Mandibular condyle morphology in relation to malocclusions in children

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The prevalence of TMJ dysfunction has been determined by Nilner[1] and Egermark-Eriksson[2] to be higher among children in the older age groups which suggests that serious symptoms develop with increasing age. Malocclusions in conjunction with forced bite, especially transverse abnormalities, have been found by Mohlin et al.[3] and Williamson[4] to be strongly correlated with an increased risk for developing TMJ dysfunction. Since there is an asymmetric muscle activity in patients with transverse malocclusions and forced bite, the cited reports indicate that functional forces may influence jaw growth unfavorably. Furthermore, structural and functional change of the TMJ was found by Stringert and Worms[5] to be related to a characteristic facial morphology. However, no occlusal characteristics were significantly correlated with dysfunction. In autopsy material from young adults, Solberg et al.[6] found that variation in form of the condyle was associated with malocclusions such as crossbite and deep bite. It was also reported that marked changes in the TMJ region were connected with age. Thus, previous studies seem to indicate a relationship between the malocclusion and dysfunction. Also, a possible correlation between malocclusion and the overall morphology of the condylar region has been suggested, but this relationship needs further investigation.

Clinical TMJ evaluation usually consists of a clinical and a radiographic examination, which commonly includes a tomographic examination.[7-9] Currently most tomographic techniques use the submento vertex radiograph (SMV), for proper transcranial alignment.[10,11] Thus, the SMV projection and tomograms are appropriate

Abstract
Recent studies show that forces applied to the mandible during treatment with functional appliances and other orthodontic therapies produce changes in the TMJ. Specific malocclusions might also apply forces that can produce changes in the morphology of the TMJ. This study examined 104 orthodontic patients (44 males and 60 females) prior to treatment. The size and location of the condyle was determined on submento-vertex and tomographic films which was related to clinical findings including age, sex, malocclusion type, facial type, TMJ symptoms, tooth eruption sequence, crossbites and midline discrepancies. The medio-lateral width of the condylar head correlated positively with the patients age ($p<0.001$) and sex ($p<0.001$). Also the antero-posterior widths of the condyle were correlated with age ($p<0.05$). The condylar size in males was found to be greater than in females. Midline discrepancy significantly altered the increase in condylar size during growth. Transversel anomalies had a markedly greater influence on condylar growth compared to other characteristics of occlusion. The major change in condylar size during growth occurred in medio-lateral dimension as compared to the antero-posterior. In addition, the medio-lateral width was affected by midline discrepancy but not the antero-posterior width.
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Key Words
Craniofacial development • Mandibular condyle • Dysfunction

Figure 1

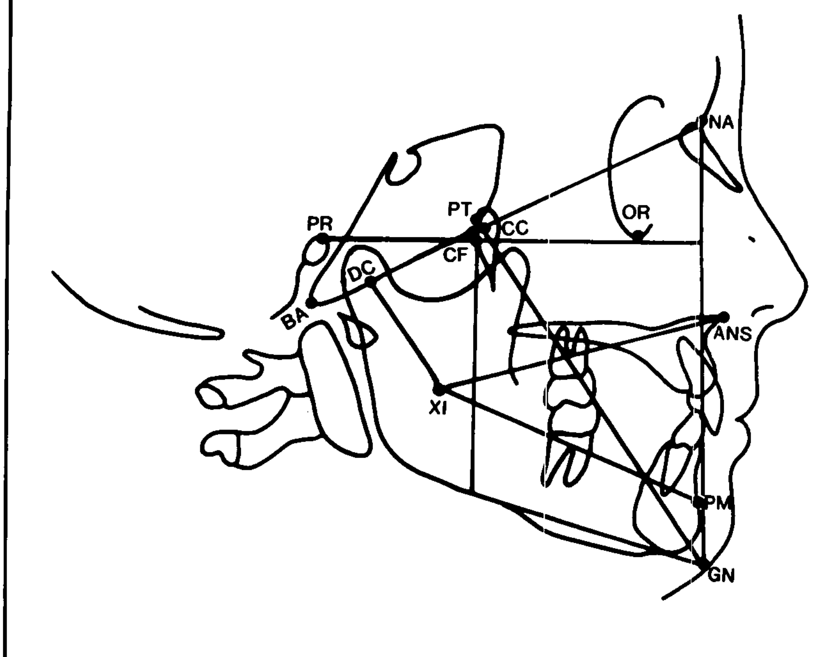

Figure 2

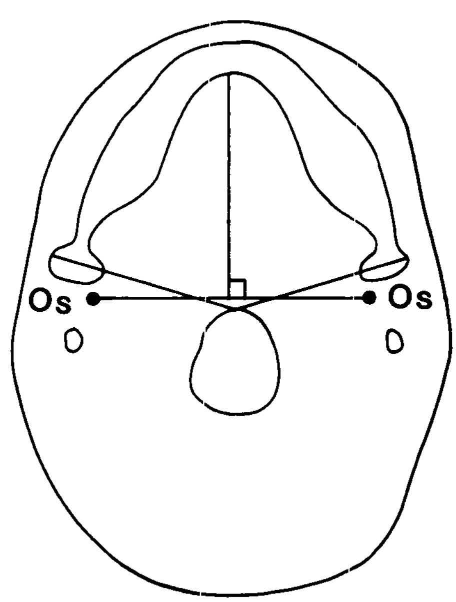

Figure 1
Reference points and lines used in the cephalometric analysis for determination of facial type as described by Ricketts et al.[14]

Figure 2
Schematic drawing of submental vertex view of the skull showing the points Os (:ossicles) and lines used in the analysis.

Figure 3
Schematic drawing of the temporomandibular joint in a tomogram showing the points and lines used in the analysis.

for use in a more extensive clinical evaluation of the TMJ.[10,12]

The objective of this investigation was to describe axial and sagittal condylar morphology and position. Correlations between condylar morphology and malocclusions, facial types and marked symptoms from the temporomandibular region would be made in children with different ages and eruption stages. This would give further insight into how the morphology of the mandibular condyle is related to normal occlusion and/or malocclusion during growth.

Material and methods

Selection of radiographs

Lateral cephalometric radiographs, tomograms of the temporomandibular joint and submento-vertical radiographs (SMV) and charts from 100 individuals were randomly selected for evaluation from those examined at the Department of Orthodontics, Loma Linda University, in 1984. The criteria for selection were good contrast and clarity and no pathology. The clinical registrations included sex, age, dental stage according to Björk & Solow,[13] type of occlusion, malocclusions, facial type[14] and dysfunction symptoms. Crossbites were classified according to location: right, left, anterior, posterior and bilateral. The degree of deflection from maximum intercuspidation centric occlusion (CO) to centric relation (CR) or retruded contact position was divided into the following types: left, right, anterior and posterior. Midline deviation in the maxilla and mandible were recorded separately. Dysfunction symptoms recorded included: crepitus, pain, clicking, limited opening and deviation upon opening.

Radiographic methods

Radiographs were taken with a Quint Sectograph* at the Section of Oral Radiology, School of Dentistry, Loma Linda University. Exposure parameters for the projections were: SMV-70 kV, 100 mAs; and lateral cephalometric radiograph 84 kV, 50 mAs. Exposure parameters for sagittal linear tomograms were 70 kVp, 50 mAs, 3 sec with a slice thickness of 4.5 millimeters. All radiographs were exposed on 8x10 films.**

Radiographic examinations

The lateral head films were evaluated to determine the facial type, using cephalometric analysis according to Ricketts et al.[14] (Figure 1). The following cephalometric characteristics were compared to mean values for that age: facial axis, facial depth, anterior face height, mandibular angle and mandibular plane angle. Standard deviations of the characteristics from the mean

Quint Sectograph, Los Angeles, CA

***Ortho G, Eastman Kodak Company, Rochester, New York* values of the given norms were calculated and given a negative sign when less than one standard deviation from the mean, and a positive sign when greater than one standard deviation from the mean. Standard deviations for the five characteristics were used to estimate the facial type (VERT number; Ricketts et al.[14]). When the VERT number was greater than one standard deviation, the facial type was classified as brachiofacial. When the VERT number was less than one standard deviation, the facial type was classified as dolichofacial. When the VERT number was within plus or minus one standard deviation, the classification was mesiofacial.

The SMV radiographs were traced using a modification of the technique described by Williamson and Wilson,[11] Figure 2. The ossicles of the ear were located and connected by a straight line. The midpoint of this line was marked and a protractor used to construct a perpendicular line. This perpendicular represents the skeletal mid-sagittal plane as defined by the ossicles. The midpoint of the lateral and medial poles of each condyle were selected, and these two points were joined to form a line which was extended to intersect the midsagittal plane. The condylar angulation was then read as the number of degrees indicated by this intersection. The width of each condylar head was determined and was defined as the distance between the medial and lateral poles. Linear and angular characteristics were measured on the sagittal linear tomograms (Figure 3): a-b describes the most narrow distance of the condylar neck; Ca-Cp describes the broadest distance of the condyle. A perpendicular line to the Ca-Cp line was drawn from the middle of the Ca-Cp line (Cm in Figure 3). The point of intersection between the perpendicular line and the line a-b was denoted Co and the line Ca-Cp, Cs (Figure 3). The highest point of the tuberculum (Ta in Figure 3) was marked as well as the most superior point of the fossa (Fa in Figure 3). The condylar angle was then measured between a line through these points on the temporal part of the TMJ and the perpendicular line to Ca-Cp.

Statistical methods

The arithmetic mean and standard deviation were calculated for each variable. To assess significant covariation between condylar characteristics and chronological age, dental stage as well as the facial type and occlusion characteristics, analysis of variance (ANOVA) was performed and supplemented with correlation and multiple regression analysis at the Department of Biostatistics, Loma Linda University, Loma Linda, California. In order to test the reproduc-

Figure 3

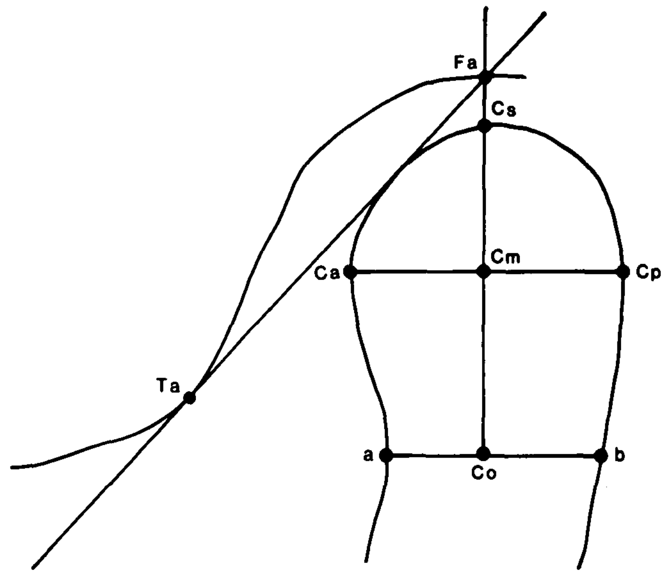

Table 1
Frequency of dental and skeletal characteristics in percent of all individuals investigated.

Characteristics		Frequency
Anterior tooth eruption stages	Incisors erupted	37.5
	Canines erupting	55.8
	Canines erupted	6.7
Molar eruption stages	First molar erupted	63.5
	Second molar erupted	36.5
Facial types	Brachiofacial	46.2
	Mesiofacial	33.7
	Dolichofacial	20.2
Angle classifications	I	32.7
	II, Div 1	53.8
	II, Div 2	8.7
	III	4.8
Crossbite	Left	8.7
	Right	9.6
	Anterior	7.7
	Bilateral	7.7
Deflection	Left	3.8
	Right	1.9
	Posterior	1.9
	Anterior	3.5
Midline deviation (> 1 mm)	Maxilla	26.9
	Mandible	41.3
TMJ symptoms		8.7

Table 2
Mandibular condyle width and angle determined on SMV radiograms. Values are given as mean ± S.D. ***: p<0.001; Males compared to Females with regard to condylar width.

Width	Males		Females		Males/Females combined	
Right side	19.6	1.7	18.9	1.9***	19.2	1.8
Left side	19.9	1.9	18.6	2.3***	19.2	2.3
Right/left combined	19.7	1.8	18.7	2.1***	—	—
Angle						
Right side	26.6	6.7	24.6	5.7	25.5	6.2
Left side	26.1	7.0	24.1	5.3	24.9	6.2
Right/left combined	26.3	6.8	24.3	5.5	—	—

Table 3
Mandibular condylar widths and angles on SMV radiographs and tomograms in four different age groups, males and females combined. The values are given as mean ± S.D. p< column show the statistical difference found between the age groups.

Age group	108-136		137-159		160-183		184-207		p<
Width (SMV)									
Right	18.1	1.6	19.0	1.7	19.5	1.8	21.3	2.0	0.0001
Left	18.0	1.7	19.1	2.4	19.6	2.1	20.5	1.6	0.0001
Right/left combined	18.0	1.6	19.0	2.0	19.5	1.9	20.9	1.8	0.0001
Angle (SMV)									
Right	23.3	7.1	27.1	6.4	24.2	5.5	23.2	4.5	ns
Left	23.8	6.4	26.3	6.3	24.0	5.9	21.5	5.2	ns
Right/left	23.4	6.7	26.7	6.3	24.1	5.7	22.3	4.8	ns
Width (Tomo)									
a-b left	6.8	0.4	7.7	0.2	7.6	0.2	8.7	0.2	0.005
a-b right	7.3	0.4	7.6	0.2	7.7	0.2	9.2	0.1	0.005

ibility of the radiographic measurements, duplicate determinations were made with an interval of one month by the same observer (J.T.). The methodological error was estimated by analysis of variance.

Results

A description of the characteristics in regards to age, sex, malocclusion, facial type and TMJ symptoms is given in Table 1. In the selected group there were 60 females and 44 males with a mean age of 155.7 months; SD = 18.6 (range 108-207). The age distribution of individuals in the material was such that it could be divided into four age groups with 35 individuals in each group. The age ranges for these groups were 108-136, 137-159, 160-183 and 184-207.

Condylar width, SMV projection: The mean condylar widths were 19.2 millimeters (SD = 1.8 millimeters) for the right side and 19.2 (SD = 2.3 millimeters) for the left side (Table 2). Since the right and left condylar width measurements were not significantly different, the measurements of the right and left side were combined. Males were found to have a significantly ($p<0.001$) wider condylar head as compared to females (Table 2).

Condylar width increased significantly ($p<0.001$) with chronological age (Tables 2 and 3). Condylar width did not significantly covariate with stage of eruption, Angle classification, facial type or malocclusions (Table 4).

Clinical findings of temporomandibular joint dysfunction, as defined in material and methods, did not significantly covariate with condylar width measurements. Presence of a deviation or deflection between CO and CR did significantly covariate with condylar width (Table 4).

Condylar width seemed to become markedly greater with age (Tables 2 and 3). However, the presence of a midline discrepancy was correlated with a significantly ($p<0.05$) slower increase in condylar width with age compared to the increase in condylar width with age in individuals with coinciding midlines (Table 5 and Figure 4). The equation for the regression line describing condylar width in changes during the age periods studied was calculated to be $y=10.2+.0.5x$, $r=0.45$, $p<0.002$ in children with no midline discrepancy; and $y=15.4+.03x$, $r=0.29$, $p<0.006$ in children with midline discrepancy.

Condylar angle, SMV projection: The mean condylar angle for the right side was 25.5 millimeters and 24.9 millimeters for the left side respectively (Table 2). Condylar angle exhibited no statistically significant difference between the age groups in this sample (Table 3). Similarly, none of the other characteristics registered as either facial type or malocclusions were found to covariate significantly with the axial condylar angle (Table 4).

Condylar morphology, tomography: The values are shown in Tables 3 and 6 covariance with CsCm ($p<0.04$). CsCm covariated with crossbite ($p<0.04$) and deflection covariated with several linear measurements: CsCm ($p<0.058$); CsCo ($p<0.051$) and CsCo ($p<0.031$). The condylar morphology in the sagittal plane (tomographic angles and widths) was similar for the right and left sides. In contrast to the SMV projection there were no differences between males and females. The only sagittal condylar characteristic that was found to significantly change with age was condylar width (distance a-b). This character covariated with age significantly ($p<0.005$).

The angles measured on the tomograms were not correlated to the angles measured on the SMV projections. In contrast, the width of the condylar neck on the tomograms showed a correlation of 0.66 ($p<0.001$) with the width measured on the SMV projections.

Reproducibility of measurements: No statistically significant increase of the methodological error was found for repeated registrations (ANOVA: $p<0.02$ level).

Discussion

The present study has shown that the overall condylar size increases significantly with age and that this increase is different in males and females. Furthermore, the development of the size was observed to be influenced by discrepancy in the midline of the dentition. In contrast to size, the inclination of the condyle in the axial view was not changed with age and it was similar in males and females. The inclination seemed to be consistent within the sample. The higher standard deviation values for angle measurements compared to the width measurements show that the angular characteristics have a great variability. It was demonstrated by Pullinger et al.[15] that linear measurements show the greatest concordance compared to angular measurements. Furthermore, a markedly wide range of horizontal angles was reported by Yale et al.[16] an angle similar to that measured in this study. That report is in accordance with the wide variation found for the condylar angle in the present study, a fact which may have hampered the detection of specific characteristics within this sample.

The width measurements showed specific variations in the sample in contrast to angular characteristics. It was observed that the size of

Table 4
Significance level of covariance between condylar characteristics on SMV and dental/skeletal characteristics.

Covariance with	Condylar width p<	Condylar angle p<
Angle	0.147	0.058
Facial type	0.481	0.296
Crossbite	0.657	0.633
Deflection	0.348	0.085
Mid-line	0.010	0.560
TMJ symptoms	0.072	0.051
Tooth eruption stages	0.125	0.357

Figure 4

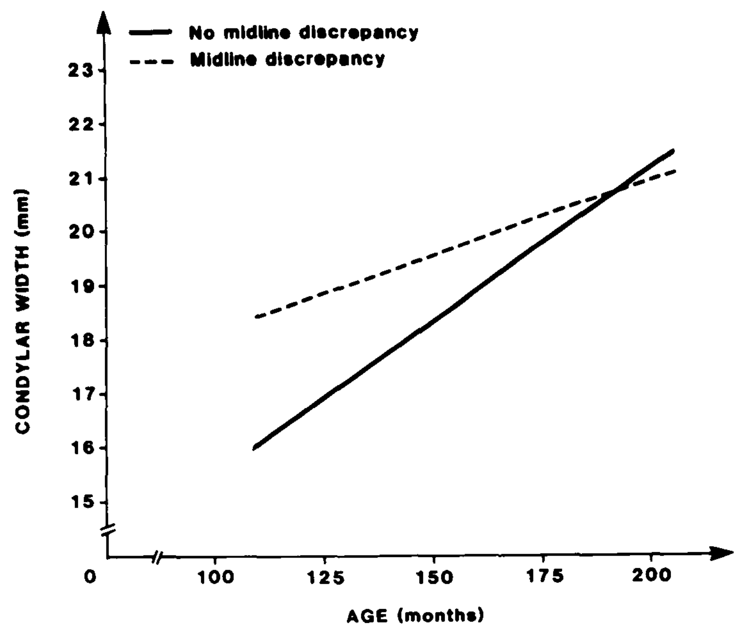

Figure 4
Change in condylar width with age in individuals with and without midline discrepancy is shown by the regression lines. A detailed description is given in the Results section of the text.

Table 5
The mandibular condyle width and angle values for individuals with and without midline discrepancy in the maxilla and mandible. The values are given as mean ± SEM, p< shows statistical significance when evaluated with analysis of variance (ANOVA) with regard to covariation between no midline or with midline discrepancy and condylar characteristics with age.

Condylar characteristic	No midline discrepancy		Midline discrepancy Maxillary		Midline discrepancy Mandibular		ANOVA p<
Width							
Right	18.5	0.3	19.7	0.4	19.4	0.3	0.001
Left	18.5	0.4	19.7	0.4	19.3	0.4	0.001
Angle							
Right	25.6	1.1	25.1	1.3	25.5	0.9	n.s.
Left	25.0	1.1	24.5	1.1	25.2	1.0	n.s.

the condyle is larger in males than in females. This is in accordance with studies on autopsy material by Öberg et al.[17] and on medieval skulls by Wedel et al.[18] As in these studies, the medio-lateral width (SMV) was found to be approximately twice the antero-posterior width (tomography). Furthermore, no difference between males and females was found in antero-posterior widths. Thus, the medio-lateral width showed a variation between the sexes which was not found for antero-posterior widths.

In addition, the present study showed an age-related increase in medio-lateral width, which was indicated by Wedel et al.[18] in medieval skulls. Furthermore, in this study the antero-posterior width of the condylar neck region increased with age. However, the major change in condylar size during growth was an increase in the medio-lateral dimension. Thus, the medio-lateral dimension of the condyle is an important growth characteristic. Although the medio-lateral condylar width showed significant correlation with age, neither this width nor the antero-posterior widths were related to stage of tooth eruption. The period of the different tooth eruption stages accordingly do not seem to markedly influence condylar size during growth. The reason might be that the period for growth changes to occur during each stage is too short. It is known from studies on correlation between tooth development and age that the statistical correlations are very sensitive to such scales of determination.[19,20]

However, the transverse anomaly of a midline discrepancy was significantly correlated to the medio-lateral dimension during growth, but not to the antero-posterior dimension. This difference might be because the medio-lateral dimension shows markedly more changes during growth, a suggestion which is supported by the conclusion of Wedel et al.[18] In that study, the medio-lateral dimension was shown to be more dependent on jaw dimension than antero-posterior width. A suggestion which relates to the observation in this study that the sagittal characteristics of the dentition and jaws did not seem to influence the antero-posterior dimension of the condyle. This lack of influence might be due to the above mentioned fact of a small overall change in this particular condylar dimension, a deduction that should not be confused with the views on functional adaptability of the condyle proposed by Williamson[21] in studies on dysfunction and by McNamara et al.[22] and McNamara[23] in studies on the effects of jaw orthopedics on condylar growth. These reports involve not only condylar size, but the position of the condyle in the fossa as well as growth of the mandibular ramus. In the present study the change in medio-lateral dimension during growth was affected by midline discrepancy. This was in contrast to the sagittal characteristics of the dentition and jaws which were not correlated to variations in condylar widths. Transverse anomalies have been correlated to abnormal morphology of the TMJ during growth.[6,24] It was postulated in these studies that change in the muscle pull might be involved.

This alteration in muscle pull could negatively influence growth of the condyle. This suggestion is supported by the fact that the sagittal occlusal characteristics did not seem to correlate with medio-lateral widths. The mechanism for the midline discrepancy to influence condylar growth is not known but the posturing of the mandible with altered muscle pull seems to be a reasonable hypothesis.

The developmental effect of the midline discrepancy on condylar width may have important ramifications in the orthodontic treatment of growing patients. Early correction of a facial asymmetry may decrease developmental disturbances and indirectly decrease the occurrence of TMJ symptoms later in life.[1,6,25] Clinical signs from the TMJ were found to be lower than those previously reported.[2,21] However, in this study only very clear clinical signs were included as indicators of structural derangement in the TMJ. The findings in this study emphasize the importance of obtaining relevant radiographic projections for proper interpretation of the TMJ region. The medio-lateral aspect is important for examination and transmaxillary or frontal tomograms are suitable for this. In addition, sagittal tomography is mandatory for locating pathology and for detecting normal variation.

In conclusion, the condylar size in males was found to be larger than in females. Further, midline discrepancy significantly caused an alteration in condylar size during the growth period. Therefore it is believed that transverse anomalies exhibit greater influence on condylar growth compared to other characteristics of occlusion. Furthermore, the major change in condylar size during growth occurred in the medio-lateral dimension as compared to the antero-posterior. In addition, the medio-lateral width was affected by midline-discrepancy, but the antero-posterior width was not. Clinical implications dictate that transverse anomalies have high priority for early treatment and that the medio-lateral aspect has to be emphasized when evaluating the TMJ region by radiographic examination.

Table 6
Mandibular condyle linear dimensions and relation to the slope of the temporal fossa (angle in Fig. 3) as determined on TOMO radiographs. Values are given as mean ± SD.

Characteristics	Males		Females		Males/Females combined	
CaCp						
Right	8.7	1.0	8.9	1.0	8.8	1.0
Left	8.7	1.2	8.8	1.0	8.8	1.2
Right/left combined					8.8	1.0
CsCo						
Right	8.7	1.5	8.5	1.5	8.6	1.5
Left	8.8	1.9	8.7	1.5	8.7	1.6
Right/left combined					8.7	1.4
CsCm						
Right	3.7	0.7	3.6	1.0	3.6	0.9
Left	3.7	1.0	3.5	0.8	3.6	0.9
Right/left combined					3.6	0.7
a-b						
Right	7.5	1.5	7.7	1.2	7.6	1.3
Left	7.5	1.6	7.6	1.2	7.5	1.4
Right/left combined					7.6	1.2
Angle						
Right	33.9	6.7	33.2	7.2	33.5	6.9
Left	30.8	6.6	32.9	8.7	32.0	8.0
Right/left combined					32.7	6.4

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