

An analytic method for evaluating condylar position in the TMJ and its application to orthodontic patients with painful clicking

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The purpose of this study was to develop a new method for evaluating the three-dimensional position of the mandibular condyle relative to the glenoid fossa and further to investigate its clinical application to orthodontic patients with temporomandibular disorders (TMD). A three-dimensional configuration of the temporomandibular joint was constructed by 108 triangles for the condyle and 180 triangles for the glenoid fossa. The shortest distance between the condyle and glenoid fossa (CGFD) was calculated in the model along a line perpendicular to the center of gravity of a triangle on the condyle. The CGFD was determined in the anterior, posterior, middle, lateral, and medial areas on the condyle. Preliminary investigation revealed that the present technique is accurate, regardless of condylar rotation and/or inclination to the tomographic table. The technique was applied to the diagnosis of orthodontic patients with painful clicking and TMD. It is shown that the present approach provides a method for evaluating the positional relationship between the mandibular condyle and glenoid fossa in patients with TMD. (AM J ORTHOD DENTOFAC ORTHOP 1992;101:88-96.)

Temporomandibular disorder (TMD) is one of the most popular topics in orthodontic literature.¹ Derangement of the temporomandibular joint (TMJ) has been studied extensively.¹⁻⁷ Some of the reports indicate that malposition of the mandibular condyle relative to the glenoid fossa may be one of the more important causes of TMD,²⁻⁶ although TMD is multifactorial in nature. Thus it is of clinical significance to develop a convenient and accurate method to evaluate the relationship between the condyle and the glenoid fossa in the TMJ.⁷

For this purpose, different techniques have been developed with various radiographs.⁷⁻¹³ It is difficult to evaluate the positional relationship with simple radiography and a single x-ray film.⁸ Highly advanced techniques such as tomography or computed tomography and magnetic resonance imaging have recently been used in the field of dentistry. However, three-dimensional quantification of condylar position in the glenoid fossa has not been successfully achieved.⁹⁻¹³

The present study was designed to develop a new

technique for evaluating a three-dimensional position of the condyle relative to the glenoid fossa in the TMJ space and to investigate the accuracy of the method. In addition, clinical application of this technique was attempted to elucidate its availability for diagnosis of TMD before orthodontic treatment.

ANALYTICAL TECHNIQUE

Method for taking tomograms

A method developed by the Department of Radiology, Osaka University Faculty of Dentistry for taking tomograms, polytomography, which takes hypocycloidal motion (POLYTONE-U, Philips Co. Ltd., The Netherlands), was used (Fig. 1).¹³ The subject's head was placed in a head positioner with the Frankfort horizontal plane perpendicular to the tomographic table. The median sagittal plane of the head was rotated 15° to the tomographic table so that the long axis of the condyle could be approximately perpendicular to the tomographic table (Fig. 2).¹³

A multifilm cassette with seven x-ray films was used. The distance between the two adjacent tomographic sections was 2.0 mm, or a total of 12.0 mm for the seven tomograms. To superimpose seven tomographic images accurately, a lead plate with two small holes was placed on the cassette as the marker for the reference points.¹³

From the seven tomograms, one tomogram display-

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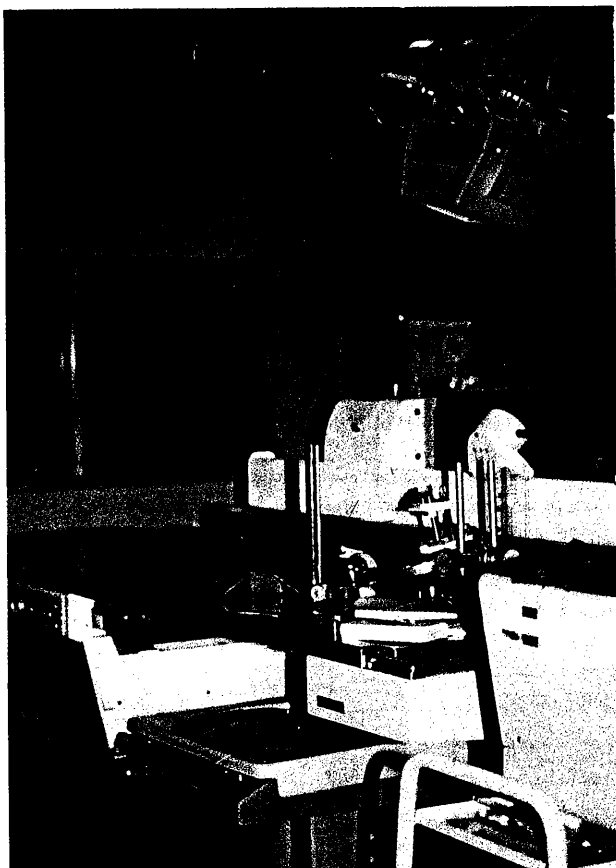


Fig. 1. Polytomography used for taking tomograms.

ing the clearest images of the lowest point of the squamtemporal fissure (point P) and the crest of the articular eminence (point E) was used for the reference coordinate system (Fig. 3). This image is usually seen on the fourth tomogram, which indicates the mediolateral center of the lateral and medial poles of the condyle.^{14,15} To establish a reference coordinate system, points P and E on the fourth tomogram are traced on an acetate paper, together with the two reference points (Fig. 3).

Analytic procedure

The hardware system for the analysis consists of a 16-bit personal computer (PC-9801UX41, NEC Corp., Tokyo, Japan) as a central processing unit with 640 KB, keyboard and digitizer (Mediagraph, NEC Corp.), printer (PC-PR201F2, NEC Corp.) and color CRT display (PC-KD551, NEC Corp.), as shown in Fig. 4.

According to the tracing obtained from the image at the mediolateral center of the condyle, the following points and lines were digitized: points P and E, reference points No. 1 and No. 2, and the contours of the

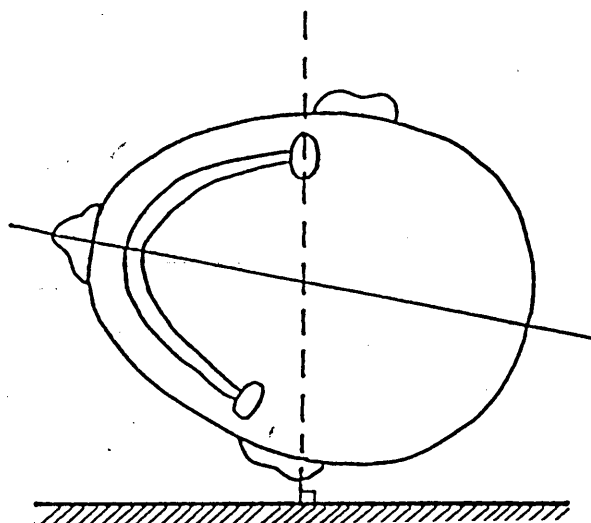


Fig. 2. Head position of patient for taking tomograms. Solid and dashed lines indicate the median sagittal plane and the condylar long axis, respectively.

condyle and glenoid fossa. All other tracings were used to digitize the contours of condyle and glenoid fossa and two reference points. These contours were divided equally into 9 parts for the condyle and 15 parts for the glenoid fossa. The X-Y coordinates of 10 and 16 points on the contours of condyle and glenoid fossa were entered into the computer. The Z coordinates along the condylar axis were also recorded in the computer, on the basis of the predefined numbers of the tomographic sections and the distance between the two adjacent tomograms.

A three-dimensional configuration of the TMJ was developed in the following manner. A triangle was created in the computer using three points, $P_{i,j+1}$, $P_{i+1,j}$, and $P_{i+1,j+1}$, on two adjacent planes, as shown in Fig. 5. A three-dimensional configuration of the TMJ was thus constructed with 108 triangles for the condylar surface and 180 triangles for the inferior surface of the glenoid fossa.

The shortest distance between the condyle and the glenoid fossa was calculated in the analytic model of the TMJ as a distance between two points (Fig. 6). One is the center of gravity of a triangle on the condyle, and the other is the point of intersection made by a triangle on the glenoid fossa and a line perpendicular to the triangle of the condyle through its center of gravity. Hereafter, this distance is referred to as the condyle to glenoid fossa distance (CGFD). Fig. 7 shows a graphic display of the CGFD for the 108 triangles on the condyle.

For easy evaluation of the position of the condyle to the glenoid fossa in a three-dimensional space, the

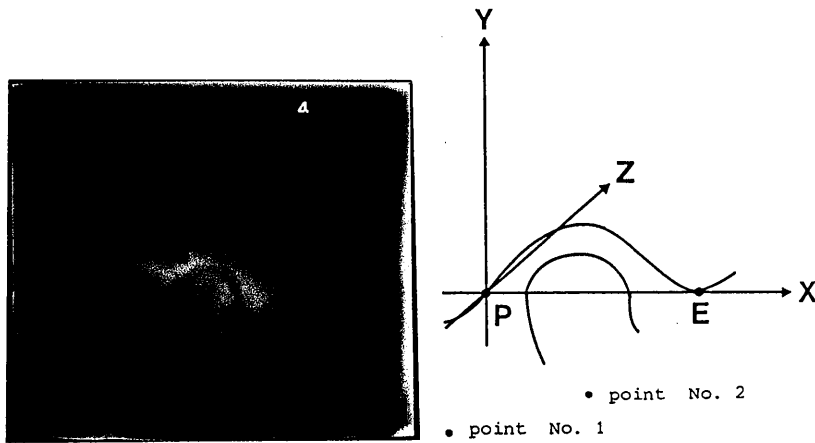


Fig. 3. Tomogram, which shows clearest images of lowest point of squamtemporal fissure (*P*) and crest of articular eminence (*E*) (*left*) and reference coordinate system established from the tomogram (*right*).



Fig. 4. Hardware system for present analysis.

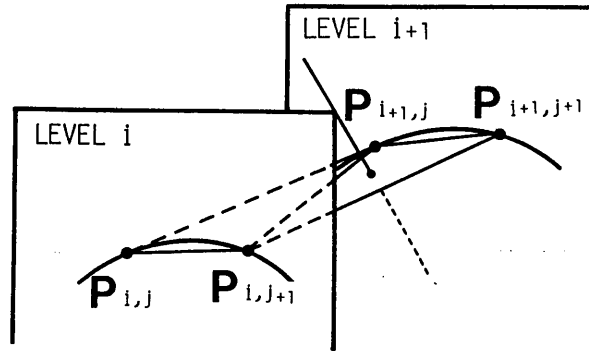
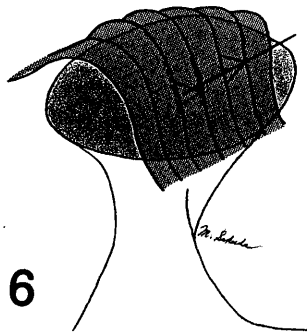
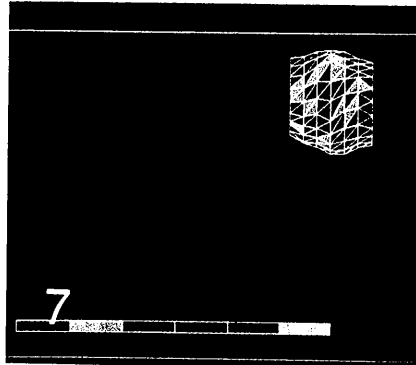


Fig. 5. Construction of triangle with three points on condyle and glenoid fossa. The condyle and the glenoid fossa consists of 108 and 180 triangles, respectively.



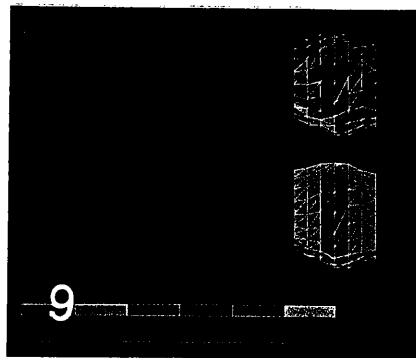
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Fig. 6. Condyle to glenoid fossa distance (CGFD). The shaded area indicates the inferior surface of the glenoid fossa. The CGFD is indicated by the red line between two triangles.

Fig. 7. CGFD for patient evaluated at 108 triangles on condyle. Each color in the triangle corresponds to the distance indicated in the caption.

Fig. 8. Five areas on condyle where CGFDs are evaluated.

Fig. 9. Mean CGFDs of patient for five areas. The CGFDs at 108 triangles (*upper*) are averaged for each of the five areas (*lower*).

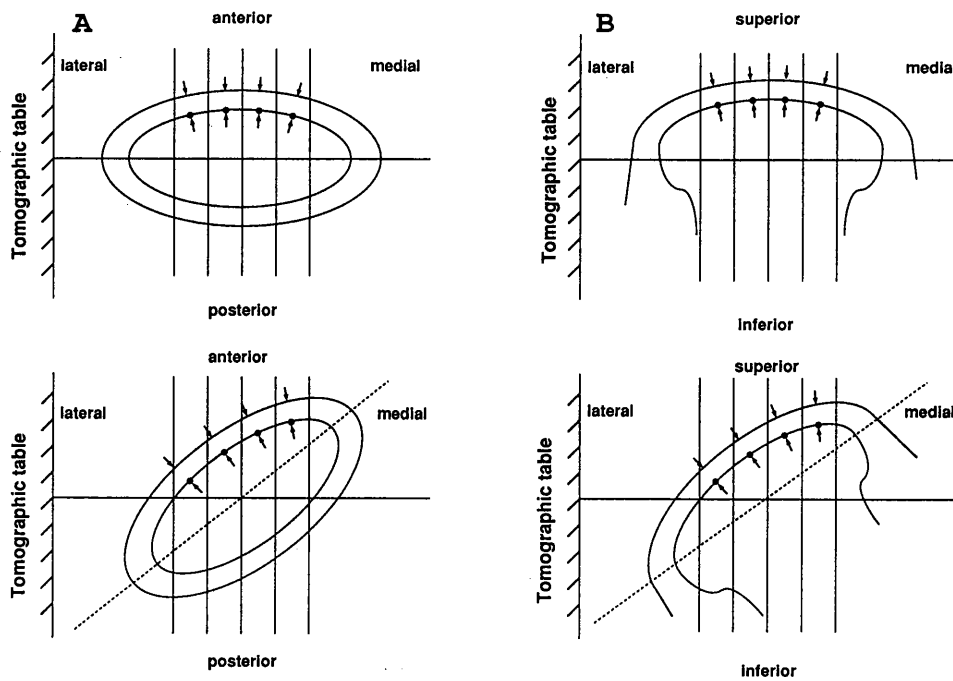


Fig. 10. Schematic representation of condyle and glenoid fossa projected in submentalvertex and anteroposterior directions. Distances indicated by arrows are CGFDs with or without horizontal rotation (A) and vertical inclination (B) of the condylar axis.

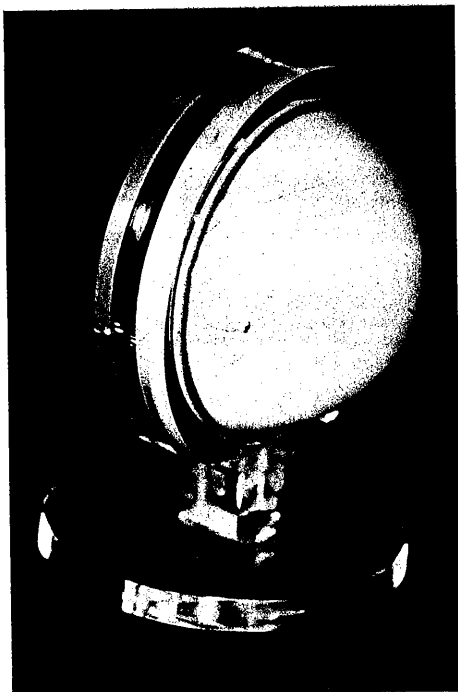


Fig. 11. Hemispheric solid shell model for investigating accuracy of present technique.

Table I. Thickness of the model from analytic and direct measurements

	No.	Mean (mm)	SD (mm)
Analytic value	15	3.07	0.10
Directly measured value	15	2.99	0.07

Two means were not significantly different at the 5% level of confidence.

surface of the condyle was divided into five areas, i.e., anterior, posterior, middle, lateral, and medial areas, as shown in Fig. 8. The CGFDs for the 108 triangles were averaged for each of the five areas. Mean CGFDs at the five areas were displayed graphically (Fig. 9).

Accuracy of method

Variations in the CGFD were first investigated with varying rotations and/or inclinations of the condylar axis to the tomographic table. Fig. 10 shows a schematic representation of the condyle and the glenoid fossa projected in the submentalvertex and anteroposterior directions, respectively. Solid and dashed lines indicate the original and the varied long axes of the condyle. In

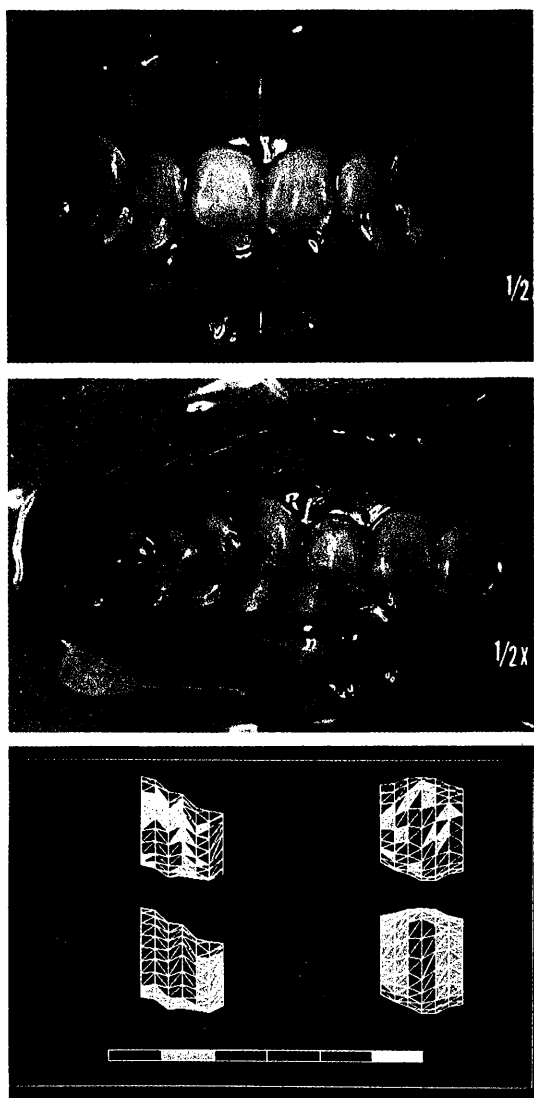


Fig. 12. Case 1. Occlusal relation and CGFD before treatment.

the two cases the CGFDs with and without changes in the long axis were almost invariable as indicated by arrows in Fig. 10, although the distances on the tomograms varied substantially. Thus the influence of horizontal rotation and/or vertical inclination of the condylar axis on the CGFD was deemed negligible in this method.

To further check whether the CGFD is accurate enough to identify the distance between the condyle and the glenoid fossa, a simple experiment was conducted with a hemispherical solid shell model (Fig. 11). Its inner and outer radii were assumed to be 20.0 and 23.0 mm, respectively. Thus the thickness of the model was designed to be 3.0 mm. Tomograms of the

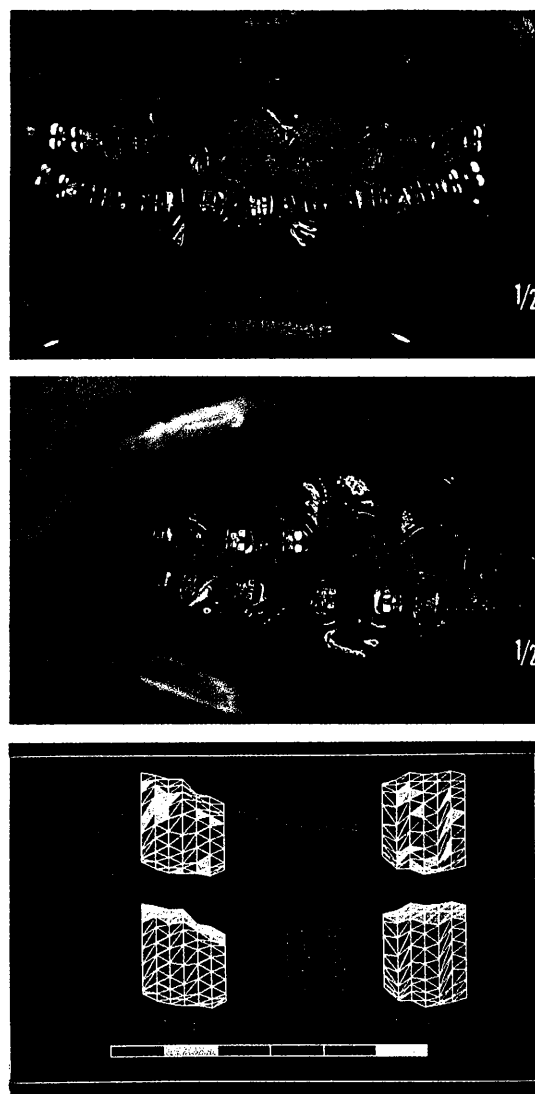


Fig. 13. Case 1. Occlusal relation during orthodontic treatment with edgewise appliance and CGFD after the splint therapy.

center area of the model were taken 15 times. The thickness was directly measured 15 times with calipers.

The means obtained from analytic and direct measurements were approximately 3.0 mm; thus it was shown that there was no significant differences between two means (Table I).

CLINICAL APPLICATION

The present technique was applied to diagnosis of orthodontic patients with painful clicking.

Case 1

The patient, a girl 16 years and 7 months of age, had an Angle Class I malocclusion and a deep bite. At the beginning

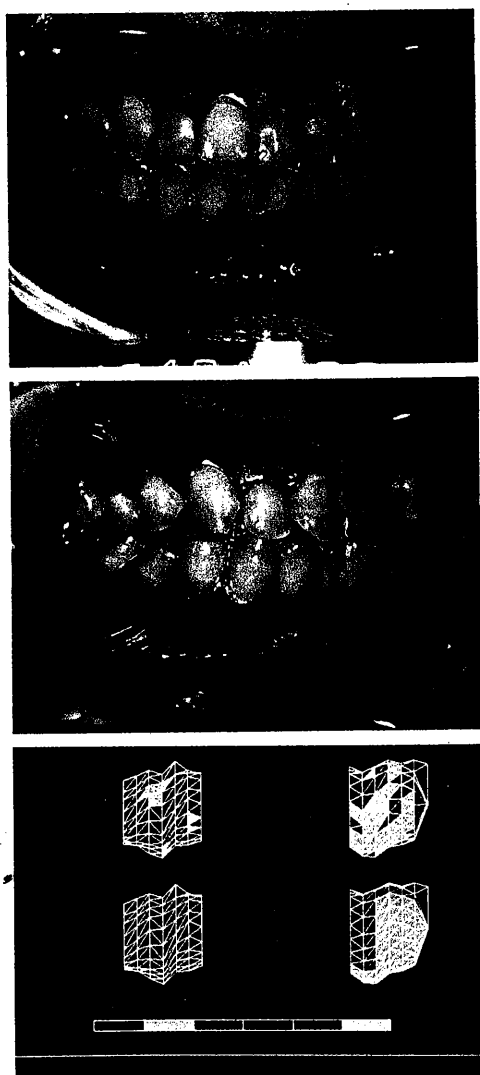


Fig. 14. Case 2. Occlusal relation and CGFD before treatment.

of orthodontic treatment, she complained of pain and clicking in the right TMJ. The mandible shifted to the right on opening, and then returned to near the median sagittal plane at maximum opening. During the mouth opening function, a clicking sound was observed.

A set of tomograms of the TMJs was taken with teeth in occlusion. Occlusal relation and graphic representation of CGFD before treatment are shown in Fig. 12. The CGFD for the posterior area of the right TMJ was 0.9 mm, as drawn in red, whereas the CGFD for the remaining areas was approximately 2.0 mm. It was found that the right condyle occupied a relatively posterior position in the TMJ space. It was speculated that this patient had an anterior displacement of the articular disk and that the displacement of the disk forced the condyle posteriorly. An anterior repositioning splint was given to correct the retropositioned condyle, with the hope of disk recapture.

After using the splint for 2 months, a set of tomograms of the TMJs was taken again with the anterior repositioning

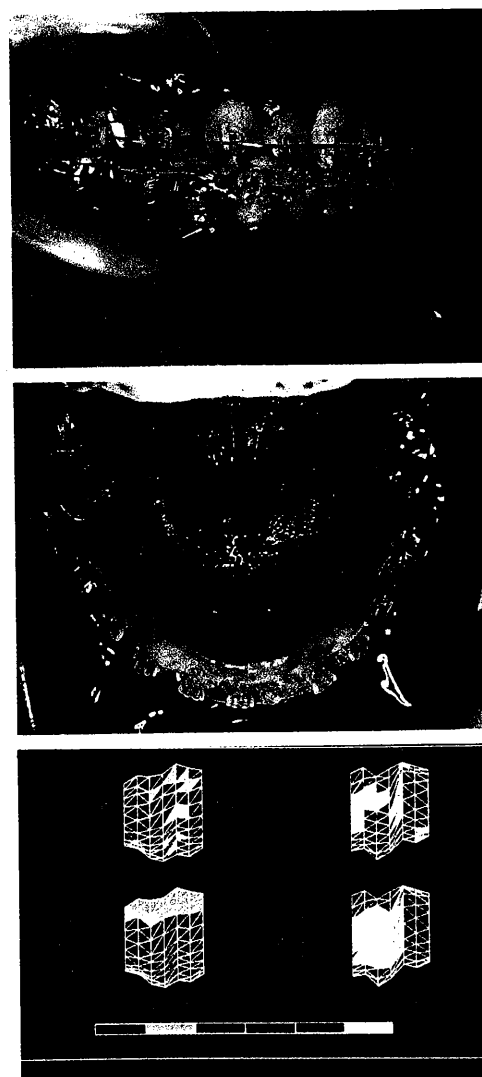


Fig. 15. Case 2. Orthodontic treatment with the splint in place and CGFD during orthodontic treatment with the splint.

splint in place (Fig. 13). The CGFD for the posterior area of the right TMJ changed from 0.9 to 2.6 mm. The pattern of CGFD distributions became symmetrical for both TMJs. The right condyle shifted significantly to an anterior position, and the pain and clicking disappeared. After the TMD decreased with the splint therapy, orthodontic treatment was initiated. An edgewise appliance was used to maintain the mandibular position guided by the splint (Fig. 13).

Case 2

The patient, a man 19 years 5 months of age, had an Angle Class III malocclusion with crowding. He had painful clicking of the right TMJ.

A set of tomograms of the TMJs was taken with the teeth in occlusion. Occlusal relation and graphic representation of CGFD before treatment are shown in Fig. 14. The CGFD for the posterior and lateral areas of the right TMJ was 2.1 mm, as drawn in yellow, and less than in other areas of the right

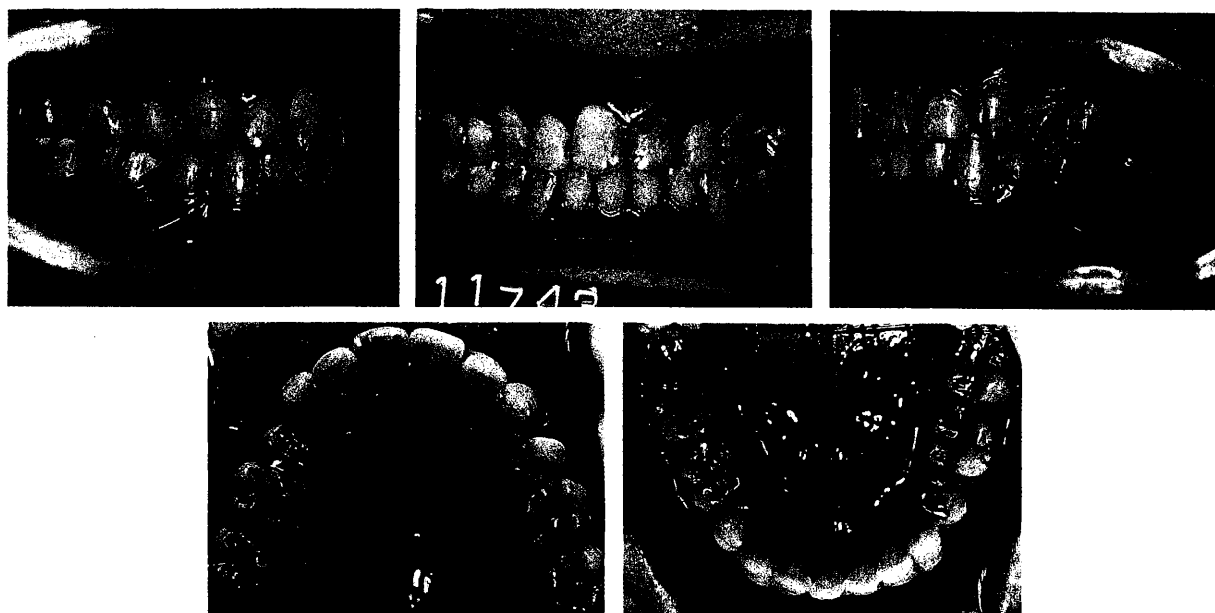


Fig. 16. Case 2. Occlusal relation after the treatment.

TMJ. For the left TMJ, distribution of the CGFD was almost uniform at the five areas. It was found that the right condyle occupied a relatively lateroposterior position in the TMJ. Anterior displacement of the articular disk was assumed, and an anterior repositioning splint was used to correct the retro-positioned condyle.

After the painful clicking at the right TMJ decreased with the splint therapy, orthodontic treatment was initiated. An edgewise appliance was used with the splint in place (Fig. 15).

A set of tomograms of the TMJs was taken again with the anterior repositioning splint in place (Fig. 15). The CGFD for the right TMJ became more uniform in the five areas than those before the splint therapy. The condyle shifted to a more anterior position. The occlusion was stable without the splint, and the appliances were removed. Fig. 16 shows the occlusal relation at the end of orthodontic treatment.

DISCUSSION

Recently, the number of patients with TMDs has increased substantially in the field of dentistry. This tendency is also observed in clinical orthodontics, and there has been much controversy over the role of orthodontic treatment. Reynders² has reviewed the literature on TMDs and concluded that most opinion and research rejects any etiologic role for orthodontics. However, some association may exist in certain cases with condylar dislocation. With respect to the latter point, orthodontic treatment may be effective for some types of TMDs, as was indicated in the two clinical cases in this article. To perform an appropriate orthodontic treatment for avoiding or curing TMDs, a multispect diagnosis with precision is indispensable.

In general, the cause of TMDs is roughly divided

into masticatory muscle disorder, degenerative joint disease, derangement of the TMJ, and bony deformation of the TMJ components.¹⁶⁻¹⁸ Among the TMDs, painful clicking is speculated to be caused by internal derangement of the TMJ, which occasionally produces pathologic changes in the fibrous and osseous components in the TMJ.^{19,20} It is well understood that internal derangement is produced by an abnormal positional relationship between the articular disk and the bony structures such as the condyle, glenoid fossa, and articular eminence. On the position of condyle in the TMJ, the relationship between the condylar position and the type of malocclusion has not been elucidated. However, certain types of malocclusion, which induce retroposition and posterior rotation of the mandible or condyle, may lead to internal TMJ derangement more frequently than other malocclusions. Such positional changes of the mandible or condyle may occur during orthodontic treatment; therefore an evaluation of the position of the condyle in the TMJ space will be needed. Thus the relationship between the condyle and the glenoid fossa should be determined accurately for diagnosis and treatment planning.

For evaluation of the relation of the condyle to the glenoid fossa, it is important to understand the influences of condylar rotation and/or inclination and depth of cut levels for laminagraphy.^{14,15,21-28} If the evaluation is performed on a planar film, the criteria previously discussed should be cleared. On the other hand, the present approach employed an evaluation in a three-dimensional model of the TMJ. Therefore the approach is quite different from the previous techniques.⁹⁻¹² The influences of condylar rotation and inclination on the

CGFD was confirmed to be negligible or insignificant. Since a tomogram with the clearest images of the lowest point of the squamatemporal fissure and the crest of the articular eminence, in general, runs through the mediolateral center of the condyle,^{14,15} the tomogram was used in this technique to define the depth of cut level for a reference coordinate system. With clinical application, it was evident that the present technique provides clinicians with useful information for determining diagnosis and treatment plans for TMD patients.

Clinical studies reported various treatments,²⁹⁻³¹ in which splint therapy was successfully used as a conservative treatment for TMDs. As illustrated in the two cases, painful clicking from internal derangement of the TMJ in particular, is first reduced by stabilization and anterior disk repositioning with a splint.³² Then the original malocclusion should be corrected by aligning the dentitions and maintaining the mandibular position obtained with the splint therapy.

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