Yoshizawa K, et al. Changes in temporomandibular joint and ramus after sagittal split ramus osteotomy in mandibular prognathism patients with and without asymmetry. *J Craniomaxillofac Surg* 2012;40:821-7.
  19. Kuehle R, Berger M, Saure D, Hoffmann J, Seeberger R. High oblique sagittal split osteotomy of the mandible: Assessment of the positions of the mandibular condyles after orthognathic surgery based on cone-beam tomography. *Br J Oral Maxillofac Surg* 2016;54:638-42.
  20. Sander AK, Martini M, Konermann AC, Meyer U, Wenghoefer M. Freehand condyle-positioning during orthognathic surgery: Postoperative cone-beam computed tomography shows only minor morphometric alterations of the temporomandibular joint position. *J Craniofac Surg* 2015;26:1471-6.
  21. Tyndall DA, Renner JB, Phillips C, Matteson SR. Positional changes of the mandibular condyle assessed by three-dimensional computed tomography. *J Oral Maxillofac Surg* 1992;50:1164-72.
  22. Katsumata A, Fujishita M, Maeda M, Arijii Y, Arijii E, Langlais RP. 3D-CT evaluation of facial asymmetry. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2005;99:212-20.
  23. Cevidanes LH, Bailey LJ, Tucker SF, Styner MA, Mol A, Phillips CL, et al. Three-dimensional cone-beam computed tomography for assessment of mandibular changes after orthognathic surgery. *Am J Orthod Dentofacial Orthop* 2007;131:44-50.
  24. Chen S, Lei J, Wang X, Fu KY, Farzad P, Yi B. Short- and long-term changes of condylar position after bilateral sagittal split ramus osteotomy for mandibular advancement in combination with Le Fort I osteotomy evaluated by cone-beam computed tomography. *J Oral Maxillofac Surg* 2013;71:1956-66.
  25. Kim YI, Cho BH, Jung YH, Son WS, Park SB. Cone-beam computerized tomography evaluation of condylar changes and stability following two-jaw surgery: Le Fort I osteotomy and mandibular setback surgery with rigid fixation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endodontol* 2011;111:681-7.
  26. Ellis E 3<sup>rd</sup>, Hinton RJ. Histologic examination of the temporomandibular joint after mandibular advancement with and without rigid fixation: An experimental investigation in adult *Macaca mulatta*. *J Oral Maxillofac Surg* 1991;49:1316-27.
  27. Hoppenreijts TJ, Stoelinga PJ, Grace KL, Robben CM. Long-term evaluation of patients with progressive condylar resorption following orthognathic surgery. *Int J Oral Maxillofac Surg* 1999;28:411-8.
  28. Hwang SJ, Haers PE, Seifert B, Sailer HF. Non-surgical risk factors for condylar resorption after orthognathic surgery. *J Craniomaxillofac Surg* 2004;32:103-11.
  29. Rotskoff KS, Herbosa EG, Villa P. Maintenance of condyle-proximal segment position in orthognathic surgery. *J Oral Maxillofac Surg* 1991;49:2-7.
  30. Tabrizi R, Shahidi S, Bahramnejad E, Arabion H. Evaluation of condylar position after orthognathic surgery for treatment of Class II vertical maxillary excess and mandibular deficiency by using cone-beam computed tomography. *Journal of Dentistry* 2016;17:318-25.
  31. Wang T, Han JJ, Oh HK, Park HJ, Jung S, Kook MS. Comparison of orthodontics-first and surgery-first approach in positional changes of the condyle after mandibular setback surgery using three-dimensional analysis. *J Oral Maxillofac Surg* 2016;74:2487-96.
  32. Hu J, Wang D, Zou S. Effects of mandibular setback on the temporomandibular joint: A comparison of oblique and sagittal split ramus osteotomy. *J Oral Maxillofac Surg* 2000;58:375-80.
  33. Kawamata A, Fujishita M, Nagahara K, Kanematu N, Niwa K, Langlais RP. Three-dimensional computed tomography evaluation of postsurgical condylar displacement after mandibular osteotomy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998;85:371-6.
  34. Ghang MH, Kim HM, You JY, Kim BH, Choi JP, Kim SH, et al. Three-dimensional mandibular change after sagittal split ramus osteotomy with a semirigid sliding plate system for fixation of a mandibular setback surgery. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2013;115:157-66.
  35. Ueki K, Marukawa K, Shimada M, Nakagawa K, Yamamoto E. Change in condylar long axis and skeletal stability following sagittal split ramus osteotomy and intraoral vertical ramus osteotomy for mandibular prognathia. *J Oral Maxillofac Surg* 2005;63:1494-9.
  36. Hollender L, Ridell A. Radiography of the temporomandibular joint after oblique sliding osteotomy of the mandibular rami. *Scand J Dent Res* 1974;82:466-9.
  37. Alder ME, Deahl ST, Matteson SR, Van Sickels JE, Tiner BD, Rugh JD. Short-term changes of condylar position after sagittal split osteotomy for mandibular advancement. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999;87:159-65.
  38. Will LA, Joondeph DR, Hohl TH, West RA. Condylar position

- following mandibular advancement: Its relationship to relapse. *J Oral Maxillofac Surg* 1984;42:578-88.
39. Ueki K, Hashiba Y, Marukawa K, Alam S, Nakagawa K, Yamamoto E. Skeletal stability after mandibular setback surgery: Bicortical fixation using a 2.0-mm locking plate system versus monocortical fixation using a nonlocking plate system. *J Oral Maxillofac Surg* 2008;66:900-4.
  40. Kim JW, Lee DH, Lee SY, Kim JH, Lee SH. 3-D CT evaluation of condyle head position, mandibular width, and mandibular angle after mandibular setback surgery. *J Korean Assoc Oral Maxillofac Surg* 2009;35:229-39.
  41. Choi KY, Lee SH. Evaluation of condylar position using computed tomograph following bilateral sagittal split ramus osteotomy. *Maxillofac Plast Reconstr Surg* 1996;18:570-93.
  42. Imamura R. Assessment of the position and morphology of the condylar head of mandible after sagittal split ramus osteotomy: A postoperative comparative study from 1 to 6 months. *Int J Oral Med Sci* 2017;15:139-51.
  43. Lee SK, Kim KW, Kim CH. Postoperative positional change of condyle after bilateral sagittal split ramus osteotomy associated with mandibular asymmetry. *J Korean Assoc Oral Maxillofac Surg* 2004;30:359-67.
  44. Jung WS, Kim H, Jeon DM, Mah SJ, Ahn SJ. Magnetic resonance imaging-verified temporomandibular joint disk displacement in relation to sagittal and vertical jaw deformities. *Int J Oral Maxillofac Surg* 2013;42:1108-15.
  45. Kim YJ, Lee Y, Chun YS, Kang N, Kim SJ, Kim M. Condylar positional changes up to 12 months after bimaxillary surgery for skeletal Class III malocclusions. *J Oral Maxillofac Surg* 2014;72:145-56.
  46. Harris MD, Van Sickels JE, Alder M. Factors influencing condylar position after the bilateral sagittal split osteotomy fixed with bicortical screws. *J Oral Maxillofac Surg* 1999;57:650-4.
  47. Park SB, Yang YM, Kim YI, Cho BH, Jung YH, Hwang DS. Effect of bimaxillary surgery on adaptive condylar head remodeling: Metric analysis and image interpretation using cone-beam computed tomography volume superimposition. *J Oral Maxillofac Surg* 2012;70:1951-9.
  48. Ueki K, Moroi A, Sotobori M, Ishihara Y, Marukawa K, Takatsuka S, *et al.* A hypothesis on the desired postoperative position of the condyle in orthognathic surgery: A review. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2012;114:567-76.
  49. Dalili Z, Khaki N, Kia SJ, Salamat F. Assessing joint space and condylar position in the people with normal function of temporomandibular joint with cone-beam computed tomography. *Dent Res J (Isfahan)* 2012;9:607-12.