

Original Article

The condylar morphology in adult females of skeletal class II division 1 malocclusion with various vertical skeletal features: a study by cone beam computed tomography

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Abstract: The purpose of this study was to evaluate the condylar morphology parameters using cone beam computed tomography (CBCT). 180 adult female patients with skeletal Class II division 1 were recruited in this study. Then the participants were divided into three groups according to the values of GoGn-SN and S-Go/N-Me. Mimics 10.01 software was used to reconstruct the CBCT images and measure the parameters including condylar volume, surface area, morphological index, inner-outer and front-back diameters on the sagittal and coronal sections. Our results showed that there were no significant difference by condylar morphological parameters in patients with the same vertical skeletal pattern ($P > 0.05$). All the measured parameters in the low angle group were significantly different with those in the average angle group ($P < 0.05$). Similarly, all the measured parameters except the morphological index in the low angle group were significantly different with those in the high angle group ($P < 0.05$). Significant difference was found between the high angle group and the low angle group regarding the parameters including condylar MI, inner-outer and front-back diameters ($P < 0.05$). In conclusion, our study demonstrated that there was significant difference regarding the condylar morphology among females of skeletal Class II division 1 malocclusion with various vertical skeletal features. The data was important and valuable for radiological diagnosis, orthodontic treatments and orthognathic surgery.

Keywords: Skeletal class II division 1 malocclusion, cone beam computed tomography, condyle morphology, vertical skeletal pattern

Introduction

Temporomandibular joint (TMJ) plays an important role in maintaining good masticating function as well as the balance of oral and maxillo-facial system. Condyle is an indispensable part of TMJ and can response to functional simulations constantly. Therefore, its morphology and volume can reflect the adaptations to the influential factors. The functional adaptation property of condyle is essential for maintaining the long term stability of TMJ after orthodontic or orthognathic surgery [1, 2].

Due to the limitations of the two-dimensional images, it was difficult to investigate the structure and morphology of condyle *in vivo*. However, with the development of technology in the

past decades, cone beam computed tomography (CBCT) has become a widely used and popular imaging tool in the field of clinical dentistry. CBCT is well suited for imaging the craniofacial area. It not only provides clear images of highly contrasted structures, but also is extremely useful for evaluating bone morphology [3]. The morphology and position of TMJ fossa and condyle are closely correlated with the types of malocclusion as well as the vertical distance of lower facial third. Thus the investigation on condyle morphology is very important. The clinician can assess whether a specific patient has abnormal condyle morphology and the potential temporomandibular disorders on the basis of normal range of condyle morphological parameters.

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The incidence of skeletal Class II malocclusions is especially high. In addition, the variations among different vertical skeletal features are great. Currently whether different vertical skeletal features have any influence on the morphology and structure of the condyle in the patients with skeletal Class II division 1 malocclusion is controversial.

In the present study, we aimed to determine whether there was any difference regarding the morphological parameters of condyle between adult females of skeletal Class II division 1 malocclusion with various vertical skeletal features.

Materials and methods

Study population

The study was approved by the Ethnic Committee of Qingdao Stomatological Hospital and the written consent was obtained from all participants. 180 females who received orthodontic treatment in the Department of Orthodontic, Qingdao Stomatological Hospital from Jan 2011 to Dec 2014 were recruited in the study. All the subjects were diagnosed as skeletal Class II division 1 malocclusion. The average age of the patients was 26.1 y (age range, 18-35 y) The inclusion criteria were as follows: 1. The patients had taken CBCT images before treatments; 2. Females diagnosed as skeletal Class II division 1 malocclusion and with ANB angle greater than 5°; 3. No TMJ disorder indicated; 4. The bilateral symmetry of facial was required, without mandibular deviations and occlusion asymmetry; 5. No prior orthodontic treatment, trauma, infection and surgical treatment history indicated. Then the 180 subjects were selected from the patient pool randomly and divided into three groups (low angle, average angle, and high angle) according to the GoGn-SN and S-Go/N-Me values [4]. The classification standard was as follows: high angle group (GoGn-SN>37.7°, S-Go/N-Me<62%); average angle group (27.3°<GoGn-SN<37.7°, 62%<S-Go/N-Me<68%) and low angle group (GoGn-SN<27.3°, S-Go/N-Me>68%). There were 60 cases in each group respectively and patients in each group were matched by age.

CBCT imaging

The NNT Viewer CBCT (QR SRL Company, Verona, Italy) with imaging parameters of 120 kV, 8mA was used to collect all the participants' images. The CBCT images were taken under natural head position. The subjects were re-

quired to relax their facial muscles, close the lips naturally and breathe peacefully. In addition, the posterior teeth were intercuspally placed. The shooting time lasted for 20 seconds and CBCT images were saved in DICOM format. The CBCT was operated by the same radiologist in this study.

Measurement of condylar volume and surface area

Different layers of CBCT images in DICOM format were imported into Mimics 10.01 software (Materialise NV Technologielaan, Leuven, Belgium) by selecting the order "import image". 3-dimensional reconstruction of condyle was performed according to previous methods [5, 6]. The gray values of the CBCT images in the software were defined as bone density values (gray value: -1024~1650; threshold value: 542~3071).

After setting the parameters, the images that above the condyle were deleted by pressing the "Edit Masks" button at the horizontal sections. Similarly, the posterior sections of condylar images were removed in sagittal planes (**Figure 1A**). Then the images in the coronal sections were amplified by rolling the computer mouse. The first white image that presented in the joint zone was set for the upper boundary of condyle (**Figure 1C**). The area that the most concave point of coracoid disappeared was defined as condylar lower boundary (**Figure 1C**). Both hard and soft tissues around condyle within this scope were removed by selecting "Edit Masks" order. Finally, 3-dimensional images of condyle were reconstructed by choosing the "Calculate 3D from Mask" order (**Figure 1B, 1D**). The condylar volume and surface area was calculated automatically by double clicking post reconstructive condylar image. All images were reconstructed twice by the same person for the measurement. The duration between two reconstructions was 1 week. The error of measurement was calculated by the following formula: $v_e = \sum (x_1 - x_2)^2 / 2n$.

Measurement of condylar back-front and inner-outer diameters

After the images were imported into Mimics software, the condyle was located in the axial images and then the layers slicing method was used by selecting the "Online Reslice" button of the software. The center point of slicing line was superposed with the center point of con-

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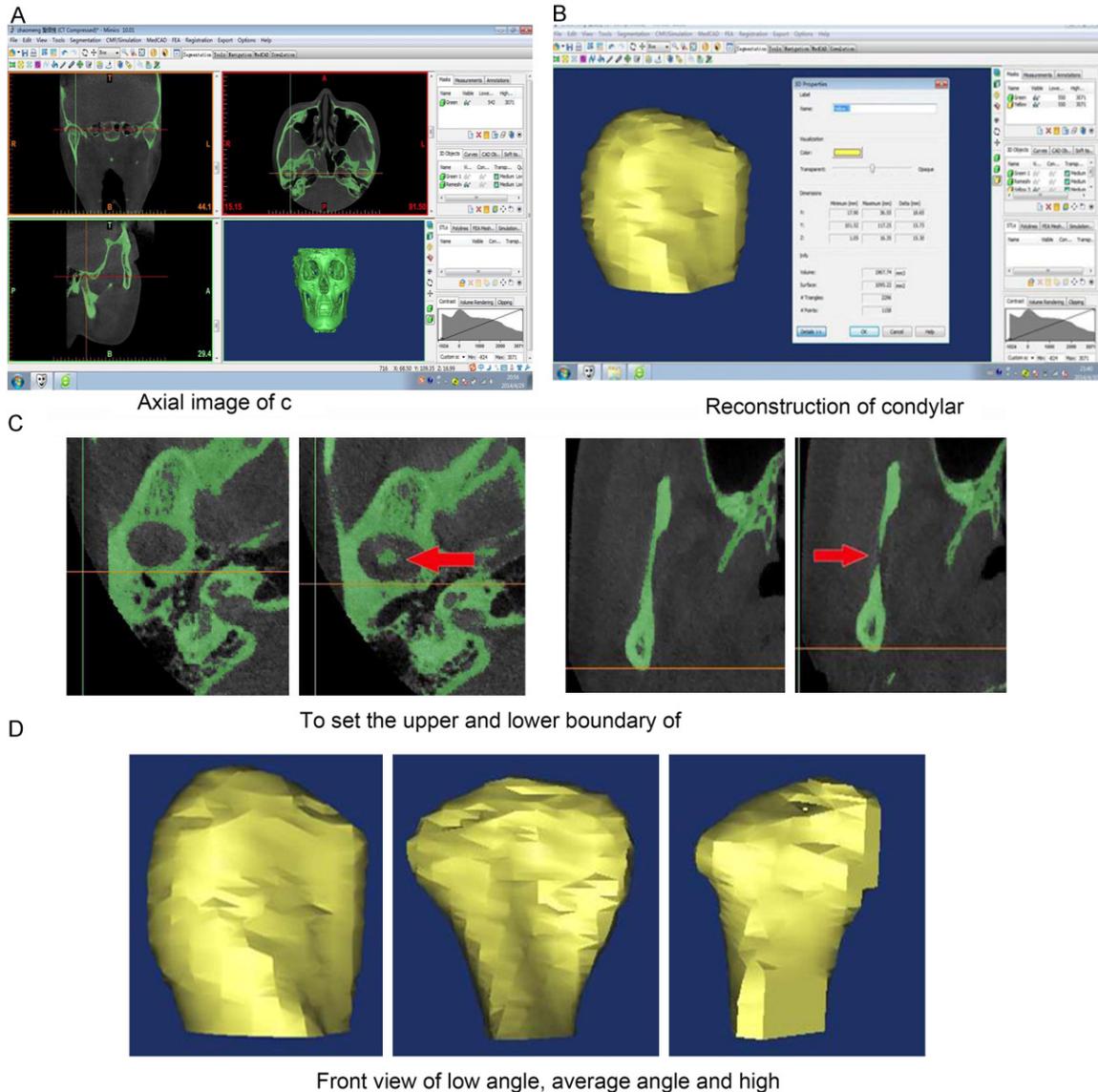


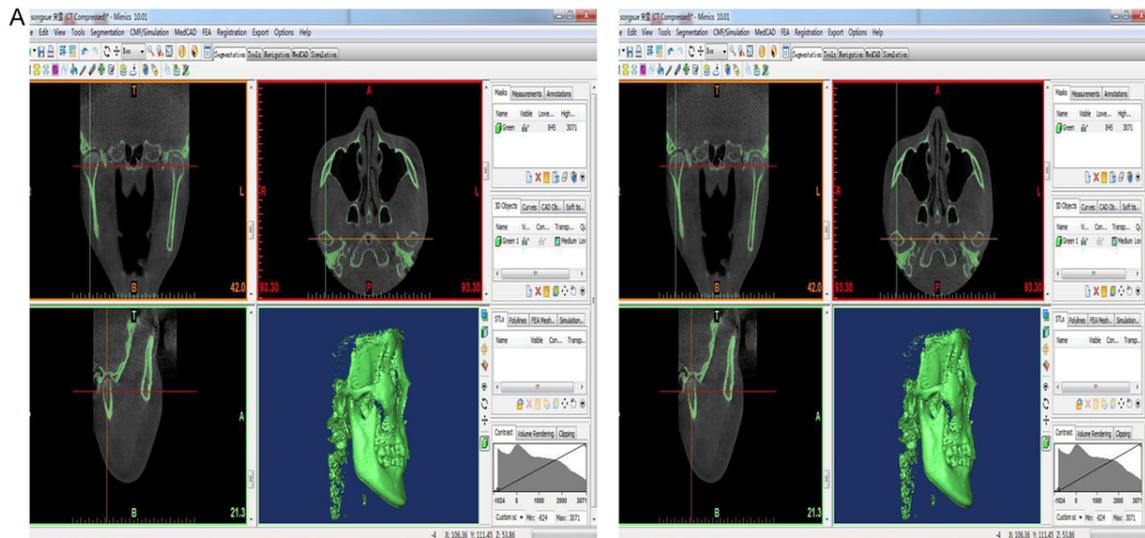
Figure 1. Reconstruction process of condylar volume and surface area.

dyle. In addition, the slicing line was perpendicular to condylar long axis with left-right symmetry. There were totally 18 slicing layers and the slicing thickness was 0.3 mm. A group of tilted images that perpendicular to the long axis of condyle was reconstructed (**Figure 2A**). The center tilted image was selected and then amplified. The most front and back points of the image were located, and the connections between them were measured. The maximum measured value was set for back-front diameter of condyle. Similarly, a group of tilted images parallel to condylar long axis was reconstructed with the same method, and the inner-outer diameter of condyle was calculated (**Figure 2B**).

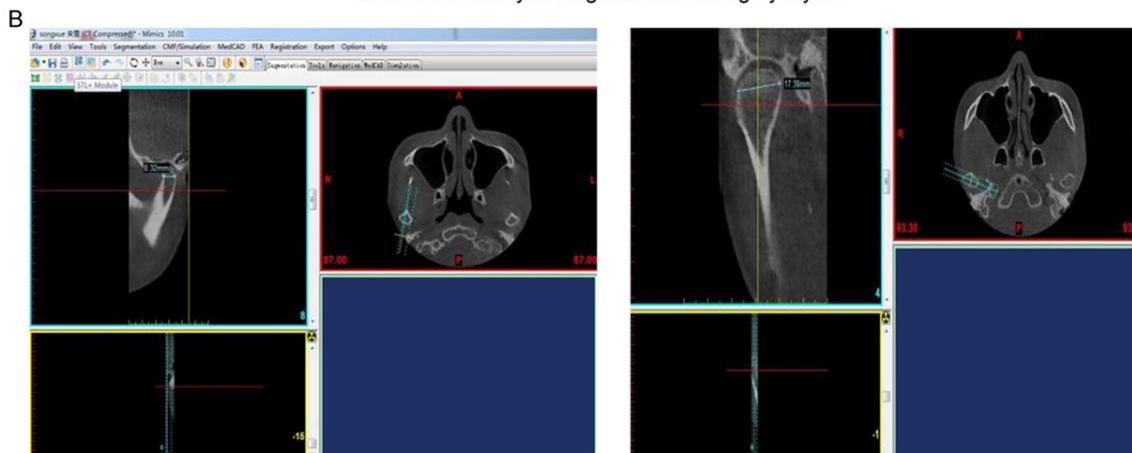
Statistical analysis

All the data in the study were expressed as means \pm standard deviation (SD). Paired t test was performed to compare the left side and right side condylar morphological parameters in patients with the same vertical skeletal pattern. One-way ANOVA was conducted to compare the condylar morphological parameters in patients with different vertical skeletal patterns. If any difference was found, further comparison between the two respective groups was performed. The software of SPSS version 21.0 for Windows (SPSS Inc, IL, USA) was used for statistical analysis. Differences were considered statistically significant when P was less than 0.05.

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Location of condylar long axis and slicing by layers



Measurements of condylar front-back and

Figure 2. Reconstruction process of condylar front-back and inner-outer diameters.

Table 1. The GoGn-SN and S-Go/N-Me values of different groups

Groups	N	Age (year)	GoGn-SN Angle (°)	S-Go/N-Me (%)
High angle	60	26.31±3.90	42.82±2.57	58.82±1.83
Average angle	60	24.86±4.01	32.91±2.81	66.28±1.23
Low angle	60	25.89±3.89	24.37±2.56	72.73±3.36

Me of three groups were summarized in **Table 1**.

Comparison of the left side and right side condylar morphological parameters in patients with the same vertical skeletal pattern

Results

The values of GoGn-SN and S-Go/N-Me values in different groups

The values of GoGn-SN and S-Go/N-Me were used to divide the participants into three groups. No significant difference regarding age was found among different groups ($P>0.05$). The average values of GoGn-SN and S-Go/N-

We first compared the difference between the left and the right side condylar morphology of the patients with the same vertical skeletal pattern. The parameters including condylar volume, condylar surface area, condylar morphology index (volume/surface area, MI), condylar inner-outer diameter and front-back diameter were measured. The results showed that no significant difference was found regarding the

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Table 2. Comparison of the left and ride side condylar morphological parameters in patients with the same vertical skeletal pattern

Parameters	Low angle group			Average angle group			High angle group		
	Left	Right	p	Left	Right	p	Left	Right	p
Condylar volume (mm ³)	2359.32±505.90	2457.27±608.74	0.287	1993.83±498.99	2050.63±609.64	0.837	1988.82±664.07	2015.36±647.68	0.303
Condylar surface area (mm ²)	1193.25±178.41	1219.34±281.01	0.701	989.50±352.48	1022.31±269.57	0.811	999.63±316.11	1005.98±321.24	0.821
Condylar morphology index (mm)	1.98±0.33	2.02±0.24	0.550	2.16±0.21	2.13±0.16	0.655	2.03±0.16	1.97±0.16	0.431
Condylar inner-outer diameter (mm)	10.26±1.17	10.35±1.32	0.838	9.37±1.01	9.47±1.08	0.802	7.60±1.23	7.68±1.32	0.772
Condylar front-back diameter (mm)	19.57±2.10	19.72±2.19	0.607	17.87±2.13	17.94±2.23	0.897	16.46±1.76	16.57±1.98	0.870

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Table 3. Comparison of condylar morphological parameters in patients with different vertical skeletal patterns

Parameters	Low angle group (L)	Average angle group (A)	High angle group (H)	LSD (t) P value		
				L vs A	L vs H	A vs H
Condylar volume (mm ³)	2397.59±600.28	2022.23±542.99	1999.04±564.51	0.042*	0.031*	0.898
Condylar surface area (mm ²)	1206.30±229.49	1011.98±305.26	1000.30±306.73	0.034*	0.025*	0.897
Condylar morphology index (mm)	2.00±0.28	2.14±0.18	1.98±0.15	0.039*	0.772	0.019*
Condylar inner-outer diameter (mm)	10.30±1.24	9.46±1.04	7.68±1.06	0.020*	<0.001**	<0.001**
Condylar front-back diameter (mm)	19.64±2.09	17.90±2.12	16.51±1.82	0.009**	<0.001**	0.033*

left-right morphology of condyle in all the participants (**Table 2**) ($P>0.05$), indicating the condylar symmetry in the investigated subjects.

Comparison of condylar morphological parameters in patients with different vertical skeletal patterns

We then compared the condylar morphology of subjects with different vertical skeletal features. As it was shown in **Table 3**, all the measured parameters in the low angle group were significantly different from those in the average angle group (* $P<0.05$; ** $P<0.01$). There was significant difference between high angle group and low angle group regarding the following parameters including condylar MI, inner-outer and front-back diameters (* $P<0.05$; ** $P<0.01$). However, no significant difference was found between the above two groups regarding condylar volume and condylar surface area ($P>0.05$). What was more, our results showed that the condylar back-front diameters and inner-outer diameters were significantly different among each group (* $P<0.05$; ** $P<0.01$). The patients in the low angle group had both longest condylar back-front and inner-outer diameters while the high angle group had the shortest.

Discussion

TMJ, one of the most complex joints in the body, is a bi-articular hinge joint that allows the complex movements necessary for many important functions such as mastication, swallow and speech. In addition, TMJ is closely correlated with development of craniofacial structures. As the condyle is the growth and development center of the mandible, its morphology can indirectly reflect the reconstructive process. The condyle also plays a major role in deciding the size of mandible. Previous study has shown that the condylar volume was not

only closely associated with the final size of mandible, but also with the maxilla-mandible relationship [7]. Patients with skeletal Class II division 1 malocclusion often have the features of developmental disorders in the sagittal direction and vertically dysplasia simultaneously. In addition, sagittal deformity was often exacerbated by vertically dysplasia. The aim of our study was to explore the potential relationship between condylar morphology and various vertical skeletal features of females who were diagnosed as skeletal Class II division 1 malocclusion. Due to the limitations of techniques, it was impossible to conduct the 3-dimension measurement of the condyle *in vivo* in the past. However, the application of CBCT in the field of clinical dentistry in the recent years has made the measurement become reality. The Mimics software we adopted to reconstruct the morphology of condyle is highly reliable and reproducible. It enables us to measure the relative parameters of condyle on the basis of the same anatomical position and section, thus it can detect the bone structure characters and differences of TMJ.

In the present study, we divided the female patients who were age matched into three groups based on the skeletal vertical features. This experimental design eliminated the difference in potential influential factors including age and gender. Our results showed that no significant difference was found between the left and right side condylar morphology in patients with the same vertical skeletal pattern, indicating that the condyles of the participants were symmetry. One of our strict inclusion criteria that the bilateral symmetry of facial was required might be also a reason accounting for the condylar symmetry in patients with the same vertical skeletal pattern. However, the parameters that can reflect condylar morphology were significantly different among the three

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groups who had different vertical skeletal patterns, suggesting that condylar morphology was closely correlated with the vertical skeletal pattern.

Large amounts of studies have been performed to investigate the TMJ joints of patients with skeletal Class II division 1 malocclusion. However, the results were various due to the difference in the research methods as well as sample size [8]. Currently it was generally accepted that the morphological variations in condyle were mainly resulting from different types of malocclusion and the various burdens that exerted on TMJ. Due to the special maxilla-mandible relationship and occlusion features of patients with skeletal Class II malocclusion, the tissues of TMJ underwent continued reconstruction to adapt to the functional changes. However, Katsavrias et al reported that no significant morphological difference of TMJ which received burdens was detected in different types of malocclusion [9]. Consistent with our study, Saccucci et al also revealed that the condylar volume and surface area of the patients in low angle group were greater than that of high and average angle group [10]. Our results also revealed that no significant difference regarding the condylar volume and surface area was detected between patients in high angle group and average angle group. Two possible reasons might be responsible for this finding. Firstly, it is possible that the condyles of patients in the high angle group tend to grow in the upper-front direction and thus have relatively slim and long figures. Secondly, the functional reconstruction of condyle in patients with skeletal Class II malocclusion might be another reason. As the anterior guidance function is lacking in high angle group patients, the occlusal burden is mainly concentrated in the posterior teeth area. Moreover, the morphology of condyle in the high angle group patients was long and slim, which made the threshold values of posterior teeth that could withstand the vertical pressure decreased. Therefore the force intermaxillary traction must be paid special attention to avoid causing unexpected TMJ injury when treating this type of patients. We induced that the significant difference of condylar morphology in females of skeletal Class II division 1 malocclusion with various vertical skeletal features might be correlated with various factors including bone density, masticating

muscle strength, genetic factors and adaptive reconstructions.

The condylar morphology of TMJ was influenced by many factors such as changes in masticating strength, genetics and facial bio-type [11]. Enomoto et al reported that the condylar width and volume of mice that fed with hard diet were greater than the mice that fed soft diets or hard and soft diets alternately, indicating changes in mastication force could markedly affect the growth of mandibular condylar cartilage as well as the morphology of mandible. Similarly, Kurusu et al showed that occlusal force played an important role in determining the maxillofacial morphology and mandibular condyle morphology [12].

The mastication muscle alignment of patients with high angle is much more tilting than that of patients with low angle. In addition, the muscle's horizontal section area of high angle patients is smaller. Therefore, this type of patients has weaker oral functions. As the front-rear distance between the central occlusion and centric relation position is rather long, the movement pattern of mandible is mainly horizontal. In contrast, the patients with low angle have stronger oral functions, greater masticating muscle strength and occlusal force. The mandibular movement pattern of low angle patients is majorly vertical. Therefore they have powerful masseter and the TMJ can withstand stronger loading force, which increases the adaptations of condylar morphology. To the best of our knowledge, this was the first study that systematically compared the condylar morphology of females of skeletal Class II division 1 malocclusion with various vertical skeletal features using the advanced CBCT technique.

In conclusion, our CBCT results showed that there was significant difference regarding the condylar morphology among females of skeletal Class II division 1 malocclusion with various vertical skeletal features, which will provide important and valuable data for radiological diagnosis, orthodontic treatments and orthognathic surgery.

Disclosure of conflict of interest

None.

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