ARTICULATOR-RELATED REGISTRATION AND ANALYSIS OF SAGITTAL CONDYLAR INCLINATION

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SUMMARY – The purpose of this investigation was to study sagittal condylar inclination values within a uniform sample (Angle class I occlusion) using 'articulator-related registration' and Camper's plane as a reference plane. The study was performed on a sample of 58 Angle class I subjects (mean age 25.1, SD 3.1). Measurements were performed with an ultrasonic jaw tracking device with six degrees of freedom. After a paraocclusal tray was fixed in the mouth, each subject had to make three protrusive movements and three right and left laterotrusive movements. From protrusive movements the software of the device automatically calculated the left and the right sagittal condylar inclination values used for setting of the articulator. The mean sagittal condylar inclination value was 41.0° (SD 10.5) for the right joint and 40.7° (SD 9.8) for the left joint. The maximum value was 65.0° for the right and 68.6° for the left joint, and the minimum value was 13.7° for the right and 21.7° for the left joint. The results of this study suggested the average articulator setting for sagittal condylar inclination for fully dentate adult subjects to be 40° in relation to Camper's plane. This is especially important for the articulators that are set up in relation to Camper's plane.

Key words: *Dental prosthesis; Dental articulators; Movement; Mandibular condyle – anatomy and histology; Camper's plane*

Introduction

Temporomandibular joint has a significant role in defining mandibular movements[1,2]. Mandibular movements are defined by the interaction between condylar guidance (posterior guidance), tooth guidance (anterior guidance), and effects from the neuromuscular system[3]. Sagittal condylar inclination (SCI) is the angle formed by protrusive condylar path and usually the Frankfort horizontal (or any other horizontal) reference plane[4]. It affects the angulation of the cusps of the teeth in both protrusive and nonworking movements[5]. If the inclination of the articulator is set up to a steeper value than the actual patient's value, prosthodontic restoration will have a positive error, which can result in occlusal interference of protrusive and nonworking movements after cementation of the restoration[5]. Weinberg[6] revealed that 5° error of the SCI caused 0.1 mm error on the second molar during laterotrusive movement (nonworking side).

As the SCI is an important parameter for the articulator set-up during prosthodontic restoration, it has been thoroughly investigated. Since the majority of investigations use different material and methods (conventional radiography[7], tomography[8], computed tomography[9], magnetic resonance imaging[10], cone beam computed tomography[11], jaw tracking devices[12],

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dry bone specimens[13], wax records[14]), with different choice of reference planes (Frankfort horizontal[15], axis-orbital plane[16], Camper's plane[17], and others), condyle reference points (hinge axis[15,18], kinematic axis[17,19]) and different samples, there is a lot of confusion in the literature about the SCI values. Reports on intersubject variability[20,21] and differences in the SCI values for the left and right side are found in the literature[13,18,22], but due to all the mentioned differences in study methods it is hard to compare the results.

Nowadays, jaw tracking devices with six degrees of freedom are commonly used for studying temporomandibular joint anatomy and function[17,19,23]. The recording of body movements with six degrees of freedom provides complete knowledge of the 3-dimensional motion of that body[24].

Registration of the individual parameters that define that same movement is necessary for precise jaw movement simulation in the articulator. Most registration methods aim to transfer different craniomandibular geometries to the articulator[25]. Proschel *et al.*[25] have proposed articulator-related registration as a clinicians' alternative for individualization of the articulator.

The purpose of this investigation was to study interindividual and sidewise variations of the SCI values within a uniform sample (Angle class I occlusion) of subjects using articulator-related registration and Camper's plane as a reference plane.

Subjects and Methods

Fifty-eight healthy young adults with Angle class I occlusion (21-35 years of age, mean 25.1, SD 3.1; 22 male and 36 female) and without previous orthodontic treatment participated in this study. All subjects had no history of signs and symptoms of temporomandibular dysfunctions. The subjects were completely dentate (up to the second molar), with a stable intercuspal position; they had no crossbite/openbite and no previous extensive restorative treatment. Each subject gave a written informed consent to participate in the study, which was approved by the Ethics Committee of the School of Dental Medicine, University of Zagreb.

Condylar and mandibular movements were performed by using an electronic ultrasound motion capture device (ArcusDigma II, Kavo, Biberach, Germany). This ultrasound contact-free measuring device has a transmitter that is attached to the lower jaw with the use of a paraocclusal tray. With the use of an ArcusEvo face bow, the receiver is attached to the upper jaw (measuring bow) (Fig. 1). The device measures real-time latency period between transmitted and received ultrasound pulses. Based on the six degrees of freedom concept, the software of the device calculates the spatial position of the temporomandibular joint, sagittal incisal point and its occlusal determinants.

First, irreversible hydrocolloid impressions (Aroma Fine Plus, GC, Tokyo, Japan) were made for each subject. Then a paraocclusal tray was made from light cured acrylic resin (Unitray, Polident, Volčja Draga, Slovenia) for each subject, according to the manufacturer's instructions. On the next visit, electronic axiography recordings were performed. Each subject was seated comfortably in a chair (upright posture). The paraocclusal tray was fixed in the lower jaw using acrylic resin for temporary restoration (Structur, Voco, Cuxhaven, Germany). It was not in contact with the

Fig. 1. Ultrasound jaw tracking device with six degrees of freedom.

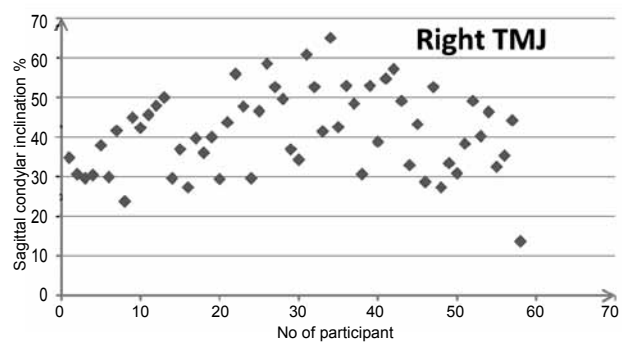

Fig. 2. Sagittal condylar inclination values for the right joint.

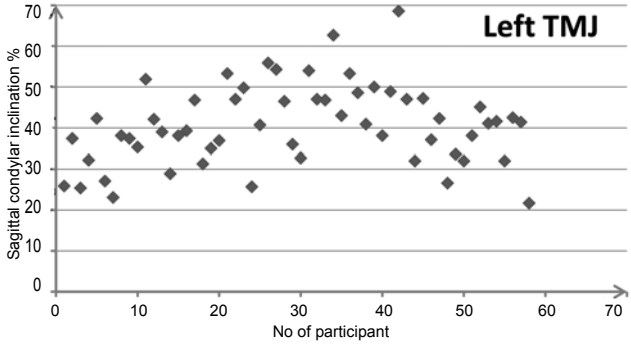

Fig. 3. Sagittal condylar inclination values for the left joint.

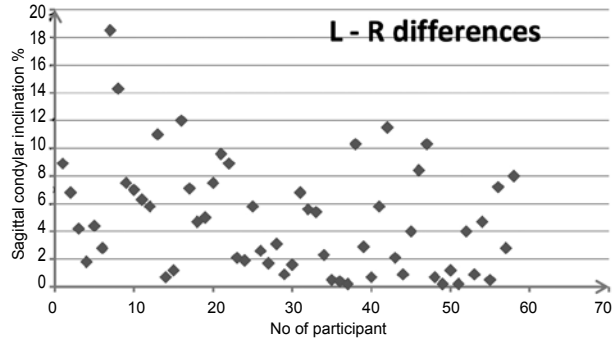

Fig. 4. Sagittal condylar inclination sidewise differences.

upper teeth in the intercuspal position or at eccentric movements, and it was firmly fixed to the lower dental arch. As a standard procedure, the subjects had to make three protrusive, three left lateral and three right lateral movements during jaw kinematics recordings. The movements were first demonstrated by the operator. From three protrusive movements, the software of the device automatically measured the SCI of the left and right condyle (articulator set-up according to articulator-related registration), which were used in this investigation. The SCI values were calculated with respect to Camper's plane. Camper's plane is a plane established by the inferior border of the ala of the nose (or the average between the two) and the superior border of the tragus of each ear[26]. All recordings and ratings were performed by a single experienced investigator to eliminate the potential problems with interexaminer reliability. Male and female samples and left-right side differences were compared using Levene's and Student's t-test (SPSS Statistics 17.0).

Results

Figures 2 and 3 show the SCI for the left and right joints for all participants. As Levene's and Student's t-test showed no significant difference (α=0.05) between male and female samples, they were treated as one sample. The mean SCI value was 41.0° (SD 10.5) for the right joint and 40.7° (SD 9.8) for the left joint. The maximum value was 65.0° for the right and 68.6° for the left joint, and the minimum value was 13.7° for the right and 21.7° for the left joint. Figure 4 shows intraindividual differences between the left and right SCI values. Levene's and Student's t-test showed no significant differences (α=0.05) between the left and right side values. The mean left-right side difference was 4.9° (SD 4.0), and the minimum and maximum left-right side SCI difference was 0.2° and 18.5°, respectively.

Discussion

In this study, sidewise and interindividual differences of the SCI values were investigated using articulator-related registration. The mean left SCI of 40.7° (SD 9.8) and right of 41.0° (SD 10.5) demonstrated considerable variability among the subjects.

Regarding differences between reference planes (assumed average difference of 15° between Frankfort horizontal (FH) and Camper's plane[27,28] and 15° between Camper's plane and axis-orbital plane[29]), the results obtained (mean left, SD, mean right, SD) were within the upper limit of the reported SCI values[4,11,12,18,19,21,22,30]. However, most informative is to compare results of this study with studies that also used Camper's plane as a horizontal reference plane. Dodić *et al.*[17] investigated SCI in subjects with and without temporomandibular disorders (TMD) using computer pantograph (Camper's plane as a reference). In 30 participants with no history of TMD, the mean SCI at 3 mm condylar protrusive movement was 45.4° for the right joint and 44.0° for the left joint, while at 6 mm condylar protrusive movement the mean SCI was 39.7° for the right joint and 39.0° for the left joint, which is similar to the results of this study. Zamacona *et al.*[18] used graphic registration for protrusive condylar movement, and tangential method to determine SCI (based on Camper's plane) in 55 patients. The mean left and right SCI was 36.6° and 35.75°, respectively.

Different values from this study can be explained by different samples; in the study by Zamacona *et al.*[18], 78.6% of patients were completely edentulous, which could explain lower SCI values.

Curtis[31] investigated protrusive mandibular movements with a pantograph. Most patients (n=20) had less than 2° difference between the right and left side SCI, which is opposite to the results of this study (Fig. 4). Some cephalometric studies[32] obtained one angle representing both right and left side. According to current literature[18,21,22], sidewise differences are normal. Hernandez *et al.*[21] found absolute left-right difference of 6.5° at 3 mm protrusive path, with 22° being maximal difference. Zabarović *et al.*[22] found a mean difference between the left and right SCI values of 6.9° and maximum difference was 33°. Considering the influence of the lower jaw function on eminence development[30], chewing habits (chewing side preference[33], different patterns of chewing movements[34]), variations in the condylar shape and condylar pathway[35], condylar position in the glenoid fossa[36], and Angle class occlusion differences[37], sidewise differences and inter-subject variability of the SCI values (left 40.7°, SD 9.8; right 41.0°, SD 10.5) can be expected, which is confirmed in the literature[18,21,22].

Results reported by Catic and Naeije[38] highlight that comparison of condylar movements among different studies is only possible when the same condylar reference point is used. Differences between patient's condylar points (most used hinge axis points) and virtual articulator condylar point used in the present study are also expected. However, transferring articulator geometry to the patient (articulator-related registration) limits the number of necessary parameters for the simulation of jaw movements to the condylar and Bennett angle[25]. Wachtel *et al.*[39] report that condylar inclination of 45° on a straight line articulator more closely approximates a ¾ inch curved pathway set to 37° inclination. Articulators from most manufacturers have different constructions. For instance, Stratos® 100 (IvoclarVivadent, Schaan, Lichtenstein), an average value articulator, has a protrusion path angle of 30°, Bennett movement of 15/30° and condylar path radius of 12.5 cm (Camper's plane)[40]. Another average value articulator, Denar® Automark (Whip Mix, Louisville, Kentucky, USA) has a protrusive angle of 25° and 7° Bennett angle[41] (horizontal reference plane consists of posterior reference points representing hinge axis, and anterior reference point, which is located 43 mm from the incisal edge of the central or lateral incisor, toward the inner corner of the eye). Artex®BN (Amann Dental GmbH & Girrbach Dental GmbH, Vorarlberg, Austria), an average value articulator (patient horizontal), has the SCI of 35°, Bennett angle of 15° and 19 mm condylar track radius[42]. Due to these differences in articulator design and differences between their reference planes, it is difficult to suggest one SCI value for average articulator adjustment for all articulator systems. In Downs' study[28], Frankfort horizontal-Camper's plane angle showed variations from 1.5° to 14°. In the study by Ow *et al.*[27], the mean Camper's plane-Frankfort horizontal angle value was 19.2°. Due to interindividual variations in the angle between different horizontal reference planes[27,28], the most informative guidance for articulator adjustment should be studies that use the same reference plane as the respective articulator.

Conclusion

Sagittal condylar inclination values demonstrated considerable variability, both interindividual and intraindividual. Due to differences between different reference planes, articulator settings should be adjusted as described in the studies using the same reference planes. The results of this study suggest that, relative to Camper's plane, the average articulator setting for SCI for fully dentate adult subjects should be 40°.

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Sažetak

ANALIZA KUTA NAGIBA KONDILNE STAZE POMOĆU REGISTRACIJE DEFINIRANE ARTIKULATOROM

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Cilj istraživanja bio je proučavanje vrijednosti kuta nagiba kondilne staze unutar jednoličnog uzorka (klasa I. po Angleu) koristeći registraciju definiranu artikulatorom i Camperovu ravninu kao referentnu ravninu. Istraživanje je provedeno na uzorku od 58 ispitanika (prosjek godina 25,1; SD 3,1). Mjerenja su izvedena pomoću ultrazvučnog uređaja za snimanje kretnji donje čeljusti na temelju šest stupnjeva slobode. Nakon što se pričvrstila paraokluzijska žlica svaki ispitanik je izveo po tri kretnje protruzije, lijeve i desne laterotruzije. Iz protruzijske kretnje program uređaja je automatski izračunao vrijednosti lijevog i desnog kuta nagiba kondilne staze koje se koriste za individualizaciju artikulatora. Prosječna vrijednost kuta nagiba kondilne staze iznosila je 41,0° (SD 10,5) za desni zglob i 40,7° (SD 9,8) za lijevi zglob. Maksimalna vrijednost iznosila je 65,0° za desni i 68,6° za lijevi zglob, dok je minimalna vrijednost iznosila 13,7° za desni i 21,7° za lijevi zglob. Rezultati ovoga istraživanja sugeriraju vrijednost kuta nagiba kondilne staze od 40° prema Camperovoj ravnini kod namještanja artikulatora prema prosječnim vrijednostima kod potpuno ozubljenih pacijenata. To pogotovo vrijedi za artikulatore vrijednosti kojih se postavljaju u odnosu na Camperovu ravninu.

Ključne riječi: *Zubna proteza; Zubni artikulatori; Mandibularni kondil – anatomija i histologija; Camperova ravnina*