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Effect of sagittal split ramus osteotomy on morphologic parameters of temporomandibular joint in patients with mandibular prognathism

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Abstract

The purpose of this study was to evaluate the change in three-dimensional morphology and clinical symptoms of temporomandibular joint (TMJ) in class III dentofacial deformity patients postoperatively for 6 months after sagittal split ramus osteotomy (SSRO).

Seventeen patients with skeletal Class III malocclusion and 10 asymptomatic volunteers (classified as Control group) were recruited for the study and underwent cone-beam computed tomography scanning. The geometries of the maxilla and mandible were reconstructed using MIMICS (Materialise, Leuven, Belgium). The morphologic measurements of the patients' TMJs were done before surgery and at 6-month follow-up – named as Pre and Post groups, respectively.

The joint spaces (medial joint space, superior joint space, lateral joint space, anterior joint space, and posterior joint space) of the Control group were significantly greater than those of the Pre and Post groups ($P < .05$), and SSRO did not significantly change the TMJ morphology parameters. Five patients were found to have preoperative temporomandibular disorder (TMD) symptoms, and 3 of them were relieved at 6 months after surgery. Postoperative TMD symptom was observed in 1 patient without preoperative TMD symptom.

SSRO did not markedly alter the TMJ morphology of the patients with mandibular prognathism. The effects of SSRO on TMD symptoms should be related to the type of deformity.

Abbreviations: 3D = three-dimensional, A = the anterior direction, AJS = anterior joint space, B = the bottom direction, CBCT = cone-beam computed tomography, CCA = coronal condylar angle, CCW = coronal condylar width, CRA = coronal ramus angle, HC = height of condyle, HCA = horizontal condylar angle, HPC = height of processus condylaris, L = the left direction, LJS = lateral joint space, MJS = medial joint space, MP = mandibular prognathism, P = the posterior direction, PJS = posterior joint space, R = the right direction, SJS = superior joint space, SRA = sagittal ramus angle, SSRO = sagittal split ramus osteotomy, T = the top direction, TC = thickness of condyle, TMD = temporomandibular disorders, TMJ = temporomandibular joint.

Keywords: mandibular prognathism, morphology, sagittal split ramus osteotomy, temporomandibular disorder, temporomandibular joint

1. Introduction

Mandibular prognathism (MP) refers to the disorder of the occlusion and the deformity of the mandible, which is caused by mandibular advance overgrowth. It brings enormous negative effects in daily life and facial appearance. Temporomandibular joints (TMJs) and many muscles are known to contribute to many active human's oral movements, like chewing, swallowing and talking, more than 2000 times per day.[1] The percentage of the Asian race with MP were more common than the Caucasian race.[2] Patients with MP were 43% of all malocclusions whose prevalence is 67.82% in China.[2,3] The proportion of patients with MP seeking for orthognathic surgery was 25% in the United States[4] and 26% in the United Kingdom.[5] Some MP could be successfully corrected by compensatory orthodontic treatment, but orthodontic and orthognathic combination is the best choice to achieve the effect of facial appearance and occlusion stability.[4]

Sagittal split ramus osteotomy (SSRO) is the representative orthognathic surgery for patients with MP.[6] It was performed frequently because of the ability to apply rigid fixation.[7] Other advantages of SSRO include retaining integrity in the overall movement of the mandible and the lower teeth, and the large contact surface between the proximal and distal cores ensuring quick bone healing without incision and scar on the face.[8] However, changes often occurred in the position of the mandibular condyles, articular disc, and paradiscal tissues after surgery.[9] Condylar position changes after mandibular surgery were problematic outcomes that may lead to malocclusion related to the risk of early relapse[10] and the development or worsening of the signs and symptoms of TMJ.[11–14] Many studies showed that inappropriate condylar positioning would lead to postoperative complications, such as condylar resorption and temporomandibular disorder (TMD).[15–20] It was

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noted that the reason for positional changes of TMJ caused by SSRO was not clear.

In the previous studies, most of the TMJ morphology parameters only included several parameters of condyle or joint space [7,21,22] and only a few three-dimensional (3D) studies were used to evaluate TMJ morphological changes.[9] The selected morphological parameters were not comprehensive sufficient to investigate the changes of TMJ after SSRO. Therefore, the purpose of this study was to evaluate the change in 3D morphology and clinical symptoms of TMJ in class III dentofacial deformity patients postoperatively for 6 months after SSRO.

2. Materials and methods

2.1. Participants

Seventeen patients (women: 11, men: 6, 22.7±3.0 years old) presented with jaw deformities diagnosed as MP were selected for the study; 10 asymptomatic patients (women: 4, men: 6, 26.75±4.89 years old) were enrolled in this study. None of them were diagnosed with facial asymmetry. All the participants were recruited after being approved by the Institutional Review Board of the Affiliated Hospital of Stomatology, Chongqing Medical University. Informed consent was obtained from each participant before the study. An oral surgeon (JL Song) assisted in recruiting the patients and the asymptomatic participants. Before SSRO, there were 5 patients (22.82±3.49 years old) diagnosed with TMD symptoms and the others (22.0±2.0 years old) diagnosed without TMD symptoms. SSRO was performed on the 17 patients from 2014 to 2016 in the Department of Oral and Maxillofacial Surgery, the Affiliated Hospital of Stomatology, Chongqing Medical University.

2.2. 3D modeling

Following a standardized protocol (120 kVp, 3–8 mA, 20 seconds, 0.4-mm voxel resolution), all the patients were scanned by a cone-beam computed tomography (CBCT) machine (KaVo 3D eXam; KaVo Dental GmbH, Biberach an der Riss, Germany) with a complete head view. The resolution of cross-sectional images was 400×400 pixels. Each CBCT scan consisted of 270 to 340 images with slice thicknesses of 0.4 mm. The data was reformatted into Digital Imaging and Communications in Medicine format. The 10 asymptomatic participants were designated as the Control group. CBCT scanning for the patients was performed before and 6 months after SSRO, named as Pre and Post groups, respectively.

According to the Hounsfield units, the boundaries of the mandible and maxilla were accurately distinguished on each slice of CBCT in MIMICS (Materialise, Leuven, Belgium). Subsequently, the 3D models of the mandible and maxillary were constructed.

2.3. TMJ morphologic measurements

Thirteen morphologic parameters were chosen to investigate the influences of SSRO on TMJ in the patients with skeletal Class III malocclusions (Figs. 1–8).[23,24] There were 5 joint spaces [SJS (superior joint space, the length from the uppermost point of the condyle to the articular fossa), AJS (anterior joint space, the length parallel to the FH plane from the front points of the condyle to the articular fossa profile), PJS (posterior joint space, the length parallel to the FH plane from the rear points of the condyle to the articular eminence profile), MJS (medial joint space, the length from the innermost point of the condyle to the articular fossa), and LJS (lateral joint space, the length from the outermost point of the condyle to the articular fossa)], 2 condylar angles [CCA (coronal condylar angle, the angle from the FH plane to the condylar long axis) and HCA (horizontal condylar angle, the angle from the condylar long axis to the RL line; the line between the foremost points of the bilateral auricles)], 2 ramus angles [SRA (sagittal ramus angle, the angle from the FH plane to the tangent of the rear profile of mandibular ramus) and CRA (coronal ramus angle, the angle from the FH plane to the tangent of the lateral outline of mandibular ramus)], and 4 condylar sizes [CCW (coronal condylar width, the distance of the most lateral point of the condyle and paralleling to the FH plane), TC (thickness of condyle, the distance from the front point to the rear point of the condyle), HC (height of condyle, the distance from the peak of condyle to the line of the most lateral points of the condyle), and HPC (height of processus condylaris, the distance between the peak of condyle and the line that paralleled to the FH plane and passed through the sigmoid notch)]. All the morphologic parameters of each 3D model were measured 3 times within a 1-week interval. The correlation coefficients of the results were greater than 0.95. Therefore, the repeatability of the measurements was acceptable in this study. In addition, the analytical parameters were the averages.

To investigate the effects of bilateral sagittal split ramus osteotomy on the TMJs, the morphologic parameters among the Control, Pre, and Post groups were compared using analysis of variance, between both the sides using t test. All the statistical analyses were performed in SPSS 20.0 (SPSS, Inc., Chicago, IL), and the statistical significance of the analysis of variance and t test were set as $P<.05$.

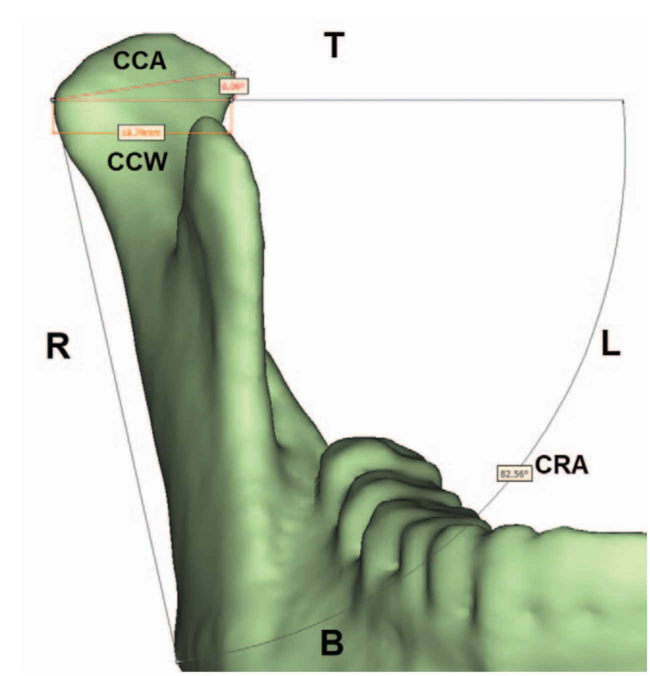

Figure 1. Measurements of the CCW, CCA, and CRA on the 3D models. 3D=three-dimensional, B=the bottom direction, CCA=coronal condylar angle, CCW=coronal condylar width, CRA=coronal ramus angle, L=the left direction, R=the right direction, T=the top direction.

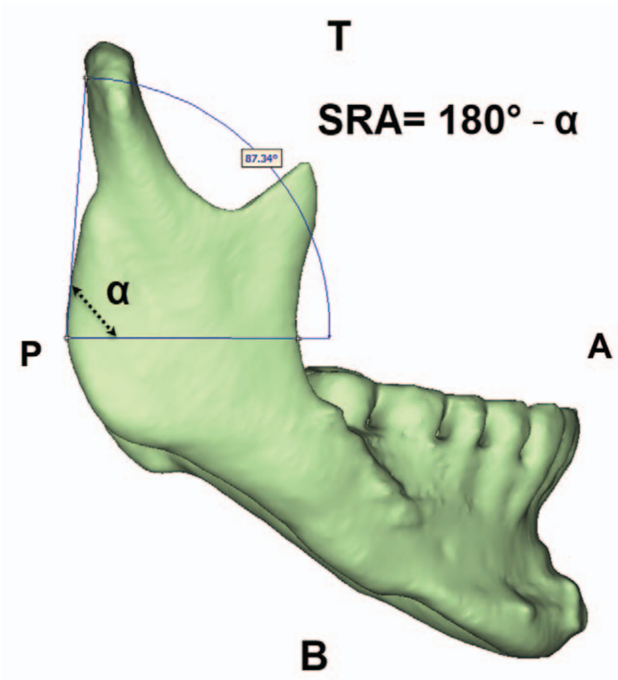

Figure 2. Measurements of the SRA on the 3D models. 3D=three-dimensional, A=the anterior direction, B=the bottom direction, P=the posterior direction, SRA=sagittal ramus angle, T=the top direction.

3. Results

There were no significant differences on the condylar angles between the Pre and Post groups, except for the SRAR (SRA of right condyle). The HCAR in the Pre group was significantly greater than that in the Control group. There were no significant differences on other condylar angles between the Pre and Control groups. Only the CCAL (CCA of left condyle), HCAL, and CRAL in the Post group were significantly greater than those in the Control group. Other condylar angles in the Post group were not significantly different from those in the Control group (Fig. 9).

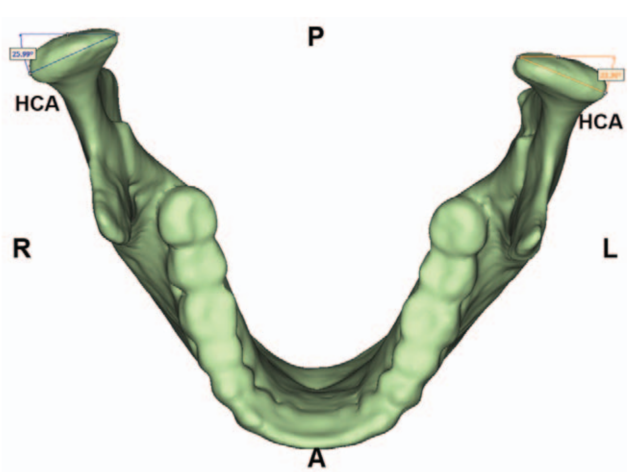

Figure 3. Measurements of the HCA on the 3D models. 3D=three-dimensional, A=the anterior direction, HCA=horizontal condylar angle, L=the left direction, P=the posterior direction, R=the right direction.

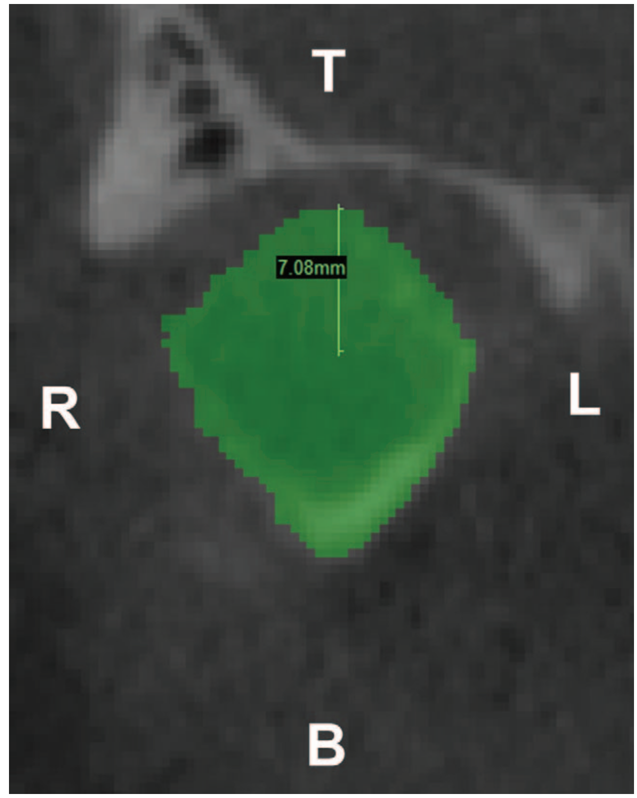

Figure 4. Measurements of the HC on the coronal CBCT images. B=the bottom direction, CBCT=cone-beam computed tomography, HC=height of condyle, L=the left direction, R=the right direction, T=the top direction.

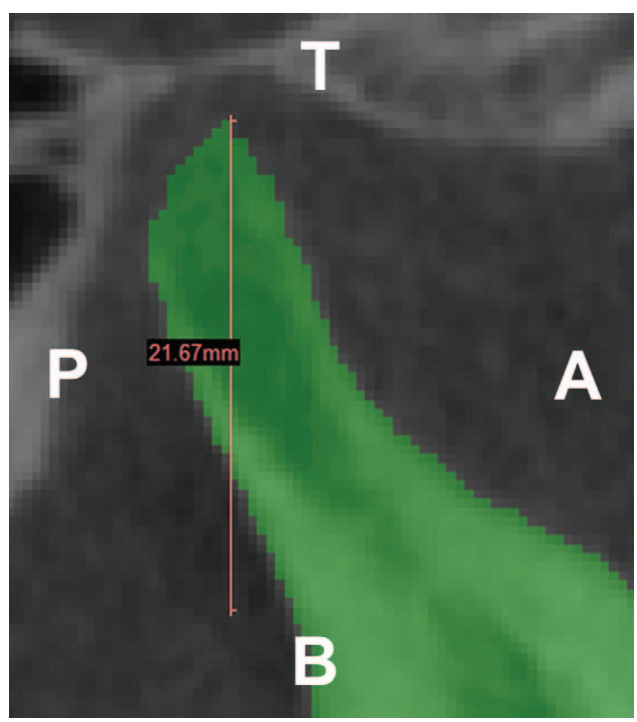

Figure 5. Measurements of the HPC on the sagittal CBCT images. A=the anterior direction, CBCT=cone-beam computed tomography, HPC=height of processus condylaris, L=the left direction, P=the posterior direction, R=the right direction.

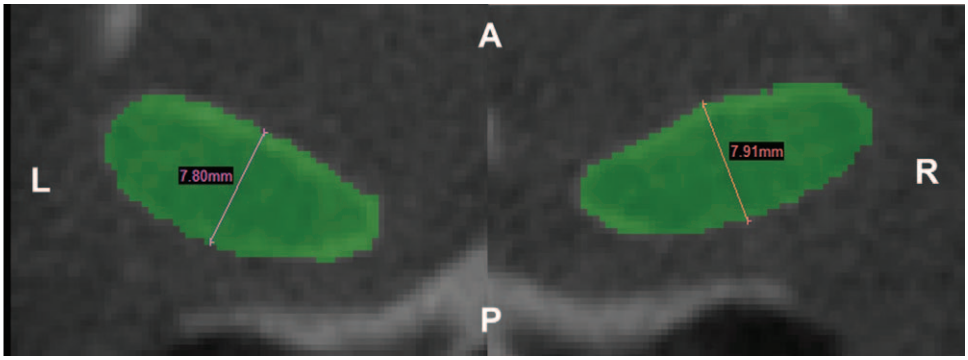

Figure 6. Measurements of the TC on the horizontal CBCT images. A = the anterior direction, CBCT = cone-beam computed tomography, L = the left direction, P = the posterior direction, R = the right direction, TC = thickness of condyle.

Most joint spaces in the Pre group were significantly lower than those in the Control group, expect for MJSL, SJS, and PJS. Similarly, most joint spaces in the Post group were significantly lower than those in the Control group, expect for PJSL, AJSL, and MJSR. There were no significant differences on joint spaces between the Pre and Post groups, but the mean value of MJSL, AJS, and PJSL in the Post group were greater than those in the Pre group (Fig. 10).

There were no significant differences for the CCW, HC, and TC among the Control, Pre, and Post groups. The HPC of the Control group was significantly lower than that of the Pre and Post groups (Fig. 11).

There were no significant differences on all the parameters between the left and right TMJs in the Control group. However, there were significant differences on preoperative LJS and TC between both the sides. Then the differences of LJS disappeared after the surgery.

4. Discussion

The condylar angles were associated with disc displacement and degenerative joint disease.[25,26] Meanwhile, the joint spaces, ramus angles, and coronal condylar width could influence the disc position and the symmetry of the mandible.[25–27] Therefore, 13 parameters were used to investigate the TMJ morphology and evaluate the surgical effect of SSRO on the TMJ of MP. Moreover, patients with asymmetrical MP had higher incidence of internal derangement than symmetrical patients, associated with differences in TMJ morphology of both sides.[25] Therefore in this study, patients with facial symmetry were chosen to ignore the symmetry influence to the results. Morphology analysis of volunteers in this study was adopted from a validated methodology developed by Zhang et al,[23,28] which showed the accuracy of morphologic parameters measured on 3D models.

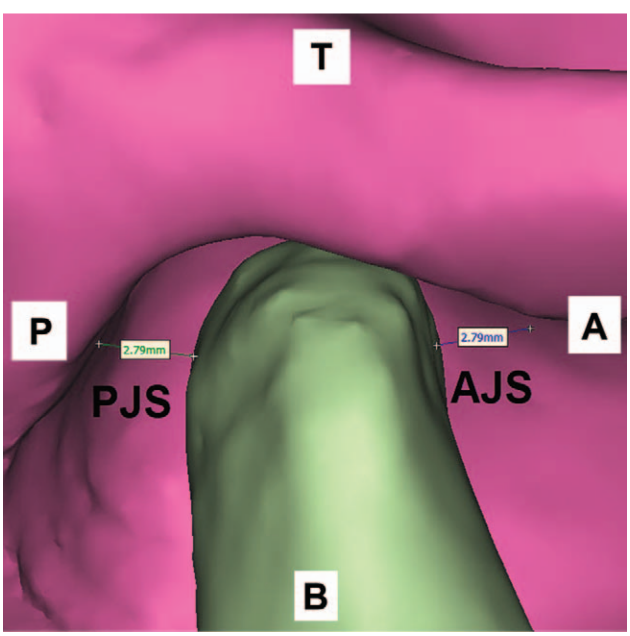

Figure 7. Measurements of the PJS and AJS on the 3D models. 3D = three-dimensional, A = the anterior direction, AJS = anterior joint space, B = the bottom direction, P = the posterior direction, PJS = posterior joint space, T = the top direction.

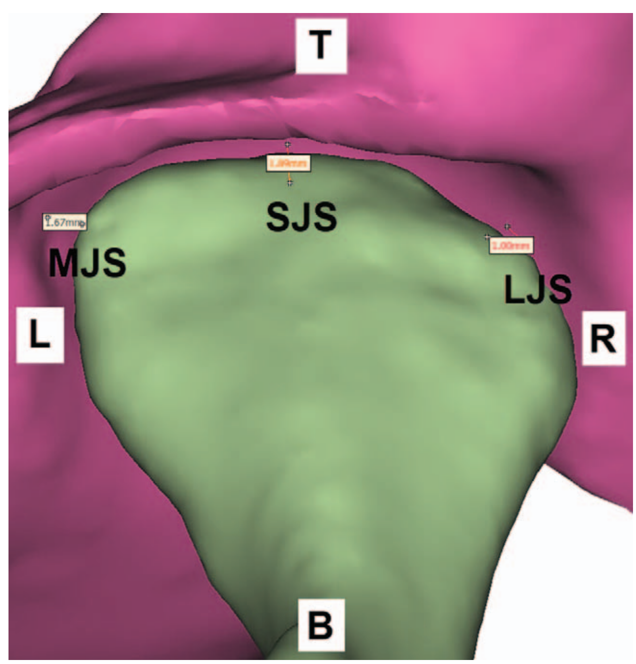

Figure 8. Measurements of the SJS, MJS, and LJS on the 3D models. 3D = three-dimensional, B = the bottom direction, L = the left direction, LJS = lateral joint space, MJS = medial joint space, R = the right direction, SJS = superior joint space, T = the top direction.

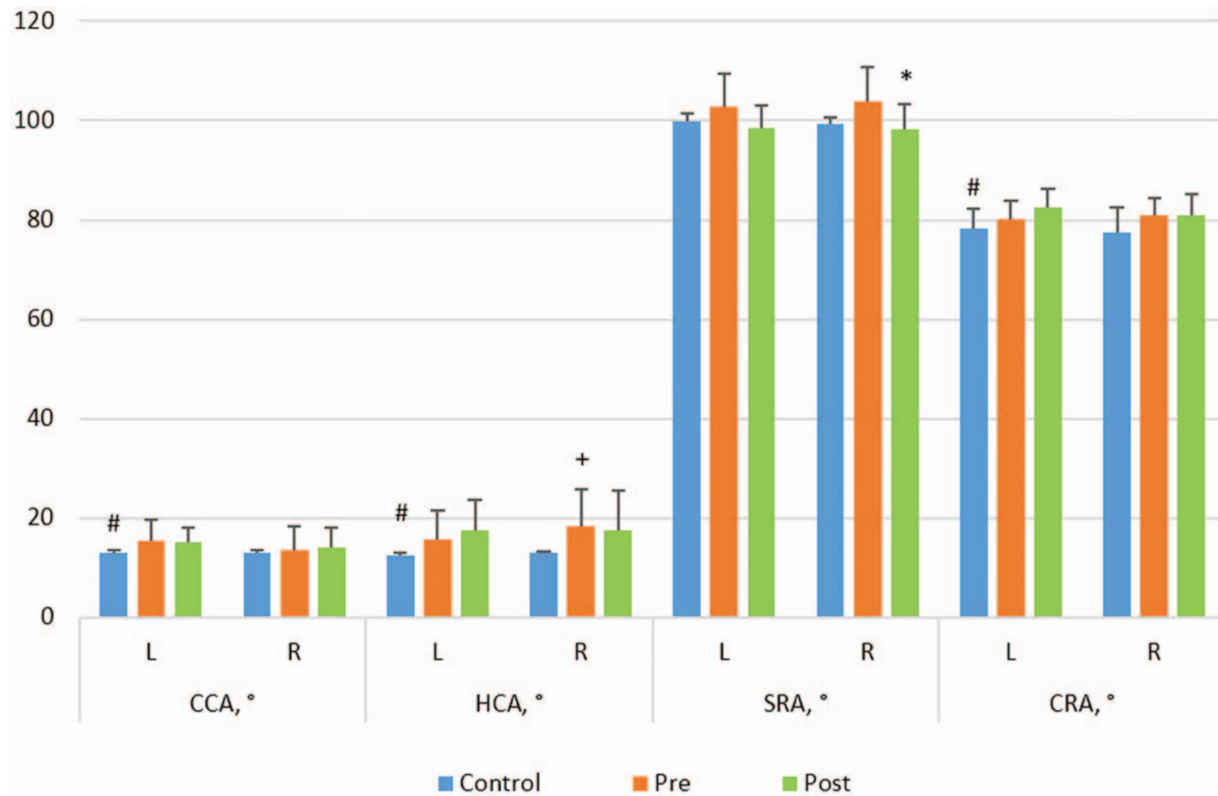

Figure 9. Mean (SD) of the angles. *Note*: $P > .05$, not significant. +Statistically significant difference between Control and Pre by ANOVA ($P < .05$). *Statistically significant difference between Pre and Post by ANOVA ($P < .05$). #Statistically significant difference between Control and Post by ANOVA ($P < .05$). Control, Pre, and Post indicated control group, preoperative group, and postoperative group, respectively. L and R indicated left side and right side, respectively. ANOVA = analysis of variance.

In the present study, there were no significant differences in the magnitudes of condyle angle and size (except for HPC) parameters between the Pre and Control groups. All the joint spaces in Pre were significantly lower than those in Control. Therefore, MP could lead to reduction of joint spaces and enlarge HPC, but not correlated with the condyle angles and sizes. For the MP patients whose mandibular advance overgrowth, stress state and range of motion of TMJ may be different from normal people during their speaking, chewing, and swallowing actions. Therefore, prolonged deformity may affect the joint spaces. After SSRO, the joint spaces in Post group were even lower than those in the Pre group, except for AJS, MJSR, and PJSL. Most joint spaces in the Post group were significantly lower than those in the Control group. After the SSRO, the reason why the joint spaces of patients did not recover to the normal level was unclear. Further research is necessary to answer this question. However, the reduction of joint spaces could lead to squeezing of articular disc in TMJ,[29] which can increase the load on TMJ and lead to osteoarthritis.[30] This in turn may cause pain in the joint and other symptoms of TMD.

TMD symptoms were commonly found in the patients with dentofacial deformities.[7] The clinical records showed 3 patients with clicking assigned as Cases 1 to 3, 1 patient with limited mouth opening assigned as Case 4, and 1 patient with chin biased to left during opening assigned as Case 5 before SSRO. After SSRO, 3 of them were diagnosed without symptoms of TMD (Cases 1, 2, 4) and other 2 patients' symptoms were changed. Another patient out of the remaining 12 patients developed postoperative clicking (Case 6). For the 3 cured patients (Cases 1, 2, 4), AJS was increased whereas LJS was reduced after SSRO, which could improve the TMD symptoms.[20,22] TMJ morphology parameters of them (Cases 1, 2, 4) were all close to those of patients without postoperative TMD symptoms. However, the symmetry of condylar angles (CCA, HCA) on the both the sides was not good in Case 3. It can be seen that the asymmetry of angle might cause TMD symptoms.[30] After SSRO, the symmetry of condylar angles was slightly improved and the AJS was greater. Furthermore, the problem of clicking in Case 3 was alleviated. For Case 5, the magnitudes of CCA were significantly different between both the sides before SSRO. Moreover, most joint spaces were greater on the right side. After SSRO, the magnitudes of bilateral CCA were close, but the joint spaces were greater on the left side. It was the reason of Case 5 with postoperative chin biased to right during opening. On the other hand, AJS was constant after SSRO in Case 6, but all the postoperative joint spaces were lower than those before SSRO. These changes could increase the intrajoint pressure and cause clicking.[30]

Compared with the previous research, the condylar and ramus angles and joint spaces of facial asymmetry patients were more significantly different from normal people than those of MP patients,[30] which suggested that facial symmetry had a huge influence on the TMJ morphology parameters. In addition, the prevalence of preoperative TMD in facial asymmetry patients (70%)[29] was higher than that in MP patients (29%). Therefore, it could be concluded that TMJ morphology parameters are closely related to the TMD symptoms. The magnitudes of SRAL,

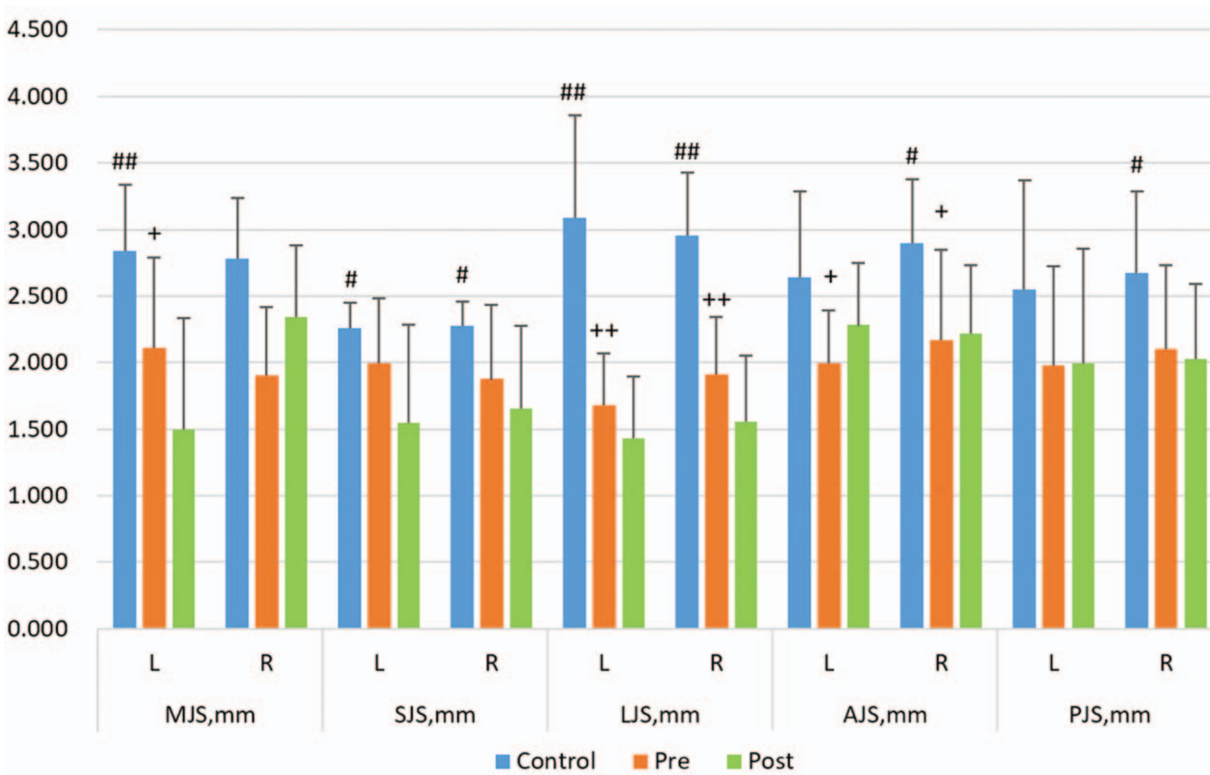

Figure 10. Mean (SD) of the joint spaces. *Note*: $P > .05$, not significant. *Statistically significant difference between Pre and Post by ANOVA ($P < .05$). **Highly statistically significant difference between Pre and Post by ANOVA ($P < .01$). #Statistically significant difference between Control and Post by independent-samples ANOVA ($P < .05$). ##Highly statistically significant difference between Control and Post by independent-samples ANOVA ($P < .01$). Control, Pre, and Post indicated control group, preoperative group, and postoperative group, respectively. L and R indicated left side and right side, respectively. ANOVA = analysis of variance.

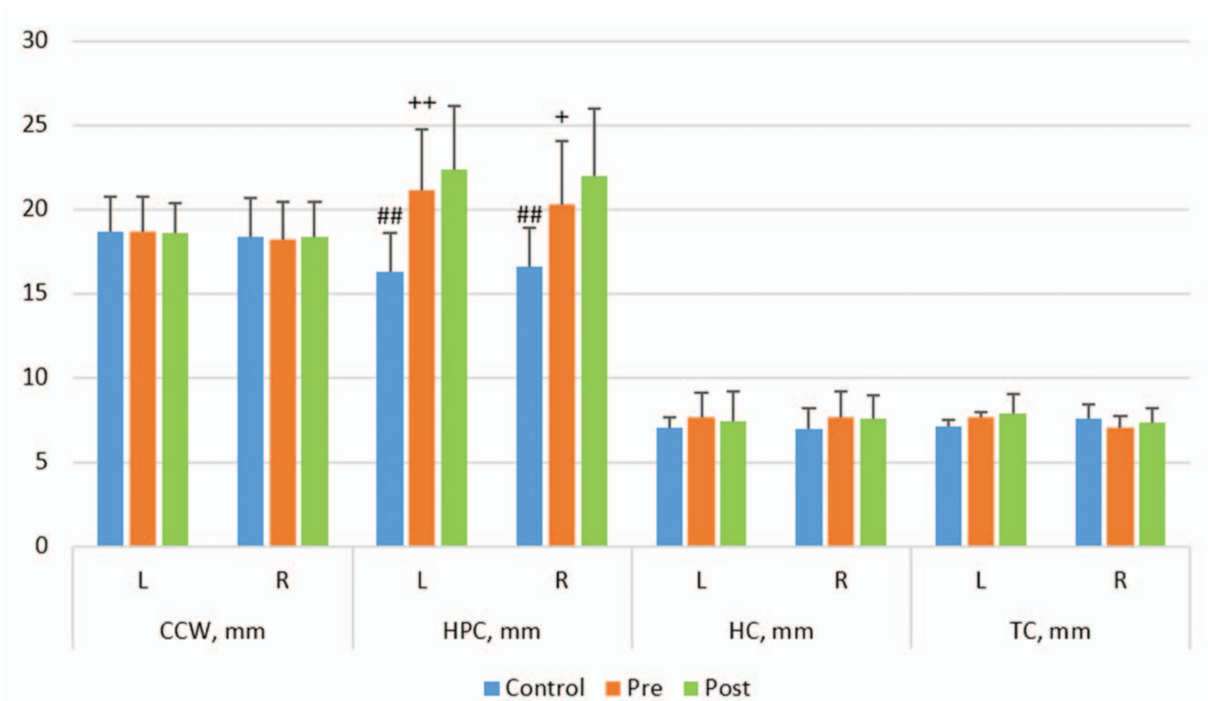

Figure 11. Mean (SD) of the condylar sizes. *Note*: $P > .05$, not significant. +Statistically significant difference between Control and Pre by ANOVA ($P < .05$). ++Highly statistically significant difference between Control and Pre by ANOVA ($P < .01$). ##Highly statistically significant difference between Control and Post by ANOVA ($P < .01$). Control, Pre, and Post indicated control group, preoperative group, and postoperative group, respectively. L and R indicated left side and right side, respectively. ANOVA = analysis of variance.

MJSL, LJSR, and SJS of patients with facial asymmetry were significantly different between the Pre and Post groups.[29,30] Because of the good facial symmetry of MP patients in this study, the effect of SSRO on TMJ morphology parameters of MP patients was not as obvious as that on patients with facial asymmetry. SSRO corrected TMD symptoms of 57% of patients without introducing postoperative symptoms.[29] The cure rate of TMD of facial symmetry MP patients was 60%, but appeared a patient with postoperative symptoms. Consequently, the therapeutic effect of SSRO might be related to the type of deformity that causes TMD.

The rapid modeling method adopted in this study shortened the processing time of 3D modeling. And it was beneficial to accurately measure the morphological parameters of TMJ, as well as to simulate 3D surgical procedures to minimize postoperative TMD in the future. Meanwhile, stress analysis of the preoperative or postoperative conditions could lead to a better reduction of TMD.[31] Surgery simulation and stress analysis would be beneficial to determine the optimized surgical treatments.[32] It was essential to prepare postoperative 3D measurements and stress analyses to evaluate and optimize the surgical plans. All these methods could be helpful to reduce the postoperative TMD.

5. Conclusion

For the MP patients, the ability of SSRO was not obvious to the change of TMJ morphology.

Author contributions

Data curation: He-Di Ma, Jing-Heng Shu.
Formal analysis: He-Di Ma, Jing-Heng Shu.
Funding acquisition: Zhan Liu.
Investigation: He-Di Ma, Jing-Heng Shu, Xu-Zhao Deng.
Methodology: He-Di Ma.
Project administration: Zhan Liu.
Software: He-Di Ma, Jing-Heng Shu, Xu-Zhao Deng.
Supervision: Zhan Liu.
Writing – original draft: He-Di Ma.
Writing – review & editing: Zhan Liu.

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