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Evaluation of intra-articular distance narrowing during temporomandibular joint movement in patients with facial asymmetry using 3-dimensional computed tomography image and tracking camera system

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ABSTRACT

Introduction: Functional overloading can lead to disc displacement in the temporomandibular joint (TMJ), and a high incidence of disc displacement has been reported in patients with facial asymmetry. The aim of this study was to assess the dynamic condylar movement in patients (n = 26) with facial asymmetry using a simulation system with 3-dimensional computed tomographic images and tracking camera system.
Material and methods: The intra-articular distance (IAD) between the condyle and glenoid fossa was recorded during TMJ movement as a parameter for functional overloading and compared between Group I with severe asymmetry and Group II with mild asymmetry.
Results: The average IAD was shorter in Group I than Group II, especially at the lowest point ($P < 0.05$). The ratio of IAD narrowing in Group I was significantly larger than in Group II ($P < 0.05$). The mean IAD were slightly smaller on the deviated side (3.41 mm) than on the nondeviated side (3.55 mm) in Group I, even though there was no statistical significance. The maximum displacement in Group I was longer than in Group II and had no significant difference between deviated side and nondeviated side.
Conclusion: We suggested that the reduced IAD resulting from TMJ overloading can lead to internal derangement in severe facial asymmetry.

1. Introduction

Temporomandibular disorder (TMD), whether a primary cause or predisposing factor, is extensively associated with mandibular asymmetry (Ahn et al., 2005). Buranastidporn et al. (2006) suggested that dental and skeletal discrepancies disrupt the normal symmetrical load to the temporomandibular joint (TMJ). Such asymmetrical loads may influence intra-articular pressure and act as a trauma to the TMJ structures, inducing the development of TMJ ID and subsequent TMJ disorders. On the other hand, TMJ internal derangement (TMD ID) itself can cause growth disturbances that may result in mandibular asymmetry. Patients with mandibular asymmetry have asymmetrical and irregular joint movements that cause mechanical disturbances in the TMJ disc (Stegenga, 2001). A high incidence of TMJ ID that is associated with mandibular asymmetry patients has been reported (Goto et al., 2005; Choi et al., 2011). Biomechanically, these structural disturbances may affect the mechanical stress that occurs within the TMJ, and these

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disturbances could play a role in the development of TMD (Buranastidporn et al., 2006). However, there is little information on how asymmetry affects the TMJ and leads to TMD.

The TMJ space or inter-articular space plays an important role in the temporomandibular disorder (TMD). The reduced joint space can lead to compressive loading on the viscoelastic TMJ disc. Theoretically, a reduction of the joint space could affect the disc by at least 50%, and up to 90% considering variable factors such as the thickness of the disc, cartilage, and soft tissues (Hansson et al., 1977). Abnormal mechanical stresses to the healthy joint structure can cause joint cartilage degeneration leading to osteoarthritis, when peak stresses, the stress rate, or the loading duration exceeds critical levels (Chen et al., 1999; Machner et al., 2000).

In the normal disc–condyle relationship, where the disc lies on the anterosuperior surface of the condylar head, the articular disc slides along the slope of the articular eminence with condylar movement during mouth opening (Stegenga, 2001). Adequate distance between the glenoid fossa and condylar head is necessary in order to avoid excessive compression of the disc. Reduced joint distance during temporomandibular joint (TMJ) movement increases the resistance between the articular disc and the condylar head. This occurrence can result in biomechanical overloading on the condylar head or articular disc (Yang et al., 2013). The joint distance is decreased when the TMJ is functionally overloaded, resulting in microtrauma and increased joint friction. This can lead to joint pathology such as anterior disc displacement (ADD) or degenerative joint disease (DJD) (Nitzan, 2003; Tanaka et al., 2008). By investigating the changes of the intra-articular distances, loading of the joint can be assumed.

Although dynamic intra-articular distance changes during TMJ movement are strongly associated with biomechanical loading, no studies have been published regarding the relationship between facial asymmetry and intra-articular distance. We hypothesized that mandibular asymmetry would produce mechanical stress at the joint due to asymmetrical and irregular joint movement. The deviated side of an asymmetric mandible may have excessive compression on the disc due to the great arc of the opening and closing movement with the wide range of motion followed by the reduction of the intra-articular distance during translational movement at the posterior slope of the articular eminence, which can result in the collapse of the lubrication system. An impaired lubrication system increases friction between the disc and fossa, and could lead to TMD. Similarly, it is possible that the impaired lubrication system may increase the acceleration or worsen TMD (Nitzan, 2003; Yang et al., 2013).

The purpose of this study was to analyze the intra-articular distance changes during TMJ movement in patients with severe facial asymmetry compared to patients with slight asymmetry, using our 3-dimensional (3D) simulation system. We investigated the minimum distances between the condyle and the glenoid fossa to determine dynamic changes during mouth opening and closing movements, which can be reduced in overloading conditions. In addition, condylar maximum displacement was calculated to investigate motion range.

2. Material and methods

2.1. Subjects

Twenty-six Korean patients who were scheduled for orthognathic surgery to correct dentoskeletal malocclusion were included in this study. The age range was 19–25 years, and there were 10 male and 16 female patients. This study was approved by the institutional review board at the School of Dentistry, Seoul National University (no: S-D20090006). Before the procedure, a detailed explanation of the study was given to all patients. Patients who agreed to perform TMJ movement tracking were included in the study.

2.2. Cephalometric radiographic analysis

The facial asymmetry was investigated with posteroanterior cephalograms. As shown Fig. 1, the mid-facial reference plane was the line that ran through the crista galli (CG) and anterior nasal spine (ANS). The angle between the facial midline and a line passing through the ANS and menton (Me) was defined as the degree of mandibular midline shift (MMS) (Inui et al., 1999). According to the study by Masuoka et al. (2007), the distance of the menton (4.28 mm) and mandibular midline shift (MMS) angle (4.31°) showed relatively high accuracy in all observers. Therefore, mandibular midline shift (MMS) angle (4°) was used as the guideline for facial asymmetry in this study. Group I included 14 patients with asymmetry (MMS $\geq$4°). Twelve patients with mild asymmetry (MMS <4°) and no deviation were included in Group II. The error of the method was determined by double measurement of the selected landmark: $\sqrt{\frac{\sum d^2}{2n}}$, where d is the difference between 2 measurements of a pair, and n is the number of subjects (Dahlberg, 1940). The mean double-determination errors for the angular measurement were 0.5°.

2.3. Patient specific splint for simulation system

The patient-specific splint for image registration and mandibular movement tracking was fabricated (Fig. 2a) (Yang et al., 2013), and the splint was mounted on the patient's teeth using a dental impression material (vinyl polysiloxane). A registration body was attached to the splint with LEGO blocks (LEGO Group, Billund, Denmark) and contained 6 iron spheres (1-mm diameter) that could be used to determine the relationship between the computed tomography (CT) coordinate system and the patient's coordinate system. Infrared markers visible to the optical tracking camera (Polaris, Northern Digital, Inc., Waterloo, ON, Canada) were also attached to

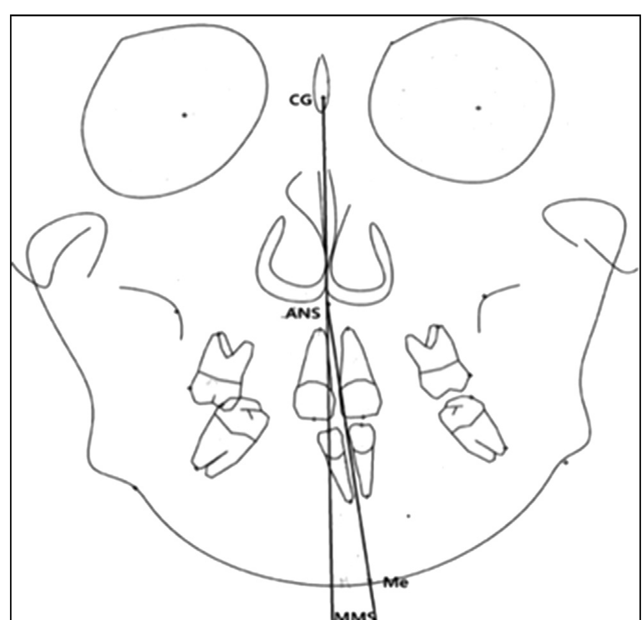

Fig. 1. Mandibular midline shift (MMS) angle determined by the angle between the crista galli to the anterior nasal spine (CG-ANS) and the anterior nasal spine to the menton (ANS-Me).