The Effect of Skeletal Pattern on Determining Articulator Settings for Prosthodontic Rehabilitation: An In Vivo Study

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Purpose: During extensive prosthodontic treatment, the use of an accurately adjusted articulator is recommended to simulate mandibular movements. This clinical study was undertaken to assess any possible effect of the underlying skeletal pattern on programming articulator settings. ***Materials and Methods:*** Subjects (n = 73, mean age: 22.8 ± 6.8 years) were recruited from a dental school and two regional specialist orthodontic units. Subjects were allocated into groups based on their underlying sagittal (I, II, or III) and vertical (reduced, average, or increased) skeletal patterns by three orthodontists and three prosthodontists who examined their profile photographs. Electronic pantographic recordings were made of each subject using the Cadiax Compact system to record the sagittal condylar inclination (SCI), progressive mandibular lateral translation (PMLT), and immediate mandibular lateral translation (IMLT). ***Results:*** Agreement between assessors for sagittal skeletal pattern classification was excellent (97% for total or good agreement); agreement for vertical skeletal pattern was high, but at a lower level than that for sagittal relationships (70% for total or good agreement). SCI settings for sagittal II subjects were significantly higher than those for sagittal I ($P < .05$) and sagittal III ($P < .001$) subjects. Differences were statistically significant, with mean SCI differences of 4 and 7 degrees, respectively. No statistical difference could be observed between SCI values in the sagittal I and III groups. Subjects with an average vertical skeletal pattern had SCI values lower than those with a reduced vertical skeletal pattern ($P = .058$) and an increased vertical skeletal pattern ($P < .01$, statistically significant). No patterns could be determined for PMLT or IMLT between the study groups. ***Conclusion:*** During prosthodontic treatment of patients with a noticeable skeletal discrepancy, appropriate consideration should be given to customizing SCI values. *Int J Prosthodont 2011;24:16–25.*

Early studies on mandibular movement noted that upon protrusion of the mandible, there was an immediate separation of the posterior teeth. This resulted from a downward and forward movement of the mandibular condyle as it followed the curvature of the articular fossa. This has been described as the Christensen Phenomenon.[1]

The role of the anterior teeth has also been deemed important during mandibular movements. Observations of healthy natural dentitions have concluded that the horizontal and vertical overlap relationships of the maxillary and mandibular anterior teeth play a role in guiding mandibular movement.[2–4] The aim of a "biologic occlusion"[5] is to allow tooth-guided mandibular movement, either in protrusion or lateral excursion, without the possibility of potentially damaging interferences.[6]

Guichet[7] advocated the controlled use of overcompensation to ensure a negative error when providing prosthodontic treatment. This should not, however, lead to the provision of posterior restorations with a flat occlusal form. In the provision of anatomically

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Table 1 Previous Research on the Correlation Between Skeletal Patterns and Morphology

Study	Study method	Study population	Location	Findings
Ricketts[14]	Laminography	Caucasian orthodontic patients	United States	Angle Class III malocclusion: shallower glenoid fossa and flatter articular eminence than Class I and Class II
Ingervall[15]	Profile radiographs	Swedish adolescents/adults	Sweden	Increased height of the articular eminence in patients with a rectangular face form; increased posterior face height and mandibular prognathism
Pullinger et al[16]	TMJ tomograms	Dental students	United States/Sweden	Class II division 1 malocclusions exhibited a more anteriorly positioned condyle than Class I subjects
Widman[17]	Axiographic tracings superimposed on lateral cephalometric radiographs	Orthodontically treated adolescents/young adults	United States	Bracycephalic (short and wide) facial types: vertical inclination of the articular eminence; doliocephalic facial types: more shallow articular eminence angle
Gianelly et al[18]	Corrected tomograms	Orthodontic patients	United States	No significant correlation between condylar position and vertical overlap
Seren et al[19]	Axial computed tomography	Adult orthodontic patients	Turkey	Class III: smaller anterior joint spaces consistent with mandibular prognathism; glenoid fossa was smaller in an AP direction compared with Class I
Cohlmia et al[20]	Lateral cephalometric radiographs and corrected tomograms	Orthodontic patients of Caucasian descent	United States	The condyles of patients with a Class III malocclusion were positioned significantly more anteriorly; a shallower articular fossa and flatter articular eminence slope was observed in the Class III group
Ikai et al[21]	Anthropologic measurements	Dry skull specimens	Japan	Inverse relationship between the angle of the articular eminence to the Frankfort horizontal plane and the ANB angle
Burke et al[22]	Lateral cephalometric radiographs and corrected tomograms	Adolescents with Class II malocclusion	Canada	Condylar head inclination and superior joint space appeared to be significantly related to patients' facial morphology
Akahane et al[23]	Lateral cephalometric radiographs and laminographs	Adult women with Class I and Class III occlusion	Japan	Class III: significantly shallower articular eminence angle and larger superior joint spaces compared to Class I controls
Kikuchi et al[24]	Lateral cephalometric radiographs and corrected tomograms	Adolescent orthodontic patients	Japan	Condyle positioned more posteriorly in the glenoid fossa in patients demonstrating a clockwise rotation of the mandible
Katsavrias and Halazonetis[25]	Corrected tomograms; Procrustes superimposition morphometric analysis	Orthodontic patients	Greece	Class III: condyle observed to be more elongated and inclined forward, the fossa was wider and shallower; condyle located closer to the roof of the fossa in Class III patients
Katsavrias[26]	Corrected lateral tomograms	Wide age range; Class II division 2 malocclusions	Greece	Great variation between articular eminence and mandibular ramus morphology

TMJ = temporomandibular joint; AP = anteroposterior.

correct posterior restorations, it is favorable for the articulator settings to closely match the mandibular movements of the patient, especially if no anterior tooth guidance exists. This is of particular importance where modern all-ceramic occlusal surfaces are common. Minimizing occlusal adjustments and posterior interferences have the advantages of reducing chairside adjustments at placement and minimizing potentially detrimental shear forces.

Some clinical studies have investigated the effects of orthodontic malocclusions on mandibular movement.[8–13] Other authors, using various techniques, attempted to assess the possible correlation between the various skeletal patterns/orthodontic malocclusion classifications and temporomandibular joint (TMJ) condyle and fossae morphology (Table 1).[14–26]

Zimmer et al[8] conducted the most thorough assessment of this problem to date, combining electronic axiographic recordings and lateral cephalograms. Fifty-seven non–orthodontically treated Caucasian patients who had no or minimal signs and symptoms of temporomandibular disorder (TMD) were divided using the Angle classification. Median values of 58 degrees for the Class I group (n = 18), 61 degrees for the Class II group (n = 20), and 47 degrees for the Class III group (n = 19) were identified. Stamm et al[10]

Table 2 Experimental Inclusion and Exclusion Criteria

Inclusion criteria	Exclusion criteria
> 18 years of age	Limitation of opening
Adult dentition	History of TMD
> 12 opposing teeth	Active orthodontic treatment
Absence of a history of clicking and locking	Mobile or absent mandibular anterior teeth
Midsagittal depression > 45 mm and lateral movements of > 7 mm	Internal derangement of TMJ

TMD = temporomandibular disorder; TMJ = temporomandibular joint.

reported on 23 Class II division 2 malocclusion patients who demonstrated a significantly higher condylar path inclination, which was, on average, 7 degrees steeper than Class I controls, using the Cadiax Compact electronic axiograph (Whip Mix). Anders et al[11] also conducted an axiographic examination of mandibular movement in 28 patients with Class II division 2 incisor relationships and found that the condylar path inclination was steeper than Class I controls by 4.5 degrees for protrusion, 6 degrees for opening, and 4.3 degrees for mediotrusion.

This study used the Denar Cadiax Compact system (Whip Mix), which is a recording and evaluation system used primarily for the setting of dental articulators and screening of TMJ function.[27] This electronic pantograph utilizes an arbitrary transverse horizontal axis point and the axis orbital reference plane. The Cadiax Compact measures protrusion, left and right mediotrusion, opening and closing movements, and has a condyle position measurement function that can discriminate between multiple recordings of a reference position.

The aims of the present study were: *(1)* to record the average measurements for sagittal condylar inclination (SCI), immediate mandibular lateral translation (IMLT), and progressive mandibular lateral translation (PMLT) in a sample population consisting of groups of subjects with different horizontal and vertical skeletal relationships, as judged by expert examiners from profile photographs; *(2)* to investigate whether there were significant differences for SCI, IMLT, and PMLT between these groups; and *(3)* to make recommendations regarding "average values" for use in the prosthodontic management of these patients. The null hypothesis was that there would be no difference in articulator settings between groups of patients demonstrating different skeletal patterns.

Materials and Methods

Ethical approval was obtained from both Trinity College Dublin Faculty of Health Sciences Research Ethics Committee and the Research Ethics Committee for the Adelaide and Meath Hospital, incorporating The National Children's Hospital, Dublin. Seventy-three subjects provided mandibular movement data: 25 adolescents or young adults from regional orthodontic units, 42 undergraduate dental students, and 6 patients receiving prosthodontic treatment. Inclusion and exclusion criteria are listed in Table 2.

Data Recording Procedure

Profile Photographs. Having consented to participate, each subject was examined by the lead investigator. A profile photograph was obtained with the subject facing to the right with the Frankfort plane horizontal and the teeth in the maximum intercuspation position. Profile photographs were taken using a digital SLR camera (Canon 20D) standardized at a focal length of 105 mm, ISO speed of 100, aperture value of F14, and shutter speed of 1/125 s. Each subject was allocated a personal identification code, and the photographs were stored on a personal computer (MESH Matrix Premium XLM, AMD Athlon 64).

Clinical Measurements. All participants were subjected to a brief clinical examination, where a screening functional assessment was undertaken to exclude patients with signs and symptoms of TMD, including a history of facial pain, symptomatic clicking, and locking.

Electronic Recording of Mandibular Movements. A Cadiax Compact electronic pantographic recording device was used to obtain digital recordings of each participant's mandibular movement. A maxillary facebow supported the recording sensors and a mandibular bow was attached to the mandibular teeth using a clutch. Recording styli were attached by means of the mandibular bow. The computation unit was connected to a personal laptop computer, and the recorded data were stored using the Gamma Dental Software package (version 3, Gamma Medizinisch).

Silicone adhesive was applied to the mandibular clutch. The clutch was attached to the mandibular anterior teeth using Kerr Take 1 Bite polyvinyl siloxane occlusal registration material (Kerr). The technique used was that recommended by the manufacturer.[27]

The starting position was recorded by asking the subject to place the mandible in the prerehearsed position, with the mandibular musculature relaxed and the teeth just out of contact with the mandibular clutch. The following mandibular movements were executed and recorded: protrusion, mediotrusion right, mediotrusion left, and opening/closing. During mandibular movement, no operator guidance was utilized. Movements were demonstrated by the operator and rehearsed by the subjects prior to the recording procedure. No central bearing pin was used, although contact between the maxillary teeth and the flat mandibular occlusal clutch could have occurred.

Allocation of Subjects into Study Groups

A PowerPoint (Microsoft Office PowerPoint 2007) slide show was constructed in which the subjects' profile photographs appeared in a random order. Three senior staff from both the orthodontic and restorative departments of the Dublin Dental School and Hospital, Trinity College, Dublin, Ireland, were recruited for assessment of the subjects' underlying skeletal patterns. Scores for horizontal and vertical skeletal type were obtained. A correlation test was used to determine agreement between the orthodontists and the restorative dentists in assessment of skeletal pattern. Subjects were allocated into groups according to their horizontal (sagittal I, II, or III) or vertical (reduced, average, or increased) skeletal classification. No criteria were provided for assessment of sagittal or vertical skeletal classification.

A measure of the agreement between the orthodontists and prosthodontists on the basis of their classification of subjects according to skeletal classification from profile photographs was determined: Each subject was given three scores for skeletal classification and three scores for vertical classification by the group of prosthodontists. The same subject was given three more scores for skeletal classification and three scores for vertical classification by the group of orthodontists. Absolute values for the differences in scores between the prosthodontists and orthodontists were obtained for sagittal and vertical characteristics. These figures were then summed together. The only possible outcomes of this process were 0, 2, 4, and 6, where 0 = total agreement between all assessors, 2 = good agreement between all assessors, 4 = poor agreement between all assessors, and 6 = total disagreement between all assessors. A statistical program was written that generated random scores for the six groups with a sample size of 74. This process was repeated to obtain 3,000 randomly selected data sets for 74 subjects.

Statistical Analysis

Data obtained for each subject was entered into an Excel spreadsheet (Microsoft Office Excel 2007). The Gamma Dental Software package was used to obtain articulator values for each subject. Articulator settings for the Denar Mark II (Whip Mix) were used for comparison between groups, since this articulator can be adjusted for sagittal and condylar guidance and immediate and progressive mandibular lateral translation. Statistical analysis was undertaken to determine the following: *(1)* correlation coefficient between the clinical assessors (orthodontists versus restorative dentists) to determine allocation of subjects according to horizontal and vertical skeletal pattern, *(2)* correlation between multiple readings for the pilot group, and *(3)* means and standard deviations of SCI, IMLT, and PMLT for the various horizontal and vertical skeletal classifications. Statistical analysis for sagittal and vertical classification was based on a sample of 74, while mandibular movement was based on 73 since one set of data was corrupt and not included for anlaysis.

R statistical software (R Foundation) was used to facilitate the statistical evaluation of the recorded data. Significance testing was undertaken to determine the effect of horizontal and vertical skeletal pattern on the SCI values using the Student *t* test.

Results

Allocation of Participants into Study Groups

The number of subjects represented in each group is shown in Table 3. The degree of agreement between the sagittal and vertical classification of subjects by the orthodontists and prosthodontists from the facial profile photographs is presented in Table 4. There was a general trend for agreement between the orthodontists and prosthodontists in their allocation of subjects according to sagittal and vertical skeletal pattern. The agreement achieved was 97% for good or total agreement with respect to sagittal skeletal pattern. The agreement was less when classifying subjects according to their vertical skeletal pattern, but still high, reaching 70% for good or total agreement.

Reproducibility of Electronic Pantograph

In an attempt to evaluate errors in reproducibility in the present study, a subset of patients were subjected to repeated measures. A sample of convenience was used, and three subjects from within the student population were asked to be subjected to repeated measures

Table 3 Allocation of Subjects into Study Groups

Group	No. of subjects
Sagittal I	16
Sagittal II	42
Sagittal III	15
Total	73
Reduced vertical	20
Average vertical	42
Increased vertical	11
Total	73

Table 4 Correlation for Classification of Subjects According to Sagittal and Vertical Skeletal Pattern from Profile Photographs

Score	Simulation*	Sagittal	Vertical
0 (total agreement)	10	36	21
2 (good agreement)	25	36	31
4 (poor agreement)	25	2	19
6 (total disagreement)	14	0	3

*Based on 3,000 random samples generated by the computer progam.

Table 5 Data from the Reproducibility Pilot Study

	SCI right (degrees)	SCI left (degrees)	PMLT right (degrees)	PMLT left (degrees)	IMLT (mm)
Mean A ± SD	41.0 ± 1.7	36.3 ± 0.6	5.0 ± 0.0	5.3 ± 0.6	0.0 ± 0.0
Mean B ± SD	44.0 ± 0	44.7 ± 3.2	10.3 ± 1.5	5.0 ± 0.0	0.0 ± 0.0
Mean C ± SD	48.7 ± 0.6	43.7 ± 1.5	5.0 ± 0.0	5.0 ± 0.0	0.0 ± 0.0

SD = standard deviation.

Table 6 Articulator Settings (Mean ± SD) for the Various Sagittal and Vertical Groups

	PMLT right (degrees)	PMLT left (degrees)	SCI right (degrees)	SCI left (degrees)	IMLT right (mm)	IMLT left (mm)
Sagittal I (n = 16)	7.19 ± 3.06	9.44 ± 4.56	44.13 ± 7.46	46.38 ± 9.03	0.12 ± 0.14	0.09 ± 0.18
Sagittal II (n = 42)	8.84 ± 3.68	8.93 ± 3.88	49.00 ± 7.02	48.93 ± 7.11	0.13 ± 0.23	0.04 ± 0.07
Sagittal III (n = 15)	8.20 ± 2.91	9.73 ± 4.11	41.87 ± 6.81	42.33 ± 5.21	0.05 ± 0.11	0.08 ± 0.12
Reduced vertical (n = 20)	9.24 ± 4.21	8.38 ± 3.43	48.10 ± 8.40	48.19 ± 8.41	0.12 ± 0.16	0.05 ± 0.08
Average vertical (n = 42)	7.31 ± 2.64	9.31 ± 4.13	44.50 ± 6.62	45.69 ± 7.27	0.12 ± 0.22	0.06 ± 0.11
Increased vertical (n = 11)	10.18 ± 3.63	10.36 ± 4.74	51.09 ± 7.60	50.00 ± 6.62	0.08 ± 0.13	0.07 ± 0.18

SD = standard deviation.

(Table 5). The standard deviation of the multiple articulator recordings for these subjects was low. Therefore, it was considered appropriate to use a single complete recording of protrusion, mediotrusion left, mediotrusion right, and opening/closing for each participant.

Articulator Settings Grouped According to Underlying Sagittal Skeletal Pattern

Means and standard deviations of the SCI, PMLT, and IMLT values obtained for all groups are shown in Table 6. To ensure that there was no underlying effect from previous orthodontic treatment on the study results, subjects' exposure to orthodontic treatment was recorded for comparison, and no differences were observed for any measurement (data not shown).

Assessing Differences Between Groups

SCI. Examination of the SCI measurements obtained for all study groups suggested that these data were distributed normally. Further assessment of the data suggested that the right and left sides were similar. The values obtained for the right and left sides were therefore combined, and formal testing was undertaken using the Student *t* test (Table 7).

PMLT. Analysis of the data recorded for PMLT determined that these values were not distributed normally. In general, the trend showed a clustering of readings at the minimum and maximum values (Fig 1). Formal testing of these data was considered to be inappropriate on the basis that this clustering makes for great difficulty in specifying a distribution (and doing formal parametric tests). Furthermore, the number of

Table 7 Results of Student *t* Test Within Sagittal and Vertical Study Groups Comparing SCI Values

Groups compared	*P*
Sagittal I–sagittal II	< .05
Sagittal II–sagittal III	< .001
Sagittal III–sagittal I	NS
Reduced vertical–average vertical	< .05
Average vertical–increased vertical	< .01
Increased vertical–reduced vertical	NS

NS = not significant.

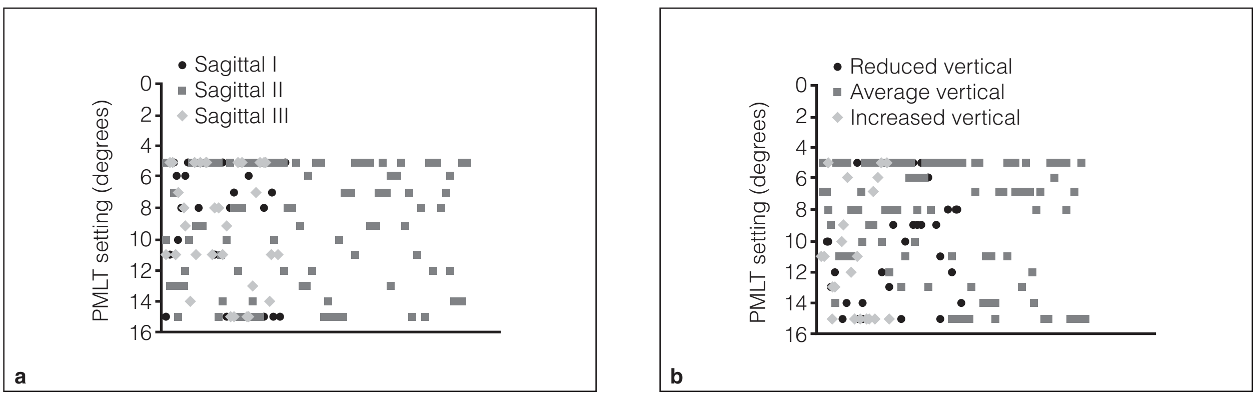

Fig 1 Scatter plots of data obtained for PMLT settings according to **(a)** sagittal and **(b)** vertical skeletal classification.

ties (repeated recordings of a similar value) prevented the application of meaningful nonparametric (rank-order statistics) methods.

IMLT. The IMLT was recorded for each subject. During recording of the data, it was noted that there was a high percentage of values equal to 0 (Table 8). Thirty-nine of 73 (55%) values for the right side IMLT and 50 of 73 (70%) values for the left side were 0. Of the 146 IMLT recordings in total, only 5 measured 0.5 mm or greater. Formal testing of this data was considered to be inappropriate, similar to that for the PMLT groups.

Discussion

For ethical reasons, radiographic assessment could not be undertaken, and the soft tissue profile was used as a surrogate measure of the underlying skeletal pattern. While this may have some limitations,[28] it is valid clinically, and routine use of lateral cephalometric radiographs for prosthodontic diagnosis and treatment planning is not common.[29]

The classification of subjects according to skeletal pattern involved the assessment of profile photographs by senior orthodontic and prosthodontic staff from the Dublin Dental School and Hospital. This method of evaluation has been analyzed by Kuyl et al[28] and was shown to be more consistent for sagittal than vertical profiles. In their study, orthodontists, irrespective of their degree of training, were more consistent in assessing soft tissue profile than general dentists. For this reason, senior orthodontic and prosthodontic staff were chosen to evaluate the profile photographs of the subjects in the current investigation.

Agreement between the two groups of assessors was determined using a random sample method. It was apparent that there was a general trend for agreement between the orthodontists and prosthodontists in their allocation of subjects according to sagittal and vertical skeletal pattern. The agreement achieved was 97% and 70% for good or total agreement for sagittal and vertical skeletal patterns, respectively. During the allocation process, no guidance was given to the assessors regarding sagittal or vertical classification. From the results, it was apparent that the two groups were more consistent in determining sagittal classification and had some difficulty in agreeing on vertical skeletal pattern. Without strict criteria for vertical classification, this result may be expected and could be considered a limitation of the present study.

Table 8 Frequency Distribution of IMLT Values for the Study Groups Classified According to Sagittal and Vertical Skeletal Pattern

		No. of occurrences of values 0 to 1 mm										
	Sample size	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Vertical class												
Reduced	40	22	9	3	3	2	1	0	0	0	0	0
Average	84	52	15	9	3	2	1	0	0	0	1	1
Increased	22	15	3	2	0	1	0	1	0	0	0	0
Total	146	89	27	14	6	5	2	1	0	0	1	1
Sagittal class												
I	32	18	6	3	2	1	1	1	0	0	0	0
II	84	51	17	7	4	2	1	0	0	0	1	1
III	30	20	4	4	0	2	0	0	0	0	0	0
Total	146	89	27	14	6	5	2	1	0	0	1	1

The investigator aimed to record the reference position for each patient at centric relation. Following a pilot study, it was apparent that when operator guidance was added using bimanual manipulation, the recorded reference position appeared to be variable. For the purposes of this study, mandibular movements and reference position were rehearsed prior to assembly of the recording apparatus. Once positioned, subjects were asked to protrude and retrude the mandible. This was followed by opening, closing, and hinging of the mandible to a point of first tooth contact on the mandibular clutch. The reference position was recorded immediately prior to first tooth contact. Condylar position measurements were recorded and showed the reference position to be highly reproducible within subjects (data not shown).

No operator guidance or central bearing pins were used during lateral or protrusive movements. However, it was possible for the mandibular clutch to contact the maxillary dentition during these movements. The mandibular clutch covered the occlusal aspect of the mandibular teeth and eliminated the influence of tooth contact on lateral and protrusive measurements.

Celar and Tamaki[30] conducted an in vitro study to measure the accuracy of the Cadiax Compact system. Articulator settings for SCI of 20, 40, and 60 degrees were used with a range of PMLT settings, which were applied and measured repeatedly. The Cadiax Compact measured the SCI and PMLT with a mean error of 1.2 degrees and was deemed clinically acceptable.[30]

A similar study was undertaken by Chang et al,[31] who attempted to test the reliability/validity of the Cadiax Compact system in calculating the condylar settings for a range of articulators at condylotrack distances of 3, 5, and 10 mm. The reliability readings for SCI, IMLT, and PMLT were more consistent at the 10 mm condylotrack distance than at 5 mm, which was superior to the measurements at 3 mm. Petrie et al[32] called into question the reproducibility of the Cadiax Compact. They compared Pantographic Reproducibility Index (PRI) scores obtained with a mechanical Denar pantograph to those obtained with a Cadiax Compact. The Cadiax Compact did not appear to be reproducible over two different clinical recording sessions, as determined by PRI scores. Nevertheless, further in vitro and in vivo studies assessing the accuracy of the Cadiax Compact have deemed it to be reproducible and suitable for clinical use.[30,31,33]

In selecting the transverse and SCI values for each subject from the pantographic recordings, it was decided that the 10-mm recording would be used for comparison. Chang et al[31] demonstrated that the Cadiax Compact was most reliable over this distance. In situations where a 10-mm recording was not available because the condyle had not traveled that far, the next reading (5 mm of translation) was used, since this is deemed to be more accurate than 3-mm readings.[31]

Errors may be introduced by inappropriate condylar inclination, as described by dos Santos et al.[34] Higher condylar guidance in the articulator could result in the provision of restorations with either protrusive or lateral interferences. These interferences can have a negative impact on prosthodontic treatment, since they may require extensive occlusal adjustment at placement or subject restorations to potentially damaging shear forces. Alternatively, setting the articulator too low may result not only in a flat occlusal morphology, but also may indicate interferences in the articulator that are not present in the patient.

Craddock[35] estimated that an increase of 10 degrees would separate the molar teeth by 0.5 mm, while a decrease of 10 degrees would bring the mandible 0.5 mm closer to the maxilla. Weinberg[36] suggested that a 9-degree error (decrease) in SCI resulted in an error in the magnitude of 0.2 mm at the second molar balancing cusp incline, and a 15-degree alteration in PMLT would result in a 0.8-mm error in the second molar cusp height on the working side.

The differences reported in this study are relevant during prosthodontic management of patients with different skeletal patterns, particularly in the absence of suitable anterior guidance. The specific skeletal patterns that may be of concern include sagittal II, sagittal III, and increased vertical relationships, where the development of an anterior guidance scheme may be challenging due to the unfavorable overlap relationships between the anterior teeth. The SCI observed in these groups may be important during prosthodontic rehabilitation, since frequently the development of anterior guidance may be challenging due to the increased horizontal overlap of the anterior teeth. In such circumstances, an appropriately adjusted articulator may be indicated for establishing a dynamic occlusal relationship. Errors may be introduced during the fabrication of restorations when the SCI in the articulator differs from that observed in the patient.

Zimmer et al[8] demonstrated a significant difference between SCI values for sagittal I and III subjects, with sagittal III subjects exhibiting a flatter protrusive curve. This relationship was not found in the present study, since the sagittal I and III groups demonstrated similar SCI values. There was, however, a tendency for shallower SCI values in the sagittal III than sagittal I groups, but this did not approach statistical significance. Both studies found that the SCI of the sagittal II group was significantly greater than that for the sagittal III group. In the present study, the sagittal II group demonstrated a steeper SCI than the sagittal I group, a difference not observed in the study by Zimmer and coworkers.[8] The trend for SCI values in the present study agreed with those of Zimmer and coworkers in that the sagittal III group demonstrated the shallowest SCI, with the sagittal II group showing the steepest values for SCI. The differences in statistical observations may be explained to some extent by the similarity between the median values for protrusive curves in the Class I and II groups of the Zimmer et al population.

The present study is in agreement with the results of two other studies that demonstrated significantly steeper protrusive paths (SCI) in Class II division 2 subjects compared with Class I controls.[10,11]

Little evidence is available regarding the effect of the vertical skeletal pattern on mandibular movement. Some studies have attempted to assess the influence of an anterior open bite on mandibular movement.[12,13] Differences in study methodology and classification of subjects do not permit comparison with the observations made in the present study, with respect to SCI measurements and vertical skeletal pattern.

The data for PMLT was collated for all groups and a clustering effect was noted, with data points grouped at the minimum value (5 degrees) and, to a larger extent, at the maximum value (15 degrees). When the quartile PMLT analyses for all study groups were examined, the median values were seen to be close to the overall median of 8 degrees (data not shown). The only exception to this was the increased vertical group, who demonstrated a higher median value of 11 degrees. This value is in agreement with that suggested for articulators with a fixed PMLT of 7.5 degrees.[37] It should be recognized that while the median values agreed with previous reports, the clustering effect at 5 and 15 degrees had not been reported previously and should be recognized as a possible limitation in the use of average value articulators.

The IMLT measurements were recorded during the clinical recording session. The Cadiax Compact imposed a threshold value of 0.5 mm for IMLT when used in the setting of the Denar Mark II articulator. Measurements below this value may be discarded as clinically irrelevant. The IMLT data obtained for all study groups demonstrated a marked clustering around 0. This may be due to a lack of sensitivity of the recording instrument or may suggest a general lack of IMLT within the subjects examined. Given that the inclusion criteria required subjects to have healthy TMJs and that the majority of the subjects were young adults, this result may have been expected. No observations could be made other than a clustering around 0 and a high predominance of IMLT values less than 0.5 mm for all study groups.

On the basis of the differences observed for SCI measurements for the sagittal and vertical study groups, the null hypothesis was rejected. However, there was a difference between the SCI of the sagittal I and II groups and between the sagittal II and III groups. On the basis of vertical skeletal pattern, differences were shown between the SCI measurements of the reduced and the average vertical groups. Differences were also observed between the average and increased vertical groups. The distribution of the data for PMLT and IMLT did not allow definitive conclusions to be made regarding differences arising from skeletal characteristics.

Conclusions

Within the limitations of the study design, the results of this research suggest the following:

- Assessment of the underlying skeletal pattern from profile photographs appears to be reliable between prosthodontists and orthodontists. Agreement for sagittal classification of the skeletal pattern is greater than that for vertical classification.
- SCI values vary according to the underlying skeletal pattern. Class II subjects demonstrate increased SCI measurements compared to Class I subjects, who, in turn, have greater SCI values than Class III subjects. In providing extensive prosthetic reconstruction for Class II patients, higher condylar guidance settings may be considered; in providing prosthetic reconstructions for Class III patients, lower condylar guidance settings should be considered.
- No statistical differences were detected between study groups for transverse horizontal guidance. However, interestingly, all study groups demonstrated clustering around the minimum (5 degrees) and maximum (15 degrees) values.
- For the majority of subjects in all groups, IMLT of clinical relevance (> 0.5 mm) was not present.

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Literature Abstract

Early loading of implants with fixed dental prostheses in edentulous mandibles: 4.5-year clinical results from a prospective study

The purpose of this study was to evaluate the survival and success of early loaded implants placed in the interforaminal area of the edentulous mandible and the survival of implant-supported fixed dental prostheses (FDPs). Thirty-seven patients (18.9% male, mean age: 64.5 years) were treated with implant-supported FDPs in the mandible. Inclusion criteria for the study were an edentulous mandible, adequate dimensions of the intermentonian region (at least 1 mm of bone around the implant vertically and horizontally), and informed consent for the immediate loading procedure. One hundred eighty-five screw-type implants were placed in the intraforaminal area of the symphysis (5 implants per patient). Within 2 weeks, the implants were rigidly connected and loaded with the implant-retained FDP torqued to 14 Ncm. A radiograph was taken to confirm the fit. The FDP had artificial teeth including the second premolar or the first molars (shortened dental arch), depending on the position of the most distal implant. The limit for the cantilever was no more than 1 cm distal to the most distal implant. During the 1- to 8-year observation period (mean: 4.5 years), a total of 32 implant-retained complications occurred. Nineteen implants were lost in 10 patients, resulting in a cumulative survival of 89.7%; 9 implants in 5 patients did not osseointegrate. Although these implants were not removed due to lack of inflammation, the cumulative success declined to 84.9%. Four implants in 3 patients had clinical signs of peri-implantitis (2.2% of all implants). Denture-related complications included 1 complete failure when 1 FDP had to be removed after the last of 5 implants was replaced. Furthermore, 10 fractures of the framework occurred in 6 patients, 3 FDPs had to be adapted or modified, and the facing of the FDP had to be repaired 16 times in 11 patients. Although single-stage early loaded implants functioned well for most patients with edentulous mandibles, the authors observed that immediate loading was associated with a larger number of implant-related complications than in other studies investigating delayed loading. Because of the substantial prosthetic complications and aftercare, this procedure was not recommended by the authors.

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