

CLINICAL RESEARCH

The relationship between Angle type of occlusion and recorded Bennett angle values



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Condylar guidance is mandibular guidance generated by the condyle and articular disk traversing the contour of the glenoid fossa.¹ The sagittal condylar inclination and horizontal Bennett angle comprise the condylar guidance settings on many articulators, and accurate condylar guidance values can help increase the precision of prosthetic restorations.² Bennett angle is the angle formed between the sagittal plane and the average path of the advancing condyle as viewed in the horizontal plane during lateral mandibular movements.¹ In addition to the Bennett angle for defining lateral movements, some articulators are also equipped with immediate mandibular lateral translation (IMLT) settings, which many clinicians value as a setting/adjustment. IMLT is the translatory portion of lateral movement in which the nonworking side condyle moves essentially straight and medially as it leaves the centric relation position.¹ After IMLT, the nonworking condyle continues with mandibular translation (progressive mandibular lateral translation).³ The Bennett angle measures the size of the progressive mandibular lateral translation, and both terms are used interchangeably.

ABSTRACT

Statement of problem. The Bennett angle can be an important parameter to accurately record and program into an articulator during restorative procedures. Few data exist regarding the impact and association of a patient's occlusion types on their recorded Bennett angle values.

Purpose. The purpose of this in vivo study was to investigate the effect of occlusion type on recorded Bennett angle values.

Material and methods. This study included 98 participants (26.0 ±5.2 years) divided into 4 study groups: Angle class I; Angle class II, division 1; Angle class II, division 2; Angle class III. All recordings were obtained using an ultrasound mandibular recording device with 6 degrees of freedom and a clutch was attached to the mandible. On each participant, 3 protrusive, 3 left laterotrusive, and 3 right laterotrusive movements were recorded. The recording device's software automatically calculated Bennett angle for each participant's left and right mandibular fossae and the data were statistically analyzed.

Results. One-way ANOVA did not show significant differences among different Angle classes of occlusion for the Bennett angle values. The average Bennett angle value for all participants was 7.7 degrees.

Conclusions. The results of this study suggest that different Angle occlusion classifications do not appear to have an impact on recorded Bennett angle values. The average Bennett angle value in this study was found to be approximately 8 degrees. This information should be considered when programming average values into an articulator with respect to desired negative error (shorter cusp) during restoration fabrication. (J Prosthet Dent 2016;115:729-735)

Accurate recording of Bennett angle, IMLT, and other condylar guidance controls are particularly important in restoration fabrication because of their effects on the occlusal morphology of the posterior teeth.² Errors in evaluating the Bennett angle will affect the ridges and groove positions in the working and nonworking sides and, to a lesser extent, the cusp height.⁴ These variations ranged between 0.18 and 0.37 mm on the groove and ridge positions for every 5 degrees of error in estimating the Bennett angle.⁵ Similarly to Price et al,⁵ Weinberg⁶

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Clinical Implications

When using average values to program an articulator on a fully dentate adult patient, clinicians should consider the ramifications of using Bennett angle settings that are greater than or smaller than 8 degrees. The Bennett angle values may be selected regardless of the Angle occlusion classification of the patient.

revealed that an error of 15 degrees in the Bennett angle results in an error of 0.8 mm in height of the second molar cusp height on the working side.

Many dentists recognize IMLT as of particular importance in lateral mandibular movements, with significant influence on posterior teeth occlusal morphology.⁷⁻⁹ Lundeen et al,⁷ in a study of mandibular border movements, determined that an IMLT of 2.5 to 3.5 mm causes a dramatic flattening of lateral movement pathways of the molar cusp as seen in the frontal plane.

The most frequent methods for evaluating the Bennett angle and IMLT are interocclusal records^{4,10-13} and the use of various types of mandibular recording devices.¹⁴⁻²⁴ Studies showed higher values of the Bennett angle obtained with interocclusal records than those obtained by mandibular recording devices.¹⁰ Obrez and Gallo²⁵ stated that only since the development of 3-dimensional recording systems supplemented with sophisticated mathematical transformation of the obtained data has it been possible to estimate condylar movements relatively accurately.

Mandibular function influences temporomandibular joint (TMJ) morphology through the remodeling process,²⁶ and variations in TMJ morphology may be expected.²⁷⁻³² Functional differences between patients with different skeletal and occlusal characteristics have been confirmed.^{24,32} Studies also showed shallower glenoid fossa and lower values for condylar inclination in individuals with Angle class III occlusion,^{26,32} while individuals with class II division 2 showed, on average, the highest condylar inclination values.¹⁸ Contrary to condylar inclination in different occlusion types, findings on the impact of different occlusion types on the Bennett angle are scarce in the literature.

The purpose of this in vivo study was to investigate the impact of different Angle classes of occlusion on the Bennett angle values by using an ultrasound mandibular recording device with 6 degrees of freedom.

MATERIAL AND METHODS

Ninety-eight young adults, (26.0 ±5.2 years) without previous orthodontic treatment participated in this study. No participant had any history of the signs and



Figure 1. Device's clutch, prepared with light polymerized acrylic resin.

symptoms of temporomandibular dysfunction. The participants were completely dentate (except third molars), had no reverse articulation or open occlusal relationship, and had no previous extensive restorative treatment. Each participant gave written informed consent, which was approved by the Ethical Committee of the School of Dental Medicine, University of Zagreb.

The participants were divided into 4 study groups based on Angle classification. All participants had the same Angle class on the left and right side. Participants with a different Angle classification on the right and left side and participants with an unclear classification were excluded from the study. The Angle class I group consisted of 58 individuals (59.2%) with Angle class I (without malocclusions), the Angle class II/1 group consisted of 10 individuals (10.2%) with Angle class II, division 1, the Angle class II/2 group consisted of 14 individuals (14.3%) with Angle class II, division 2, and the Angle class III group consisted of 16 individuals (16.3%) with Angle class III occlusion. Studies showed that the prevalence of different malocclusions varied in different populations.^{33,34} Bishara et al³³ found that, of 121 participants (242 sides) followed from deciduous dentition to permanent dentition for an average period of 8 years, a total of 61.6% of the sides end in a class I molar relationship, 34.3% in class II, and 4.1% in class III. Sidlauskas and Lopatiene³⁴ found 70.2% Angle class I, 22.6% Angle class II, and 5.5% Angle class III molar relationships at adolescence. The sample distribution in the present investigation was comparable with the aforementioned studies, with the exception of Angle class III; the authors decided to recruit additional participants for statistical relevance of the results.

All recordings were obtained using a 6-degrees-of-freedom ultrasound mandibular recording device (Arcus Digma II; Kavo). This contact-free recording device has a transmitter attached to the mandible with a clutch (Fig. 1) and a receiver attached to the maxilla with a facebow (measuring bow). The device measures the real-time latency period between transmitted and received



Figure 2. Mandibular recording device with 6 degrees of freedom.

ultrasound pulses. Based on the 6 degrees of freedom concept, the software of the device calculated the spatial position of the condyles and the sagittal incisal point and its occlusal determinants. The 6 degrees of freedom concept presents the freedom of movement of a rigid body (in this case the mandible) in 3-dimensional space. The rigid body can move freely (translation) along the 3 perpendicular axes (forward/backward, up/down, left/right), as well as rotate around those 3 axes. The overall sum of all the translation and rotation movements for each plane defines 6 degrees of freedom.

Irreversible hydrocolloid impressions (Aroma Fine Plus; GC Corp) were made for each participant. Following the manufacturer's recommendations, a clutch was made for each participant from light-polymerized acrylic resin (Unitray; Polident) on prepared stone casts (ISO type 2, Alabaster; Polident). At the next appointment, mandibular movements were analyzed. Each participant was seated comfortably in a chair (upright posture). A clutch was fixed to the mandibular teeth with acrylic resin (Structur; Voco). The clutch was firmly attached to the mandibular teeth so that it was not in contact with the maxillary teeth in intercuspal position or during any eccentric movements. After the clutch had set, the mandibular and maxillary bows of the recording device were mounted (Fig. 2).

Recordings were made using the software module of the Kavo Transfer System of the device as recommended by the manufacturer. Three protrusive, 3 left laterotrusive, and 3 right laterotrusive movement recordings were made on each participant. The right and left laterotrusive movements were not guided; instead participants were trained to perform maximum laterotrusive and protrusive movements on the investigator's command. Differences in the obtained values of the Bennett angle and IMLT between the guided and nonguided recording technique are expected, with the guided technique showing higher values.¹⁶ Celar et al¹⁷ questioned the exclusive recommendation of the guided technique

for obtaining articulator setting values. Since patients do not function beyond unguided boundaries,³⁵ the authors chose a nonguided technique for recording the mandibular movements.

From the laterotrusive movements, the device's software automatically calculated the average left and right side Bennett angle values and the average left and right side IMLT values (Fig. 3). The mandibular recording device used does not allow protrusive movement of the nonworking condyle during the automatic calculation of the IMLT values, contrary to most past studies of IMLT.^{7,8,11,13,16} Therefore, IMLT values were also manually calculated in the software (Kavo Integrated Desktop; Kavo) with 0.5 mm anterior translation of the nonworking condyle during lateral mandibular movement (Fig. 4), as in the study by Hobo.¹¹ A single investigator (S.C.) experienced in making mandibular movement recordings performed all recordings to eliminate the possible problems of error and lack of consistency with multiple investigators.

In the present study, as in several studies,^{12,15,21} the values of both condyles were combined, because in such a sample size statistically significant side-related differences are not expected. Descriptive statistics were calculated for all study groups. One-way ANOVA was used (Statistica 7.0; StatSoft) to compare Angle class groups ($\alpha=.05$).

RESULTS

Table 1 shows the mean values for the Bennett angle for all study groups and participants. The minimal value was 0 degrees in all study groups, while the maximal values were 29.1 degrees in Angle class I, 21.9 degrees in Angle class II, division 1, 20.7 degrees in Angle class II, division 2, and 24.5 degrees in Angle class III. The 1-way ANOVA did not show differences among the study groups ($F=0.530$, $P=.789$). The threshold value where 80% of participants were found to have a lower Bennett angle value was 12.1 degrees. More than 15.0 degrees was found in 9.7% of TMJs. All participants showed 0.0 degrees for the automatically calculated left and right IMLT values. Manually calculated (at 0.5 mm anterior translation of the nonworking condyle) values of the IMLT were: 0.12 ± 0.13 mm (min 0.0 mm, max 0.68 mm) for the Angle class I group, 0.09 ± 0.11 mm (min 0.0 mm, max 0.41 mm) for the Angle class II, division 1 group, 0.16 ± 0.15 mm (min 0.0 mm, max 0.59 mm) for the Angle class II, division 2 group, and 0.13 ± 0.12 mm (min 0.0 mm, max 0.59 mm) for the Angle class III group. One-way ANOVA did not show differences between the study groups for the manually calculated IMLT values ($F=0.950$, $P=.418$). The average manually calculated IMLT value for all participants together was 0.12 ± 0.13 mm (min 0.0 mm, max 0.68 mm).



KAVO PROTAR Articulator Report

Page 1



Patient: Born.: ID Number: adfs6m
 Records: 23.10(Oct).2011 Axis: Individual
 Institute name here

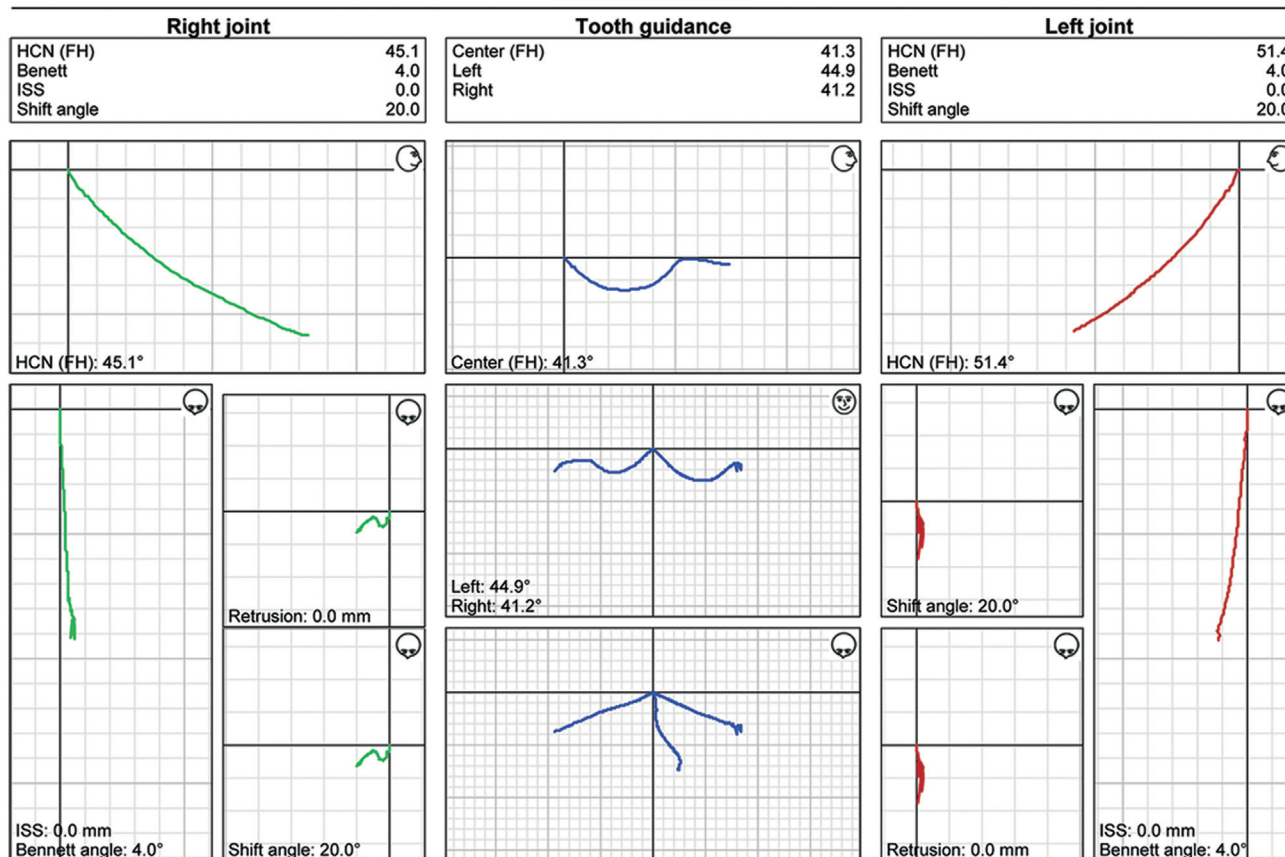


Figure 3. Image of recordings on computer display.

Table 2 shows intraindividual differences between right and left side Bennett angle values. Identical Bennett angle values between left and right side were determined in 5 participants in the Angle class I group, 1 participant in Angle class II, division 1 and Angle class II, division 2, and none in Angle class III. Left-to-right side Bennett angle differences of less than 5 degrees were found in 32 participants with Angle class I (55.2%), 4 participants with Angle class II, division 1 (40%), 5 participants with Angle class II, division 2 (35.7%), and 5 participants with Angle class III group (33.3%).

DISCUSSION

In this study, Bennett angle values were recorded from a patient pool comprised of different Angle classes of occlusion types. Statistical analysis found no significant differences in Bennett angle values among different Angle classes of occlusion. The average value of the Bennett angle was 8 degrees.

Automatically recorded IMLT values showed 0.0 mm for every participant, contrary to past studies of the

IMLT.^{7,8,11,13,16} Two main reasons for the nonregistration of the IMLT could be the recording technique (non-guided) and the measurement criteria. In a study of voluntary and induced Bennett movement, Tupac¹⁶ showed that induced IMLT values (guided recording technique) are higher compared with voluntary IMLT values (nonguided recording technique). Besides different recording devices, different studies of the IMLT have variously defined their measuring criteria, thereby contributing to differences in the obtained values of the IMLT. Lundeen and Mendoza¹³ used a mandibular recording device for the IMLT and obtained 1.66 mm for the right and 1.50 mm for the left TMJ. The authors¹³ stated that they allowed more than the manufacturer's recommended 3 mm of anterior translation for measuring the IMLT, and that this may have led to increased measurements. Hobo¹¹ used a mandibular recording device and obtained 0.38 ± 0.24 mm for the IMLT. Tracings of the nonworking horizontal condylar path laterally and ≤ 0.5 mm forward were considered IMLT values. If no forward movement of the nonworking condyle is allowed during the measurement of the IMLT

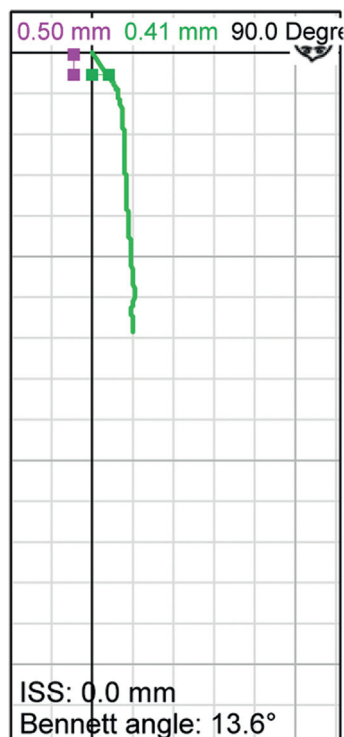


Figure 4. Manual measurement of immediate mandibular lateral translation. First line represents 0.5 mm protrusion movement of nonworking condyle, while second line, perpendicular to first, presents value of immediate mandibular lateral translation.

with a nonguided technique, IMLT may not be expected in participants with healthy TMJs. The manually recorded values of the IMLT in the present study (0.12 ± 0.13 mm) are lower than those in most past studies,^{7,8,11,13,16} but similar to those of Canning et al.²¹ Using a pantograph and a nonguided recording technique, 55% of the right TMJ and 70% of the left TMJ showed 0 mm for the IMLT.²¹ If the nonguided technique for recording the articulator setting values is preferred, the clinician should be aware that average IMLT values are approximately 0.1 mm regardless of the Angle type of occlusion.

The Bennett angle values obtained in the present study (Table 1) were less than half the Bennett angle values obtained in a number of investigations (Isaacson,¹⁹ Aull).²⁰ However, the values of the present study were similar to those obtained in Canning et al (8 degrees),²¹ Theusner et al (7.6 degrees),²² and Hernandez et al (approximately 8 degrees).²³ The differences in the Bennett angles values obtained in the 2 different groups of studies may be attributed largely to a difference in investigation and technique protocols. For example, studies which used mandibular recording devices showed Bennett angle values in the range of 7 to 8 degrees, which is similar to the results obtained in the present study (Table 1), while the Bennett angle values obtained using interocclusal records were consistently higher.^{10,21-23}

Table 1. Bennett angle values for study groups and all participants together (n= total number of left sides plus total number of right sides; degrees)

Group	Bennett Angle			
	\bar{X}	SD	Minimum	Maximum
Angle class I (n=116)	7.7	5.4	0.0	29.1
Angle class II/1 (n=20)	6.4	5.3	0.0	21.9
Angle class II/2 (n=28)	7.9	5.2	0.0	20.7
Angle class III* (n=31)	8.2	6.1	0.0	24.5
All participants (n=195)	7.7	5.4	0.0	29.1

At one participant condylar movement during right laterotrusion was minimal so value of left Bennett angle was not calculated or included in statistical analysis.

Table 2. Right and left side Bennett angle value differences (degrees)

Group	Mean	SD	Minimum	Maximum
Angle class I (n=58)	5.7	5.1	0.0	22.7
Angle class II/1 (n=10)	6.8	5.4	0.0	17.9
Angle class II/2 (n=14)	7.0	4.9	0.0	15.1
Angle class III (n=15)*	7.7	7.1	0.1	24.5
All participants (n=97)	6.3	5.3	0.0	24.5

At one participant condylar movement during right laterotrusion was minimal so value of left Bennett angle was not calculated or included in statistical analysis.

Boulos et al⁴ state that variations of the Bennett angle values depend on the inclusion of the IMLT. A Bennett angle calculated with IMLT will always be greater than the Bennett angle which does not include or account for IMLT, regardless of the interocclusal recording material or the type of the straight line, semiadjustable articulator used.⁴

In many average value articulators, the Bennett angle value is set to 15 degrees. Many clinicians believe that average value articulators should provide a “room for error factor” in condylar guidance values. As explained by Hobo et al,² the values set on articulators when using simplified manipulations are not necessarily the average values but a value higher (higher for Bennett angle and lower for condylar inclination) than that found in most individuals. Using a condylar inclination value that is too large increases the possibility of interference in excursive movements, while using a Bennett angle value that is too small also increases the possibility of excursive interference and hence the adjustment time. The average Bennett angle value has been consistently reported as 7 to 8 degrees²¹⁻²³ (along with present study results, see Table 1), which confirms that 15 degrees in average value articulators ensures higher values of the Bennett angle than those found in most individuals. According to the present study results, 80% of individuals have values lower than approximately 12 degrees. Without the “room for error factor,” the suggested average value for articulator setup could be 12 degrees.

Canning et al²¹ investigated the effect of different skeletal patterns on determining articulator settings for prosthodontic rehabilitation with an electronic

pantograph. Sagittal class I patterns showed values of right 7.2 ± 3.1 degrees, left 9.4 ± 4.6 degrees, sagittal class II patterns showed values of right 8.8 ± 3.7 degrees, left 8.9 ± 3.9 degrees, and sagittal class III patterns showed values of right 8.2 ± 2.9 degrees and left 9.7 ± 4.1 degrees for the Bennett angle. Although statistical analysis was not performed and it cannot be stated that no difference exists in Bennett angle values between different skeletal patterns, the average values and standard deviations between study groups were similar, as in the present study. Ko et al²⁴ studied the effect of class III malocclusion on the Bennett angle values using an ultrasonic mandibular recording device. The authors found no difference between Bennett angle values between participants with class III and participants in the control group. The results obtained in the present study (Table 1) along with the results of other studies^{21,24} suggest that significant differences in the Bennett angle values in different occlusion types are not to be expected, regardless of the proven differences of the joint morphology in patients with different skeletal or Angle classes of occlusion.²⁶⁻²⁸ In addition to the osseous morphology of the TMJs, mandibular movements are determined by articular disk, the degree of tension on the associated ligaments, the neuromuscular system, and the guiding planes of the teeth.³⁵ Unlike sagittal condylar inclination values, where different average values are expected for patients with Angle class I, Angle class II, and Angle class III,^{18,32} Bennett angle values may be considered to be consistent for all Angle occlusion types.

In the present study, the average left to right side differences of the Bennett angle was 6.3 ± 5.3 degrees (Table 2). Studies of the spatial interrelationships of the TMJ showed variations and asymmetry of the left and right TMJ.^{28-30,36} Cohlmiä et al²⁸ relate asymmetry of the left and right TMJ with the normal asymmetry of the cranial base and mastication side preference. Keshvad and Winstanley³⁷ stress that a natural asymmetry exists in all paired organs of the body, such as muscles, ligaments, and osseous boundaries and that anatomic structures of the left and right TMJ cannot be expected to be completely symmetrical. In concordance with other studies of the posterior disclusive angles,^{29,31} left to right side differences of the Bennett angle can be considered normal and may be expected.

CONCLUSIONS

Based on the results of this in vivo study, individuals with different Angle classes of occlusion do not show significant differences in Bennett angle values. The average recorded value of the Bennett angle without provision for IMLT is approximately 8 degrees. Clinicians should consider the ramifications of using Bennett angle settings that are greater or smaller than 8 degrees and

whether or not they wish to incorporate provisions for IMLT when using the average settings for condylar guidance on an articulator.

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Noteworthy Abstracts of the Current Literature

Changes in lower facial height and facial esthetics with incremental increases in occlusal vertical dimension in dentate subjects

Orenstein NP, Bidra AS, Agar JR, Taylor TD, Uribe F, Litt MD

Int J Prosthodont 2015;28:360-2

Purpose. To determine if there are objective changes in lower facial height and subjective changes in facial esthetics with incremental increases in occlusal vertical dimension in dentate subjects.

Materials and methods. Twenty subjects of four different races and both sexes with a Class I dental occlusion had custom diagnostic occlusal prostheses (mandibular overlays) fabricated on casts mounted on a semi-adjustable articulator. The overlays were fabricated at 2-mm, 3-mm, 4-mm, and 5-mm openings of the anterior guide pin of a semi-adjustable articulator. Direct facial measurements were made between pronasale and menton on each subject while wearing the four different overlays. Thereafter, two digital photographs (frontal and profile) were taken for each subject at maximum intercuspation (baseline) and wearing each of the four mandibular overlays. The photographs of eight subjects were standardized and displayed in a random order to 60 judges comprising 30 laypeople, 15 general dentists, and 15 prosthodontists. Using a visual analog scale, each judge was asked to rate the facial esthetics twice for each of the 80 images.

Results. For objective changes, although an anterior guide pin-lower facial height relationship of 1:0.63 mm was observed, the findings were not correlated ($P > .20$). For subjective changes, the visual analog scale ratings of judges were uncorrelated with increases in anterior guide pin opening up to 5 mm, irrespective of the judge's background status or the sexes of the judges or the subjects ($P > .80$).

Conclusions. Incremental increases in anterior guide pin opening up to 5 mm did not correlate to similar increases in lower facial height. Additionally, it made no difference in a judge's evaluation of facial esthetics irrespective of the judge's background status (layperson, general dentist, or prosthodontist) or sex.

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