Original Article

Condylar Disc Relationships and Vibration Energy in Asymptomatic Class I 9- to 12-Year Olds

Defne Kecik, DDS[a]; Ilken Kocadereli, DDS, PhD[b]; Isil Saatci, MD[c]

Abstract: A proper diagnosis is the key to successful treatment. The purpose of this study was to evaluate the temporomandibular joints (TMJ) by means of lateral and anteroposterior cephalograms, transcranial temporomandibular radiographs, magnetic resonance imaging (MRI), and TMJ electrovibratography (EVG) in asymptomatic and orthodontically untreated Angle Class I subjects. The study sample comprised 31 (13 boys, 18 girls) asymptomatic Class I children with a mean age of 9.7 years. The lateral cephalometric findings revealed that the subjects were mesofacial with an Angle Class I skeletal relationship, and the anteroposterior cephalograms showed a symmetrical craniofacial skeleton. Transcranial TMJ radiographs showed that the TMJs on both sides were symmetrically positioned. The time-frequency distributions of sounds from both right and left TMJs showed a wide range, and the vibrations measured by EVG were considerable. The MRI revealed unilateral disc displacement with reduction in four of the 31 subjects (13%), bilateral disc displacement with reduction in three subjects (10%), and bilateral disc displacement without reduction in one subject (3%). The data confirm that a standardized clinical examination to determine the status of the joint is not an efficient tool. This study suggests that the clinical diagnosis should be supported by extensive TMJ evaluation techniques. (*Angle Orthod* 2004;75:54–62.)

Key Words: Temporomandibular joint; Magnetic resonance imaging; Electrovibratography; Transcranial temporomandibular joint radiography

INTRODUCTION

The masticatory system is primarily responsible for chewing, speaking, and swallowing and consists of bones, joints, ligaments, muscles, and teeth. To manage masticatory disorders effectively, one must understand the various types of problems that can exist and the variety of causative etiologies. A proper diagnosis becomes an extremely important part of managing the patient's disorder and the key to successful treatment.[1]

The first part of a clinical examination is a patient's history, which may include questions regarding temporomandibular joint (TMJ) noises and sounds. If noises and sounds are present, an examiner may or may not consistently hear (auscultation) or feel (palpation) (or both) these noises and sounds.[2] Clinical examination is often misleading with respect to the status of the joint; therefore, a reliable imaging technique such as magnetic resonance imaging (MRI), arthrography, or TMJ radiographs is needed.[3] Any factor that damages the ideal relationship between the TMJ components may cause TMJ signs and symptoms.[4]

Generally, hearing and touch are rather poor and crude diagnostic tools for the diagnosis of temporomandibular joint disorder (TMD).[5] Several researchers have stated that the position of the condyle in the glenoid fossa varies in different malocclusion types.[6–10] TMJ sounds have been reported in many studies,[2,11–18] and ''clicking'' and ''crepitation'' are terms used to describe the various types of TMJ vibrations. Clicking is generally used to diagnose meniscus displacement with reduction.[19–21] Vibration can be detected in normal imaged joints, which can be confusing to the clinician.[2,11–16]

Objective assessments or special tests such as MRI, analysis of study casts, etc., in conjunction with history and clinical examination can assist diagnosis. MRI is a noninvasive procedure that produces high-quality tomographic images in any plane with excellent soft tissue resolution and without exposing the patient to ionizing radiation or any known biologic hazards.[22] It has become the gold standard for examination of the soft tissues of the TMJ.[23–26]

There is little data on which variations in the TMJ ar-

[a] Research Assistant, Department of Orthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.
[b] Professor, Department of Orthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.
[c] Professor, Department of Radiology, Faculty of Medicine, Hacettepe University, Ankara, Turkey.
Corresponding author: Ilken Kocadereli, DDS, PhD, Department of Orthodontics, Faculty of Dentistry, Hacettepe University, Süslü sokak No: 4/6 Tandogan Mebusevleri, Ankara 06580, Turkey (e-mail: ikocadereli@hotmail.com).

Accepted: January 2004. Submitted: November 2003.

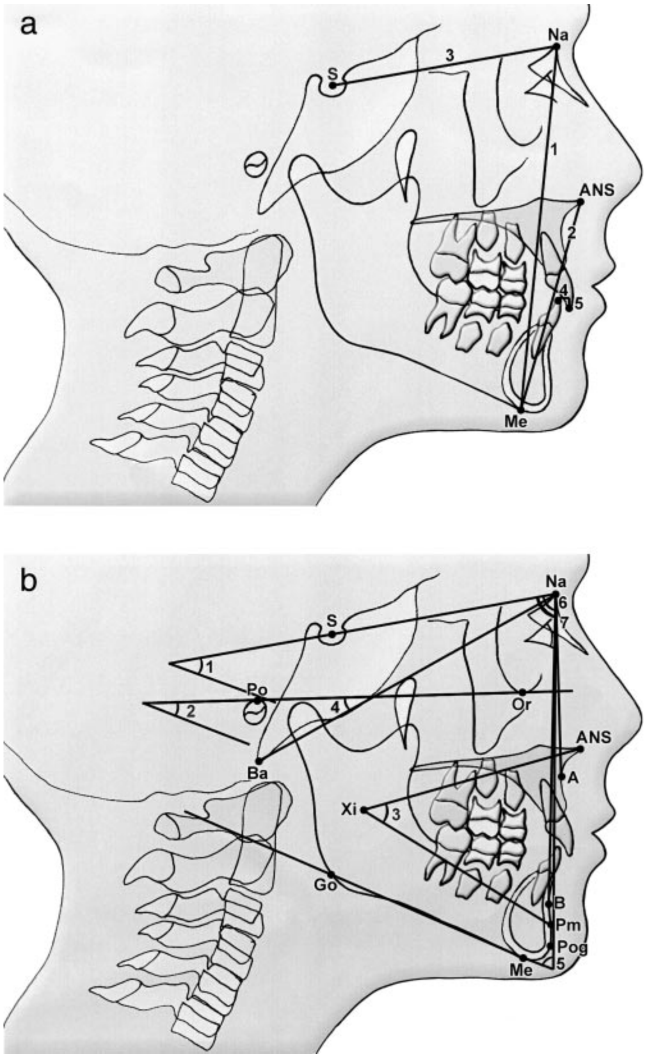

FIGURE 1a The linear measurements of lateral cephalograms: (1) anterior face height (NA-Me) (mm); (2) lower facial height (ANS-Me) (mm); (3) length between sella and nasion (SN) (mm); (4) overjet (mm); (5) overbite (mm). **(1b)** The angular measurements of lateral cephalograms: (1) GoGnSN (°); (2) FMA (°); (3) lower facial height angle (ANS-Xi-Pm) (°); (4) cranial deflection (°); (5) facial taper (°); (6) SNA (°); (7) SNB (°).

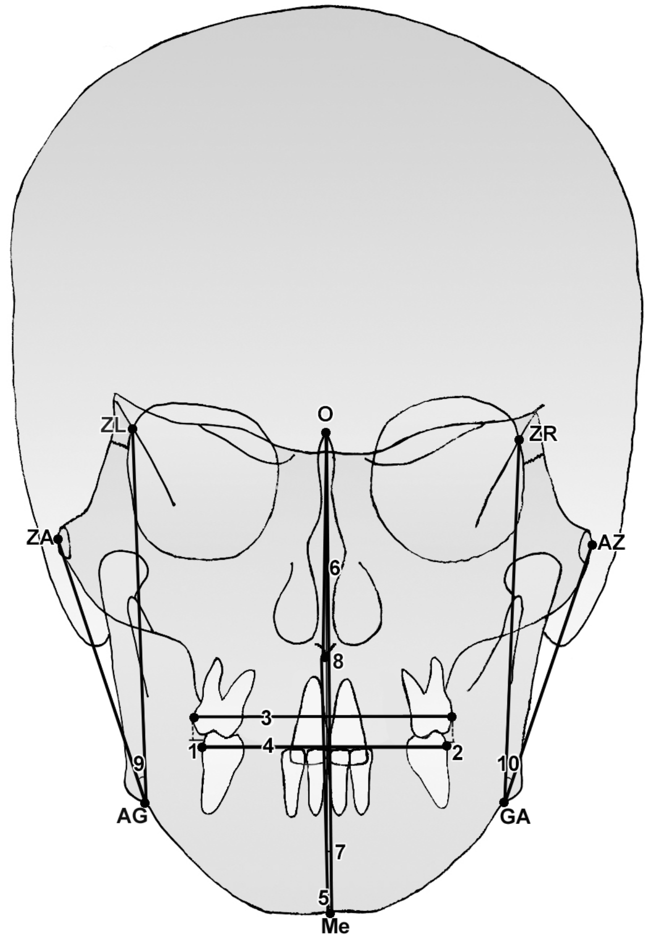

FIGURE 2. The measurements of anteroposterior cephalograms: (1) distance between the buccal contour crests of upper and lower right molars (mm); (2) left intermolar distance buccal contour crests of upper and lower left molars (mm); (3) upper intermolar width (mm); (4) lower intermolar width (mm); (5) distance between menton and midsagittal plane (mm); (6) transmaxillary position, O-ANS to midsagittal plane (°); (7) transmandibular position, O-Me to midsagittal plane (°); (8) transverse jaw relationship, O-ANS to Me-ANS (°); (9) positional symmetry angle (ZL-AG-ZA) (right) (°); (10) positional symmetry angle (ZR-GA-AZ) (left) (°).

chitecture predict normal function vs dysfunction or symptom progression. The absence of scientific proof makes decisions about otherwise normal joints problematic.

The purposes of this study are to:

- evaluate the vibration energy of asymptomatic TMJs with normal joint anatomy
- clarify disc position relative to the condyle and condylar position relative to the glenoid fossa in clinically asymptomatic and orthodontically untreated young Angle Class I subjects by MRI.

MATERIALS AND METHODS

The study population consisted of 31 (13 boys, 18 girls) clinically symptom-free and orthodontically untreated Angle Class I subjects with a mean age of 9 years 7 months (range 7 years 1 month to 11 years 7 months). The criteria for selection were: (1) no history or clinical symptoms of TMD, (2) no asymmetry of the mandible, (3) no history of orthodontic treatment, (4) no previous trauma to the face, (5) no deviation at opening, and (6) a range of opening greater than 40 mm. The exclusion criteria were pain, sounds, and clicking in the TMJ area; deviation of the lower jaw on opening; and range of opening less than 40 mm.

The study sample consisted of Angle Class I volunteer subjects who were referred to the Departments of Orthodontics or Pedodontics for routine oral examination and

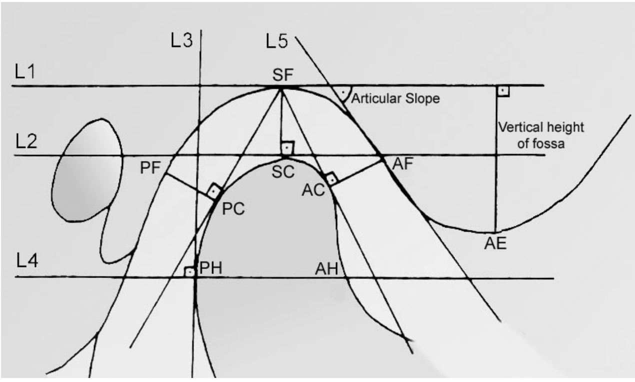

FIGURE 3. Measurements from transcranial temporomandibular joint radiographs: AJS, anterior joint space between AC and AF (mm); PJS, posterior joint space between PC-PF (mm); SJS, superior joint space between SC-SF (mm); condylar width, distance between AH and PH (mm); vertical height of articular fossa as the measurement of a perpendicular line extending from AE to line 1 (mm); angle of articular slope (°); percentage of posterior to anterior joint space (%).

who agreed to participate in this research project. Informed consent was obtained from each subject and their parents before obtaining the records. Lateral cephalometric radiographs were obtained to study skeletal features, and anteroposterior cephalograms were obtained to analyze facial asymmetry (Figures 1a,b and 2). Transcranial TMJ radiographs were obtained to evaluate the position of the condyles (Figure 3). The condylar position in the glenoid fossa was located as a percent of anterior and posterior displacement from absolute concentricity (zero) using the formula:

$$\frac{\text{Posterior joint space} - \text{anterior joint space}}{\text{Posterior joint space} + \text{anterior joint space}} \times 100 = \text{condylar position}$$

A positive value indicated an anteriorly positioned condyle, and a negative value indicated a posterior condylar position. A definite displacement of the condyle was defined as more than 12% deviation from concentricity.[27]

In the transcranial radiograph, line 1 (L1) was drawn tangent to the most superior point of the glenoid fossa (SF) and parallel to the superior border of radiogram. Line 2 (L2) was drawn parallel to line 1 and tangent to the most superior point of the condyle (SC). Then, two lines were drawn from SF point passing tangent to anterior condyle (AC) and posterior condyle points (PC). Perpendiculars to these tangents from AC and PC points intersected at the glenoid fossa at anterior fossa (AF) and posterior fossa (PF), respectively. A line was drawn through AF point tangent and best fit to the anterior slope of the glenoid fossa as the articular slope (AS). Line 3 (L3) was the line drawn perpendicular to horizontal lines and passing through the posterior border of condyle (PH). Line 4 (L4) was drawn parallel to lines 1 and 2 through the most convex point on the posterior aspect of the condylar head. The intersections of line 4 with anterior and posterior aspects of the condyle are referred to as anterior head (AH) and posterior head (PH) of the condyle, respectively. AE point showed the most inferior aspect of the crest of the articular eminence.

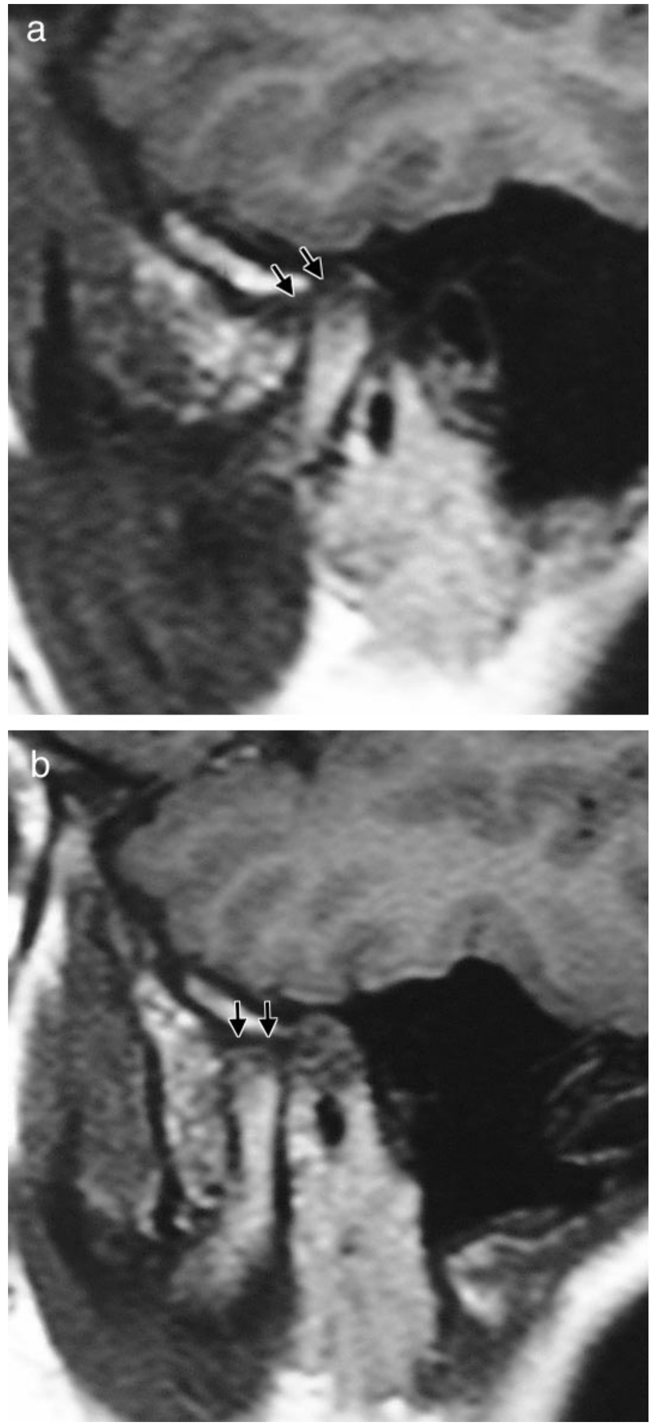

FIGURE 4. Normal temporomandibular joint. (a) Closed-mouth and (b) open-mouth oblique sagittal T1-weighted images showing normal position of disc (arrows).

The position of the articular disc was evaluated by an MRI performed with Siemens 1.5 tesla MR scanner (Sym-

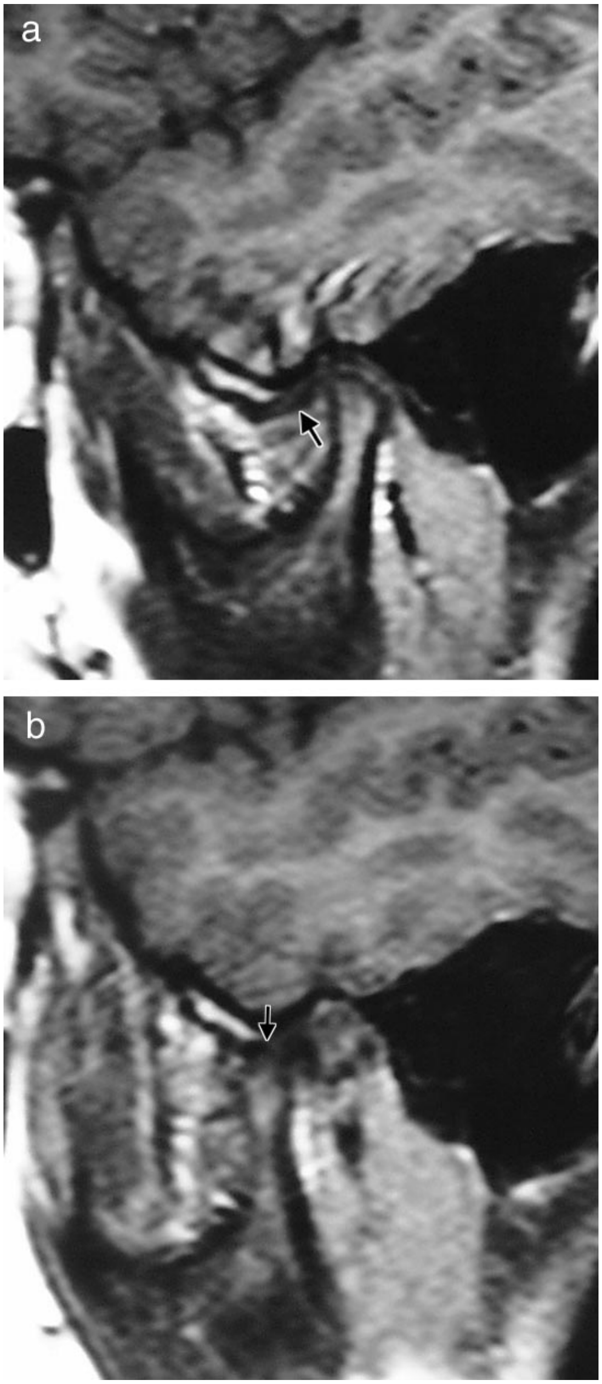

FIGURE 5. Anterior TMJ disc displacement with reduction. (a) Closed-mouth and (b) open-mouth oblique sagittal-weighted images demonstrating the disc (arrow) anteriorly displaced when the mouth is closed (a). The disc (arrow) establishes its normal position during the mouth opening (b).

phony, Siemens, Erlangen, Germany). Images were obtained at closed- and open-mouth positions. Bilateral closed-mouth sagittal sections were obtained perpendicular to the long axis of the condyle (Figures 4 and 5), and coronal images were obtained parallel to the condylar long axis. To prevent muscle fatigue, bilateral open-mouth sagittal images were produced by placing an acrylic bite plane set at 10 mm below the maximal voluntary interincisal mouth opening. Subjects were instructed to rest the anterior teeth on the acrylic bite plane. The imaging criteria for the classification of the status of the TMJ was according to Paesani et al.[3]

Normal disc position with normal function was defined as the disc located with its posterior band superior to the condyle and the inferior aspect of the central thin zone of the disc articulated against the anterior prominence of the condyle. The displaced disc establishing its normal relationship with the condyle during the mouth opening was referred to as the disc displacement with reduction. Disc displacement without reduction was the disc located more anterior than its normal position during all mandibular movements.

Surface vibration of the bilateral TMJs was recorded through electrovibratography (EVG) (SonoPAK system, Bioresearch Inc., Milwaukee, Wis). Patients were instructed to perform maximal jaw opening and closing movements guided by an electric metronome signal. The skin surface vibration signals were detected by two piezoelectric accelerometers and were sent to a differential amplifier. The attenuated filtered signal (Figure 6) was sampled on-line about 4000 sample points by a PC attached to an 8-bit A-D converter handling 1300 samples per second. The raw signal within the 200 ms window (Figure 7) was subjected to a fast Fourier transform algorithm with a resolution of 5 Hz that computed the power spectrum density function of the vibration signal (Figure 8). The following terms were calculated: total integral; integral $<$300 Hz/integral $>$300 Hz; peak amplitude; peak frequency; and medium frequency.

After running the fast Fourier transform algorithm, the peak and the median frequency (Hz) were computed. The peak frequency has the highest amplitude in the power spectrum density function. The median frequency is the frequency that divides the power spectrum density function into two regions with equal power. The integral of the EVG is the area under the curve of the power spectrum density function. The ratio of the frequencies below and above 300 Hz is the ratio between the integrals above and below 300 Hz. Peak amplitude is the absolute amplitude of the peak frequency.

Error of the method

Measurements were made twice within a 1-month interval to determine repeatability of landmark identification and measurement techniques. All angular and linear variables had a coefficient of intrarater reliability ($r = \Sigma^2$ total/Σ^2 between) between 0.85 and 1.00; thus, this error was considered negligible.

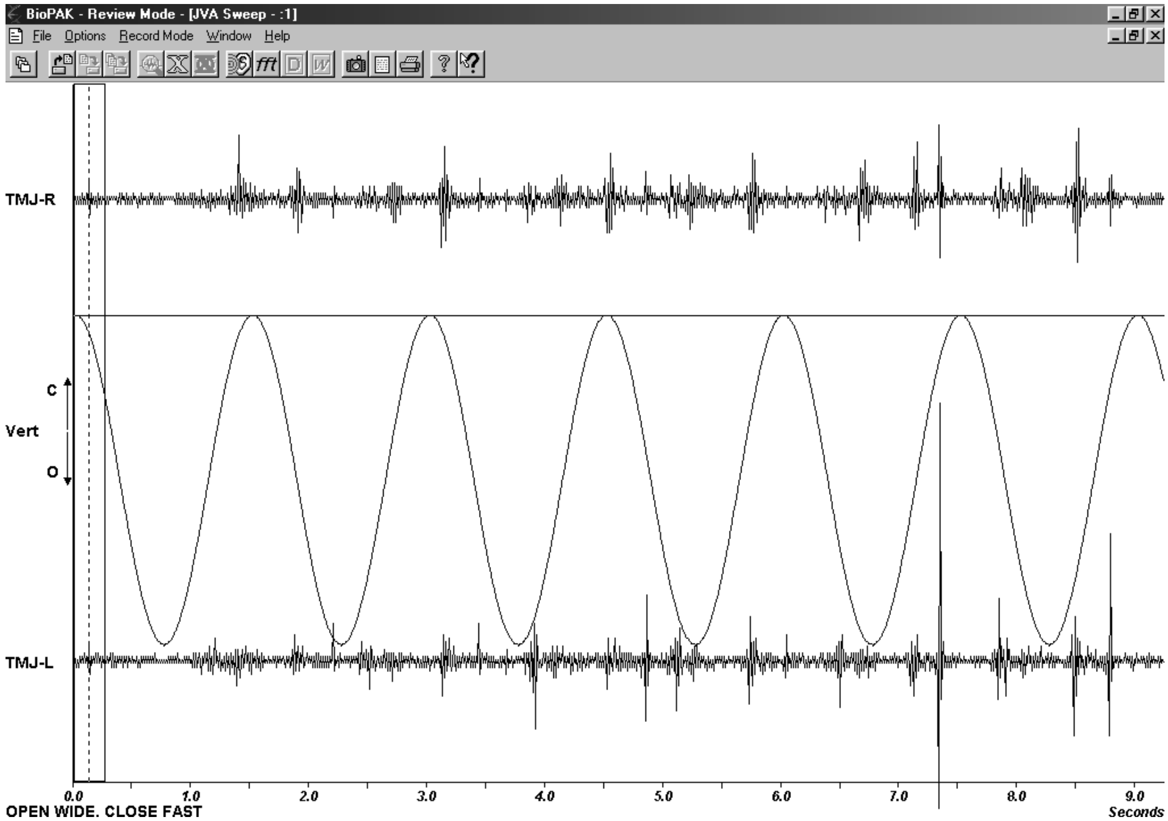

FIGURE 6. An example of raw data display obtained from a patient. The upper line shows the right TMJ vibration and the lower line shows the left one. The sinusoidal curve shows the mouth opening and closing periods.

TABLE 1. Descriptive Statistics of the Lateral Cephalometric Radiographs (n = 31)

Variables	Minimum	Maximum	Mean ± SD
Na-Me (mm)	102.46	110.36	106.03 ± 2.42
ANS-Me (mm)	58.75	69.46	62.52 ± 2.17
SN (mm)	71.31	74.04	73.18 ± 1.81
GoGnSN (°)	30.25	33.26	32.15 ± 1.29
FMA (°)	24.23	28.36	26.48 ± 1.21
ANS-Xi-Pm (°)	43.15	48.91	46.04 ± 1.50
Cranial deflection (°)	25.35	30.17	28.38 ± 1.08
Facial taper (°)	64.17	70.31	67.27 ± 1.75
SNA (°)	78.65	83.03	80.75 ± 1.17
SNB (°)	76.52	81.03	78.79 ± 1.28
Overjet (mm)	1.97	3.38	2.64 ± 0.45
Overbite (mm)	1.77	3.79	2.83 ± 0.55

Statistical analysis

Descriptive statistical analysis is performed for lateral and anteroposterior cephalometric values and transcranial TMJ radiographic values. Differences of means were tested with paired samples *t*-test, and *P* values were 2-tailed with a significance level of .05.

RESULTS

Descriptive statistics of lateral cephalometric, anteroposterior cephalometric, and transcranial TMJ radiographs are presented in Tables 1–4. According to lateral cephalometric measurements, all subjects had a mesofacial growth pattern and Class I maxillary and mandibular skeletal relationship (Table 1). The anteroposterior cephalometric measurements showed that the maxilla and mandible were positioned symmetrically with no skeletal asymmetry (Table 2). The condyles were centrically positioned in the glenoid fossa (Tables 3 and 4), and no significant differences were found between the left and right joints with respect to EVG ($P >$ .05) (Table 5).

The MRI revealed unilateral disc displacement with reduction in four of the 31 subjects (13%), unilateral disc displacement with reduction in three subjects (10%), and bilateral disc displacement without reduction in one subject (3%).

The time-frequency distributions of sounds from both right and left TMJs showed a wide range, and the results are summarized in Tables 6–8. The differences between the right and left TMJs were not statistically significant ($P >$ .05).

DISCUSSION

The imaging and EVG findings were used as a gold standard in this study. According to transcranial TMJ radiographs of the left and right TMJs, no significant differences

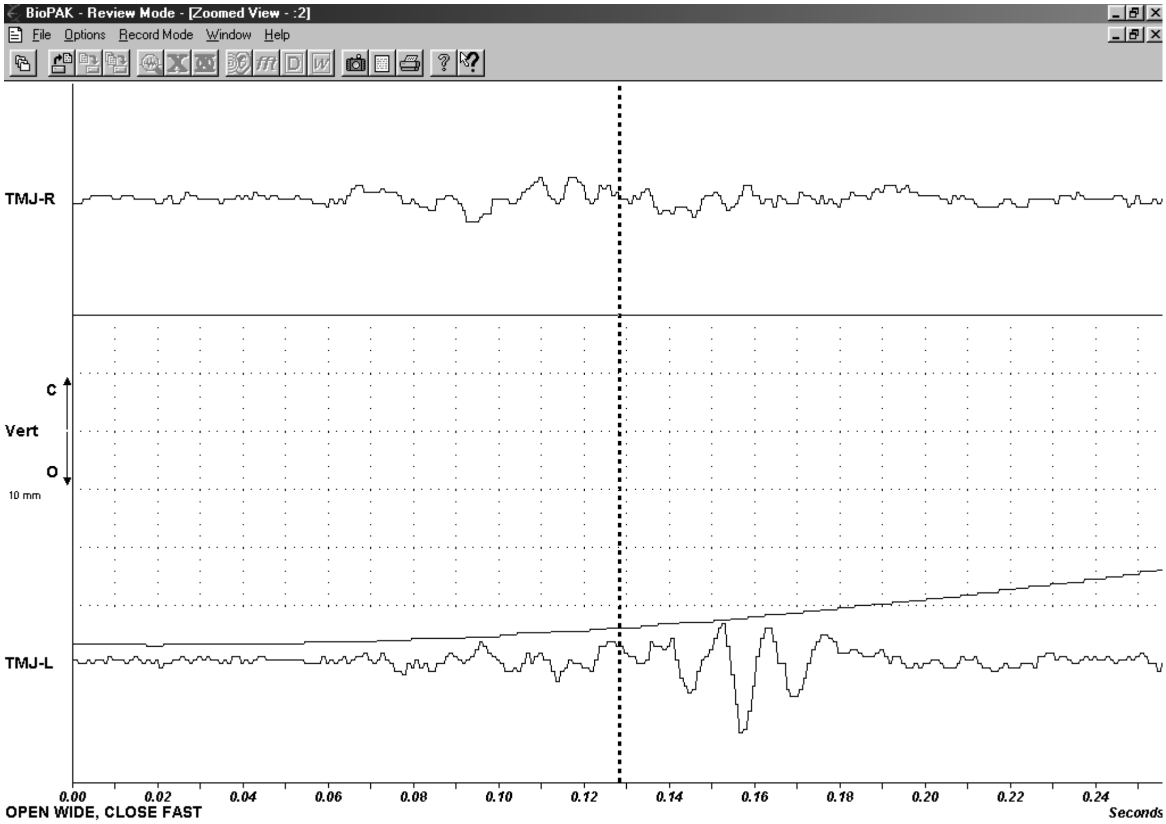

FIGURE 7. The zoomed display within the window (10 ms).

TABLE 2. Descriptive Statistics of the Anteroposterior Cephalometric Radiographs (n = 31)

Variables	Minimum	Maximum	Mean ± SD
Right molar relationship (mm)	1.28	110.36	1.85 ± 0.36
Left molar relationship (mm)	1.32	69.46	1.83 ± 0.28
Upper intermolar Width (mm)	54.2	74.04	59.96 ± 2.78
Lower intermolar Width (mm)	50.98	33.26	56.59 ± 2.77
Me-midline (mm)	0	1.35	0.79 ± 0.38
Transmaxillary position (°)	0	0.35	0.27 ± 0.17
Transmandibular position (°)	0	1.18	0.56 ± 0.28
Transverse jaw relationship (°)	0	1.35	0.33 ± 0.27
Positional symmetry angle difference (°)	0.46	1.69	0.78 ± 0.39

TABLE 3. Descriptive Statistics of the Transcranial Temporomandibular Joint Radiographs (Right TMJ) (n = 31)

Variables	Minimum	Maximum	Mean ± SD
Anterior joint space (mm)	2.21	2.71	2.49 ± 0.13
Superior joint space (mm)	2.27	2.9	2.57 ± 0.18
Posterior joint space (mm)	2.29	2.71	2.48 ± 0.11
Condylar width (mm)	8.52	11.87	10.11 ± 0.79
Articular slope angle (°)	32.15	52.86	45.52 ± 5.46
Articular height (mm)	8.52	11.87	5.8 ± 1.19
Condylar position (%)	0.87	0.95	0.89 ± 0.19

in the condylar position, joint spaces, and joint morphology were found. Some previous studies have suggested that the condyle of a normal individual is symmetrically positioned in the glenoid fossa.[27–29] On the other hand, others have reported that subjects with TMD tend to reveal asymmetric condylar positions.[30,31]

The results of the MRI findings in the present study showed TMJs with "no apparent TMD" to be associated with a high rate of internal derangements (IDs) like disc displacement with or without reduction (total percentage of IDs in this study was 26%). By choosing a group of young subjects and by using the applied exclusion criteria, we an-

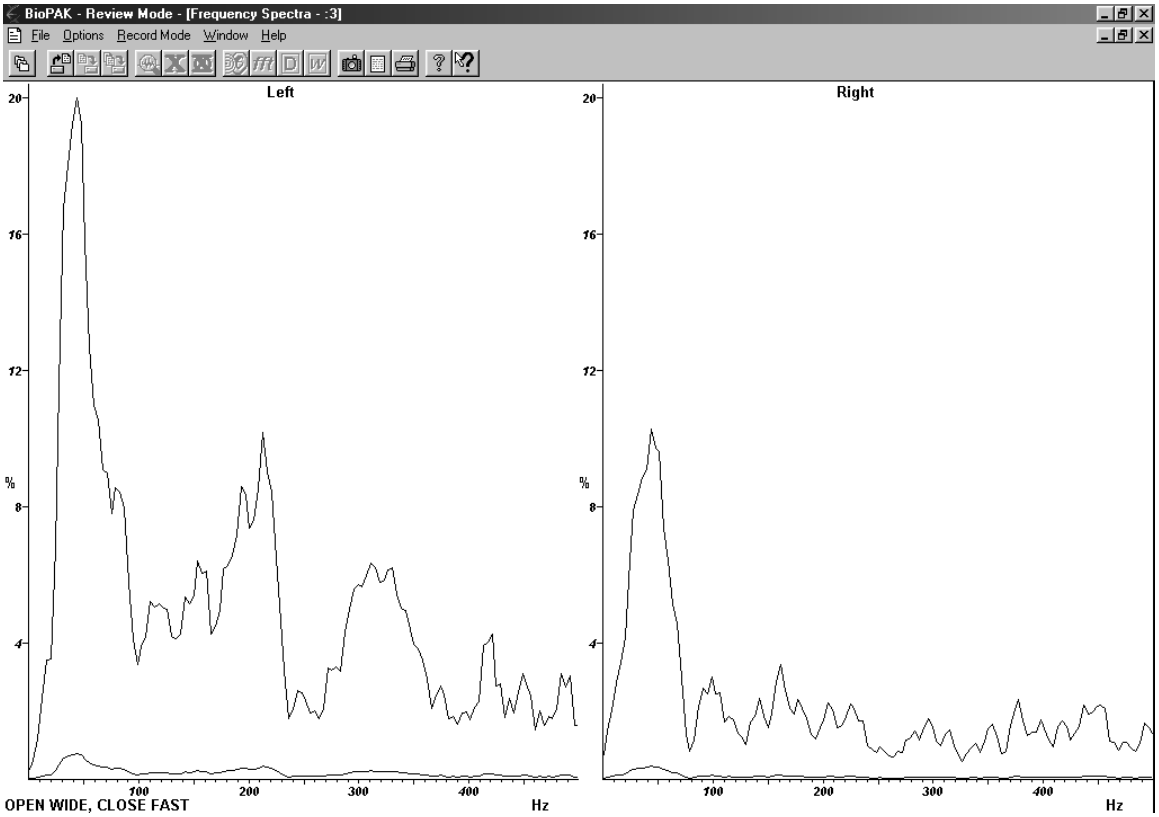

FIGURE 8. This display shows a power spectrum density function of the bilateral TMJ vibration signals. The horizontal axis represents the frequency from 0 to 500 Hz.

TABLE 4. Descriptive Statistics of the Transcranial Temporomandibular Joint Radiographs (Left TMJ) (n = 31)

Variables	Minimum	Maximum	Mean ± SD
Anterior joint space (mm)	2.26	2.73	2.48 ± 0.12
Superior joint space (mm)	2.29	3.1	2.65 ± 0.21
Posterior joint space (mm)	2.19	2.73	2.47 ± 0.19
Condylar width (mm)	8.59	11.86	10.17 ± 0.13
Articular slope angle (°)	31.97	52.76	45.79 ± 5.45
Articular height (mm)	8.59	11.86	5.91 ± 1.01
Condylar position (%)	0.86	0.94	0.88 ± 0.15

TABLE 5. Comparative Statistics of the Right and Left Transcranial Temporomandibular Joint Radiographs (n = 31)

Variables	Means Differences	*P* value
Anterior joint space (mm)	0.01 ± 0.01	.319
Superior joint space (mm)	0.08 ± 0.01	.217
Posterior joint space (mm)	0.01 ± 0.02	.418
Condylar width (mm)	0.06 ± 0.03	.372
Articular slope angle (°)	0.27 ± 0.01	.159
Articular height (mm)	0.11 ± 0.09	.316
Condylar position (%)	0.04 ± 0.12	.459

ticipated including individuals with little chance of exhibiting abnormal changes of the joint components derived from trauma, dysfunction, and so on. Despite these measures, four individuals (13%) had various types of disc displacements. This finding is consistent with those of other studies.[32–35] Given the fact that TMJ ID alone may not always be associated with pain and dysfunction, several other imaging studies have also demonstrated bilateral TMJ IDs with frequencies ranging from 51% to 71%.[3,36–38]

Electronic TMJ sound recordings have potential diagnostic value. The acoustic characteristics of the sound per-

TABLE 6. Descriptive Statistics of the Right Temporomandibular Joint Vibration Analysis (n = 31)

Variable	Minimum	Maximum	Mean ± SD
Total integral (Hz)	3.3	11.6	5.81 ± 1.83
Integral < 300/integral > 300 (Hz)	0.21	0.48	0.08 ± 0.33
Peak amplitude (Hz)	0.2	1.4	0.29 ± 0.51
Peak frequency (Hz)	35.7	111	58.97 ± 8.15
Median frequency (Hz)	41.5	205	73.81 ± 5.97

TABLE 7. Descriptive Statistics of the Left Temporomandibular Joint Vibration Analysis (n = 31)

Variable	Minimum	Maximum	Mean ± SD
Total integral (Hz)	3.5	12.8	7.38 ± 3.49
Integral < 300/integral > 300 (Hz)	0.2	0.54	0.07 ± 0.35
Peak amplitude (Hz)	0.1	1.5	0.27 ± 0.5
Peak frequency (Hz)	37.2	122	59.69 ± 7.1
Median frequency (Hz)	57	220	78.35 ± 3.83

TABLE 8. Comparative Statistics of the Right and Left Temporomandibular Joint Vibration Analysis (n = 31)

Variable	Means Differences ± SD	*P* value
Total integral (Hz)	1.67 ± 1.66	.087
Integral < 300/integral > 300 (Hz)	0.01 ± 0.98	.576
Peak amplitude (Hz)	0.02 ± 0.01	.922
Peak frequency (Hz)	1.72 ± 1.05	.819
Median frequency (Hz)	4.73 ± 2.14	.397

ceived by the listener may differ greatly from those of the sound electronically recorded to a computer via a microphone or an amplifier in the earpiece.[39] Piezoelectric transducers can be used to measure fine vibrations at the surface of the skin in the region of the TMJ. The method does not depend on the movement of air as does a microphone and, therefore, is relatively free of noise from extraneous sounds but not vibrations such as those arising from tooth contact.[40]

In our study, samples of the complex wave forms resulting from detected vibrations were subjected to fast Fourier transformations that separated the component frequencies and indicated their amplitudes. Parameters such as peak frequency, median frequency, and the integral ratios of the area below 300 Hz and above 300 Hz are used to describe the sample. The term EVG is used to embrace these measurements and to distinguish them from other methods such as sonography. Our data suggest that the vibrations recorded are not sensed by the individual or by the clinician during clinical examination and palpation.

TMJ sounds are frequently found among TMD patients.[11,17,18] It has been reported that certain groups of TMD patients show a higher incidence of TMJ sounds,[41,42] and it is very important to demonstrate the diagnostic specificity and sensitivity. Previous authors have suggested the possibility of using EVG in patients with ID. The results of these studies also suggest that the diagnostic ability of EVG analysis could be superior to that of physical examination alone.[11] According to Sano et al[43] TMJ sounds from patients who also had other signs of TMD had larger amplitudes than sounds from otherwise asymptomatic subjects and the frequency content extended beyond 1000 Hz. This finding supports the concept that TMJ sound is an important sign to consider in TMD diagnosis. Christensen et al[44] showed that 60% of the asymptomatic subjects had objective EVG findings and that the average severity and intensity of the vibrations was rather mild.

Christensen and Orloff[45] suggested that EVG signals are reproducible. In addition they stated that the EVG distinguishes between the TMJ IDs (clicking) and TMJ osteoarthrosis (crepitus). The ratio between integrals above and below 300 Hz provides information on the relative distribution of high and low vibration frequencies. Steindler[46] proposed that severe joint pathology such as osteoarthrosis would increase the relative area of the higher frequencies. The severity of TMJ clicking may also be associated with an increase in the peak amplitude.

CONCLUSIONS

This study has shown that the standardized clinical examination to determine the status of the joint is not an efficient tool. In this study, the MRI revealed unilateral disc displacement with reduction in four of the 31 subjects (13%), unilateral disc displacement with reduction in three subjects (10%), and bilateral disc displacement without reduction in one subject (3%). Nearly one of four normal joints can show ID when examined by MRI. The findings raise the question as to whether the use of clinical TMD diagnoses may need to be supplemented by MRI to identify clinically misdiagnosed TMD. From a methodological point of view, etiology, prognostic statements, and implications for treatment are considered the main indicators for the diagnostic classifications.

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