An analysis of maximum mandibular movements, craniofacial relationships and temporomandibular joint awareness in children

By Leonard H. Rothenberg, DDS

Quality assessment is dependent upon the existence of pretreatment records. Adequate records vary with the complexity of the presenting condition, but at a minimum they must be sufficient to identify the pretreatment orthodontic-dentofacial, orthopedic, and/or craniomandibular problems, and enable the clinician to develop an acceptable course of treatment. Potential signs and/or symptoms of temporomandibular joint problems in a child might require modification of a treatment plan or, at minimum, alert the orthodontist to possible future changes. One such early sign may be the child's range of mandibular movements.

Williamson[1] noted that incipient joint problems in patients 6 to 16 years old will likely be overtly seen at age 30. An examination designed by Egermark-Eriksson[2] takes into account the range of mandibular movement in the functional examination of the masticatory system in children.

Dawson,[3] in his description of the healthy joint, notes that the range of motion should be within normal limits. Maximum openings should be in the range of 40 mm or more; smaller maximum openings indicate probable muscle incoordination. Maximum openings of less than 20 mm indicate possible intracapsular problems. No mention is made, however, as to whether these values pertain to children as well as to adults.

Agerberg[4,5] studied maximal mandibular movements in children. The size of maximal movements of the mandible was studied in two age groups, 1 to 2 years and 6 years. None of the children had pain or severe temporomandibular joint dysfunction symptoms. In the younger group of 33 children, mouth opening was recorded using an indirect method. Highly signifi-

Abstract

This paper evaluates the relationship between maximum mandibular vertical opening and the following variables: chronological age, craniomandibular relationships, and temporomandibular joint awareness in children. The range of mandibular movement was evaluated in 189 children between the ages of 4 and 14 years, using the method of Agerberg. Measurements were found to be accurate and reliable only in the vertical plane. Cephalometric tracings were made on 131 of the subjects. Significant relationships were noted for maximum vertical opening with age, anterior facial height, and mandibular length. A temporomandibular joint awareness questionnaire was verbally given to all subjects with no parental input. Responses to the questionnaire were found to be unreliable, based upon a retest of 25 subjects one month later. It is noteworthy that all of the changes in responses on the retest were to the same question, "Does your jaw ever feel tired?"

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Key Words

Temporomandibular joint awareness • Maximum mandibular movements • Condylar path angle

Figure 1
Cephalometric Landmarks

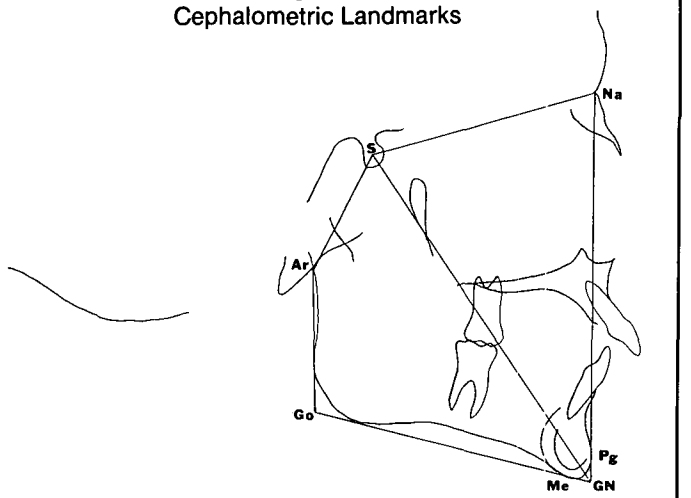
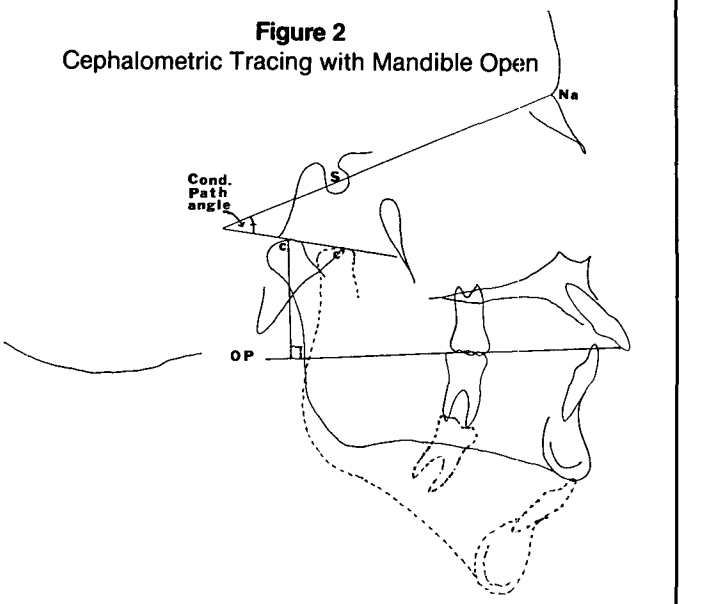


Figure 2
Cephalometric Tracing with Mandible Open



cant differences were found between three recordings with the third having the largest mean, 38.4 mm. The older group consisted of 75 boys and 75 girls. The mean maximal opening was 44.8 mm. The means for left, right and protrusive maximal movements were each approximately 8 mm. No differences in vertical or horizontal movements were found between the sexes. The values of the older group agree with 46.0 mm and 46.2 mm measurements, given by Nevakari,[6] and Sheppard and Sheppard,[7] respectively, for the interincisal distance in 6- to 10-year-old children, and the value of 46.4 mm given by Ingervall[8] for opening capacity in 7-year-old children. The small differences between the means were thought to be due to the slightly greater age of the children.

Agerberg[9] also investigated maximal mandibular movements in young adults. He found a mean maximal vertical opening in 20-year-old healthy men of 58.6 mm (range 44-77), whereas for women of the same age it was 53.3 mm (range 42-75). This difference in vertical movements of the mandible was not noted in the children's study. The lack of difference between sexes in the children's group could be explained by the fact that mouth opening was correlated with other body dimensions and at 6 years, girls are 5% to 8% more advanced in their development toward maximum height and weight. In these studies the relationship of maximal mandibular movements and mandibular size and shape, was not investigated, nor were any other craniomandibular relationships.

Grummons[10] pointed out that the range of mandibular movement varies with different facial types. The brachyfacial type had vertical opening range of 50-60 mm and had a steep articular eminence. The dolichofacial type had a vertical opening range of 40-50 mm with a shallow articular eminence. Grummons noted that the measurements on children would be similar, only 2-3 mm less.

In 1985, Smith[11] studied the relationship of mandibular movements to condylar translation. He noted that it might be possible for wide mandibular openings to take place without condylar translation were it not for the vertical arrangement of the human mandible, in which the condyle is placed well above the occlusal plane. This implies that condylar height (above the occlusal plane) might be a factor in maximal mandibular opening. One factor left unmentioned in his study was whether the steepness of the condylar path was significant in mandibular opening.

The purpose of this study was to investigate whether any relationship exists between maximal mandibular movements in children, and

1. mandibular size or shape, craniomandibular relationship, condylar path angle, or
2. temporomandibular joint awareness.

Materials and methods

This investigation was carried out on 189 subjects presenting for orthodontic evaluation in a private practice. The subjects were healthy, Caucasian, untreated children and young adults

Figure 3

Name: _____

Date: _____ 19____ Birthday: _____ 19____

Age: _____ Years _____ Months Sex: ____ M ____ F Height: ____ Ft. ____ In.

Records: ____ Y

Pre-Tx: ____ Class I Class II division 1 Class II division 2 Class III

Crossbite: Anterior Posterior (Bi or Uni)

Midline discrepancy: ____ Y

Mid-Tx: _____

Post-Tx: _____

Examination and Maximal Jaw Movements

Maximum opening: _____ mm. Deviation: _____ mm. ____ L ____ R

Protrusive: _____ mm.

Right side: _____ mm. Left side: _____ mm.

TMJ has: clicking and/or crepitus _____ Y Tenderness: _____ Y

Y 1. Did you have any muscle or jaw pain or discomfort during any of these movements of your jaw?
Y 2. Do you ever have any funny feeling or pain in your jaws or in your ears?
Y 3. Do you ever hear any noises or popping or clicking, like your knuckles cracking, in your jaws or in your ears?
Y 4. Do you ever have any problems opening your jaws wide when you are talking, yelling, eating a bagel, or yawning?
Y 5. Does your jaw ever get stuck open or closed?
Y 6. Do you ever grind your teeth at night or during the day?
Y 7. Does your jaw ever feel tired?
Y 8. If you want, can you move your jaw out of joint and make it pop?

from 4 to 14 years old. The sample was comprised of 52.3% females and 47.7% males. A clinical orthodontic evaluation was performed. The measurement of the various maximal mandibular movements were accomplished with the patient sitting in an upright position.[5]

Maximal mandibular opening (interincisal distance) was measured with a millimeter ruler. One end of the ruler was placed in the median plane against the incisal edge of one of the mandibular central incisors and the distance of the incisal edge of the opposing maxillary incisor was measured, while the subject opened his/her mouth as wide as possible. Three measurements were made with the operator instructing the subject to "open as wide as you can without hurting yourself." To determine maximal opening, the vertical overbite was also measured using the method of Lundstrom[12] and added to the value found for mouth opening.

Maximal lateral movements were measured using the maxillary and mandibular midlines as guides if they coincided. If not, vertical marks were made with a marking pencil in the median plane on the labial surfaces of two opposing central incisors. The subjects were instructed to "move your jaw as far to the side as you can" without specific instructions as to left and/or right. They then were instructed to "move your jaw as far as you can to the other side." This was repeated twice and the largest measurements were recorded. The protrusive measurement was made in a similar way with the instruction to "move your jaw out as far forward as you can." At times it was necessary to change this instruction to "move your jaw back as far as you can" in order to get a protrusive movement. This was also repeated twice and the largest measurement was recorded. The amount of overjet was added to this measurement to establish the total protusive movement. All recordings were made to the nearest millimeter and were performed by the author.

Following the examination of maximal jaw movements, subjects were asked the questions in Figure 3. Only positive responses were re-

Figure 4

Name: _____

Age: _____ Sex: _____

2nd Data: _____ Ceph. wide open: _____

Mandibular Movements

A. Maximum opening (vertical): _____ _____

B. Maximum right: _____ C. Maximum left: _____

D. Maximum protrusive: _____

E. TMJ: yes ____ no ____

Cephalometric Measurements

1. N-S-Ar (saddle angle) _____
2. S-Ar-Go (articular angle) _____
3. Ar-Go-Me (gonial angle) _____
4. Sum of angles _____
5. Go-Me (mandibular body length) _____
6. Ar-Go (ramus height) _____
7. SN-MP (mandibular plane angle) _____
8. S-Gn (Y-axis) _____
9. SN-OP (occlusal plane) _____
10. S-Go (posterior facial height) _____
11. Na-Me (anterior facial height) _____
12. Ratio S-Go / Na-Me _____
13. Condyle tip — OP (perp) _____
14. Condylar path (angle / FH) _____

corded. No parental guidance was given to the subjects.

Twenty-five subjects were reexamined within 3 months of their initial examination to measure the reliability of the author's measurements and the subjects' responses to the questions on Figure 3.

Complete orthodontic records were made on 131 of the subjects. The records included a standard lateral cephalometric radiograph taken in the natural head position.[13] Cephalometric landmarks and measurements used are indicated in Figures 1 and 4.

Cephalometric radiographs with the mandible wide open were also taken on 20 randomly selected patients to evaluate the constructed path of the condyle from a closed mandibular position to maximum vertical opening. Tracings of these subjects were superimposed on the anterior cranial base of the previous cephalogram as described by Baumrind, Miller, and Molthen.[14] As seen in Figure 2, the path of the condyle was measured relative to Sella Nasion. Additionally, the cephalogram with the mouth wide open provided better visualization of the condyles, allowing accurate measurement of the perpendicular distance between the tip of the condyle and the occlusal plane.

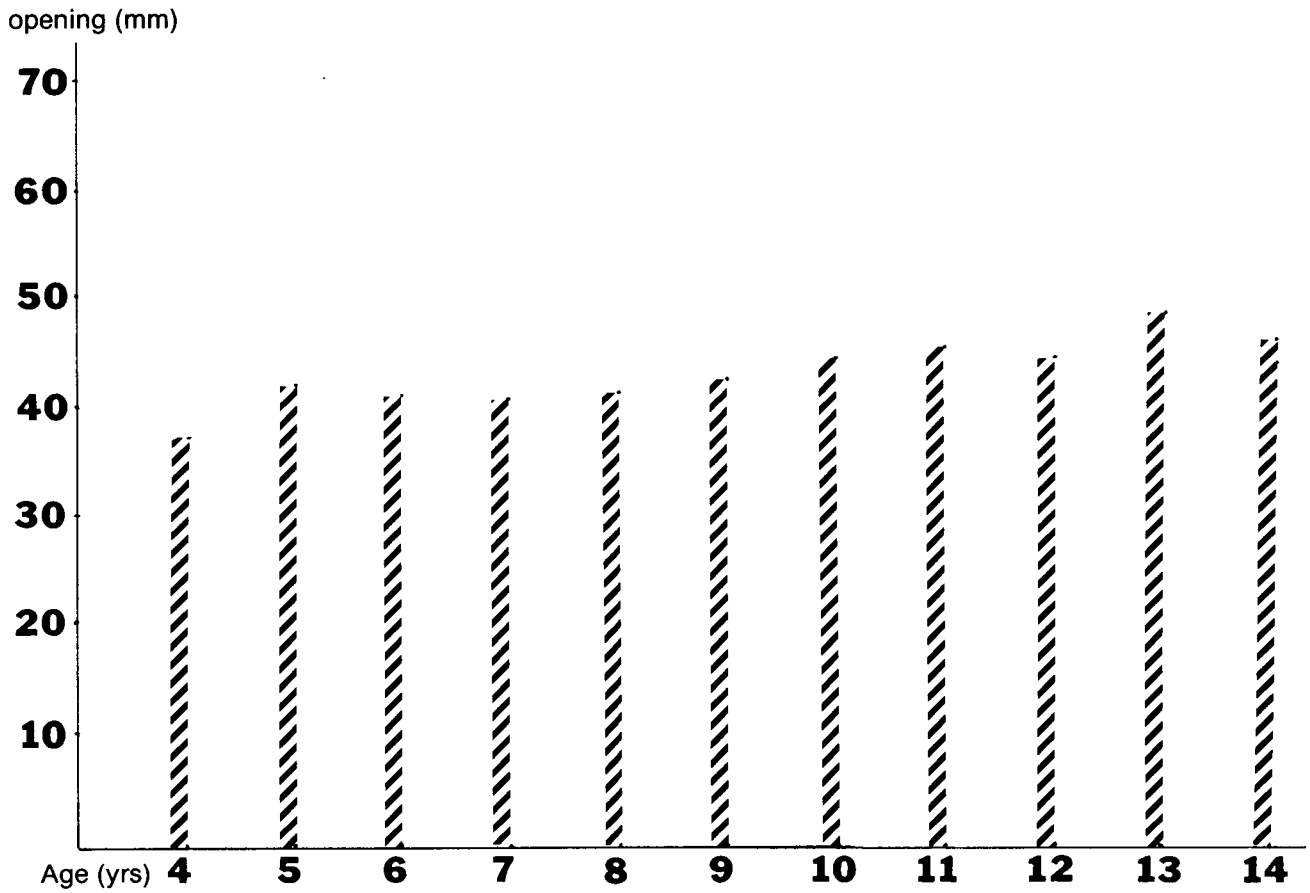
Statistical analysis of the data included means, standard deviations and standard error of means for all measurements. Pearson's correlation coefficients were calculated to evaluate any significant relationships between maximal opening and any other variable. Additionally, a stepwise regression procedure was used to evaluate a multiple relationship between the dependent variable opening and any other variables. *T*-tests and Chi-square tests were used to further determine the significance of all relationships.

Results

Repeated measurements

In the 25 children selected for retesting, good inter-rater reliability was noted for maximum vertical opening (0.87). This reliability was low for the other mandibular excursions, ranging

Figure 5
Mandibular Opening vs. Age



from 0.49 to 0.53. This has been noted by previous authors. The reliability of the TMJ awareness questions also proved to be very low, 0.27, with 7 out of 25 responses changed by the subjects during their retests.

Descriptive statistics

The TMJ awareness data in Table 1 indicates that 24% of those examined had at least one positive response to the questions in Figure 3. These positive responses were considered as subjective symptoms only; no objective differentiation was made at this time.

The means, standard deviations, minimum and maximum values, and standard error of means are noted in Table 2. Additionally, this table distinguishes between the 189 children having mandibular range of motion measurements, and the 131 children having cephalometric measurements. The cephalometric results were within 1 standard deviation of the means of Björk.[15] Also included in Table 2 was the data obtained from the 20 subjects for which an additional cephalogram was taken with the mandible wide open.

The mean age of the 189 subjects examined for maximum vertical opening was 120 months. The mean opening measurement for this group was 43.9 mm. The extreme values for maximum vertical opening were 32 mm and 64 mm. The mean lateral mandibular movements were 9.8 mm.

Plottings of mandibular opening versus age are presented in Table 3 and Figure 5. An increase of mandibular opening with age is noted. It should be noted that the sample sizes of the 4-, 5- and 6-year-old groups were very small.

Correlation analysis

Pearson's correlation coefficients were calculated for maximum opening relative to subject's age, mandibular size, and craniomandibular position. Significant relationships are noted in Table 4. The highest correlation was between age and maximum opening. This significant relationship existed whether the group treated was male only, female only, or males plus females. Addi-

Table 1
Temporomandibular joint awareness

TMJ	Frequency	Percent
No	144	76%
Yes	45	24%

Table 2
Descriptive statistics and frequencies

Variable	N	Mean	Standard deviation
Opening	189	43.99	5.78
Maximum right	189	9.76	2.08
Maximum left	189	9.87	2.19
Maximum protrusive	189	7.30	1.72
Saddle angle	131	124.31	5.24
Articular angle	131	144.51	6.35
Gonial angle	131	124.24	6.52
Sum of angles	131	392.99	5.16
Mandibular body length	131	67.55	6.16
Ramus height	131	41.75	5.71
Mandibular plane angle	131	33.29	5.07
Y-axis	131	67.20	3.37
Occlusal plane	131	18.63	3.91
Posterior facial height	131	70.80	6.44
Anterior facial height	131	110.50	7.37
Condylar tip (perp)	20	35.85	5.11
Condylar path angle	20	24.10	9.38
Age (months)	189	119.93	32.55

Table 3

Age (years)	Sample size	Maximum opening (mm.)	Standard deviation
4	4	37.5	1.3
5	7	42.1	5.3
6	8	41.8	5.6
7	30	41.6	4.4
8	29	41.7	4.7
9	18	42.9	5.0
10	25	44.6	6.5
11	26	45.6	4.9
12	24	45.2	5.7
13	11	49.0	5.4
14	7	46.3	4.6

tionally, a significant relationship between maximum opening and mandibular body length and anterior facial height was seen. As expected with growth, both anterior facial height and mandibular body length were significantly related to chronological age (Table 5).

A stepwise regression procedure for the dependent variable opening was also calculated. Step 1 entered the variable age and an R-square value of 0.15501 was obtained. The probability was < 0.01. Step 2 entered the variable articular angle (S-Ar-Go) into the regression analysis. The R-square value increased minimally to 0.17806 with a probability also of < 0.01. Step 3 introduced the variable anterior facial height. The R-square value increased to 0.20065 at the same probability, < 0.01. No other variables met the 0.1500 significance level for entry into the model. These results are displayed in Table 6.

The *t*-test was used to evaluate any relationship between the variable opening and TMJ awareness. A significant relationship at the 0.05 level was determined. The values are presented in Table 7.

The *t*-test was also used to evaluate any relationship between the variable opening and sex. No significant relationship was determined.

The *t*-test procedure for the variable age versus TMJ awareness produced a significant relationship (Table 8) with the probability < 0.01. This is consistent with other reports that show an increased TMJ awareness in adults versus children.

Discussion

The measurement of maximum mandibular movements in children using the method prescribed by Agerberg[4,5] was found to be accurate and reliable in the vertical plane (0.87). However, when the author retested 25 subjects for lateral and protrusive excursions, it was difficult to get repeatable recordings. This was more difficult in the younger subjects (under 8 years) than in the older children. This difficulty in obtaining accurate lateral and protrusive excursions was also reported by Ingervall.[8] Grum-

Table 4
Pearson's correlation coefficients between maximum mandibular vertical opening, age and craniomandibular relationships

Variable	Maximum opening
Age	0.42063*
Age (females, N = 99)	0.32*
Age (males, N = 90)	0.41*
Anterior facial height	0.35141*
Mandibular body length	0.33284*

*significant at 0.05

Table 5
Pearson's correlation coefficients between age and craniomandibular relationships

Variable	Age
Anterior facial height	0.63415*
Mandibular body length	0.62986*
Posterior facial height	0.62046*
Ramus height	0.49450*

*significant at 0.05

mons[10] measured lateral excursive and protrusive movements using a tongue blade as a bite plane to allow lateral and protrusive movements at a fixed vertical dimension, thus eliminating any vertical error. This technique will be used for future measurements.

Seven of the subjects retested changed their responses to the TMJ questions. Of the 25 subjects retested, only more positive responses were noted; no change was recorded from positive to negative. Additionally, the change always involved question No. 7, "Does your jaw ever feel tired?" There may be several explanations for these changes in response to the questionnaire. The most obvious explanation may be that this question is not a reliable question for evaluating TMJ awareness. Perhaps it is too vague and too open to a positive response. This bears future testing. Secondly, it might simply be that the younger subjects were more apt to change their minds. It may also be that the subjects were educated about their temporomandibular joint by being previously questioned about it. Possibly, the subjects had some discussion with family members during the interim between examinations. Apprehension might have been a factor, since the examination was conducted at the first office visit. Additionally, no parental input was allowed in the children's responses. Perhaps by the second visit, when the retest was conducted, the child's familiarity with the environment and the author made them pay more attention to the questions being asked. The author is presently retesting all the subjects to evaluate the reliability of this questionnaire as a measuring instrument for TMJ awareness.

The mean maximum opening of 43.7 mm compares favorably (within 1 standard deviation) to the results previously noted by Agerberg[4,5] in his sample of 6-year-olds. The intra-age variations in maximum opening were quite large even in the small children. As much as 17 mm difference was recorded for the 5 year-old group. Therefore, it is difficult to set a lower limit for the normal range of mouth opening for small children. The mean maximum right and left excursive movements were 9.8 mm. The mean protrusive movement was 7.3 mm. As previously noted, the reliability of these excursive values were low in the younger children. The values are, however, within the range determined in the previously mentioned studies.

Maximum vertical mandibular opening increased with age. This was shown to be statistically significant at the 0.05 level. An apparent linear relationship exists (Figure 5). Table 4 also shows that the relationship between opening and age was significant for males, females, and males plus females. No significant relationship was determined between opening and gender. A difference in vertical movements of the mandible between the sexes in a 20 year-old population was reported by Agerberg.[9] This difference was not observed in his younger groups. The population of the present study seems to better reflect this younger sample. One reason might be that the majority of male subjects in this

Table 6
Stepwise regression procedure for the dependent variable opening

Step	Variable entered	R-Square value
1.	Age	0.15501
2.	Articular angle	0.17806
3.	Anterior facial height	0.20065

**no other variables met the 0.1500 sig. level for entry into the model

Table 7
Maximum vertical opening vs. TMJ awareness
T-test procedure

Variable = opening (mm)

TMJ awareness	N	Mean	Standard deviation
No	144	43.2	5.4
Yes	45	45.3	5.8*

**T*-test value of -2.19 w/187 degrees of freedom Significant at 0.05 level

sample were pre-pubertal or circum-pubertal, thus there were no extreme differences seen in facial size as might be expected in a more mature population.

Pearson's correlation coefficients were determined for mandibular opening relative to age and to the various craniomandibular measurements. The strongest relationships were noted in Table 4. These were, in decreasing order: age, anterior facial height, and mandibular length. No other measurements were strongly related.

A stepwise regression analysis for the dependent variable opening was calculated. The variables entered (Table 6) were age, articular angle, and anterior facial height. No other entries were made because no other variables met the 0.1500 significance level. Other craniofacial measurements may have been closely related to opening and not entered into the regression analysis. The reason for their exclusion was their close relationship to a previous entry. Thus, they were eliminated as a separate entry into the regression analysis.

A significant relationship was determined between the variable, opening, and TMJ awareness. The *t*-test (Table 7) results showed a significant relationship at the 0.05 level. This relationship would seem to imply that TMJ aware subjects have an increased maximum vertical opening. This difference is only 2.1 mm and the standard deviation is large, thus, the clinical importance is minimal.

A significant relationship (0.05 level) was determined for TMJ awareness versus age (Table 8). A mean age of 127.5 months was noted in the significant group versus 113.2 months for the non-significant group. Again, the standard deviations of these groups are large and the clin-

Table 8
Age vs. TMJ awareness
T-test procedure

Variable = age (months) TMJ awareness	N	Mean	Standard deviation
No	144	113.2	28.5
Yes	45	127.5	26.3*

*T-test value of 2.9 w/187 degrees of freedom
Significant at 0.05 level

ical implication is questionable. The frequency statistics indicated a 24.1% positive response to at least one of the questions asked. As previously noted in the reliability discussion, this figure may be a low calculation. In Nilner's[16] group of children 7 to 14 years old, the prevalence of subjective symptoms was 36%. The perceived prevalence of symptoms of mandibular dysfunctions (e.g., TMJ sounds, tiredness in the jaws and face, and difficulties in mouth opening) was very low in Egermark-Eriksson's[2] study. They found chronic TMJ symptoms to occur less than 1% of the time. The prevalence of these same symptoms occurring occasionally was as high as 25%. If pain or tiredness in the jaws and face during chewing gum is included as a symptom, the prevalence increases to as high as 74%.

The practicing clinician should be aware of the range of mandibular movements for each individual patient. Baseline measurements should be recorded and retested to determine accuracy. Any change in the range of mandibular movement should be closely evaluated. One should also record subjective as well as objective TMJ symptoms before initiating treatment, and periodically during active treatment. A positive TMJ response during a recall period prior to active treatment will allow the orthodontist to more adequately inform the family and patient of possible future problems. The fact that a child does not report TMJ awareness to the examiner at the first visit may reflect a lack of understanding on the child's part. Additionally, a positive response during treatment does not indicate a cause-effect relationship between treatment and TMJ awareness. One must consider the multifactorial nature of the problem, but one fact seems certain: Whether a patient is 4 or 40 years old, a comprehensive examination and evaluation is indicated.

In summary, maximum mandibular movements of the mandible vary a great deal from individual to individual. As the Swedish investigator Posselt[17] reported, mandibular movements are characteristic for each person. They do not necessarily correspond to the physiological movements of the mandible. It behooves the practicing orthodontist to determine and monitor these borderline movements before, during, and after the active treatment phase.

Author Address
Dr. Leonard H. Rothenberg
9000 S.W. 152nd Street, #208
Miami, Florida 33157

L.H. Rothenberg is in private practice in Miami. He is co-chairman of the Orthodontic Department at Miami Children's Hospital in Coral Gables.

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