A Study of Temporomandibular Joint Sounds Part 2. Acoustic Characteristics of Joint Sounds

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Abstract

In an attempt to gain a better understanding of temporomandibular joint (TMJ) sounds, we recorded joint sounds from 14 non-orthodontically treated dental students, analyzed the acoustic characteristics of the TMJ sounds, and correlated the sound characteristics with axiographic features, morphologic observations of X-ray images and clinical history. The group with a low peak frequency (< 500 Hz) of the opening click had a shorter history of subjective joint sound, a longer distance between the opening and closing curves, and a low rate of TMJ transformation. For the closing click, the history of subjective joint sounds tended to be longer when the duration of the wave was short.

Acoustic analysis of TMJ sounds could be an aid to the differential diagnosis of temporomandibular disorders, although it is difficult to deduce the clinical history and internal deformities of the TMJ based solely on acoustic characteristics.

Introduction

It is generally considered that temporomandibular joint (TMJ) sounds should be a sign of stomatognathic dysfunction. Epidemiologic studies have suggested that TMJ sounds indicate irregularities and adhesions on the articular surfaces and disk displacement with reduction^[1,2]. In our previous study^[3,4], the incidence of TMJ sound, and the relationship between the presence of sound and the prevalence of disc displacement were investigated in an attempt to find the causes of TMJ sounds. Early opening sounds may be related to irregularities at the lateral pole of the condyle owing to tension from the lateral ligament and/or stretching of the ligament. Late opening sounds may follow the slight condylar slips over the anterior ridge of the disc close to the maximum mouth opening position, and this may be associated with a decrease of synovia. In this study, we concentrated on the acoustic characteristics of TMJ sounds, and separated the signals into their spectral components. The time frequency distributions were also analyzed in order to accumulate some diagnostic information on TMJ disorders.

Materials and Methods

Non-orthodontically treated dental students at Nihon University School of Dentistry who complained of TMJ sounds were examined for the presence of clicking using a stethoscope. Fifteen joints producing sounds during jaw opening and 14 joints producing sounds during closing movement were detected among 14 students (Table 1). These joint sounds were then recorded on a DAT (SONY TCD-D10) using a microphone (TOEI MM80S) with resin caps made for fitting to the external ear (Fig.1). An analog/digital converter with a $25\ \mu\text{s}$ conversion time and a 12-bit resolution was used for digitization of the recorded signal, and the duration of the wave was measured. The digital wave was separated into its spectral components by the fast Fourier transform (FFT) after 7-point smoothing, and the peak frequency and limits of maximum

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frequency of the power spectrum were measured. Thereafter the time frequency distribution of the sound was calculated and displayed as a sonogram. Joint movements were traced by a computer-aided axiograph (SAM CADIAX). On the axiographic tracings of the hinge-axis point, maximal distances between the opening and closing curves were measured (Fig.2) and the bulge suspected to indicate the presence of disarrangement was investigated (Fig.3). Information about restricted condylar movement and the history of subjective joint sounds was obtained from an interview questionnaire. Presence of transformation of the condyle was diagnosed using X-ray images for each subject.

Table 1 Distribution of TMJ sounds

	TMJ sounds	
	During opening movement	During closing movement
Right	8	8
Left	7	6
TOTAL	15	14
Male	8	6
Female	2	1
TOTAL	10	7
Age (mean)	23.3 y	23.6 y

Fig. 1 A pair of microphones with resin caps for fitting to the external ears

Fig. 2 A method of measuring maximum distance between the opening and closing curves of the axiographic tracing

Fig. 3 The bulge suggestive of disarrangement on the axiographic tracing

Results

The results of acoustic analysis of joint sounds during opening along with diagnostic information are shown in Tables 2 through 4. With regard to the duration of digital waves, no significant difference was observed (Table 2). The subjects were divided into two groups by the peak frequency at 500 Hz. There were significant differences in the maximal distance between the opening and closing axiographic curves, the history of subjective joint sounds and the transformation of the condyle (Table 3). We then sorted the subjects according to the limits of maximal frequency of the power spectrum. No significant difference between the high-frequency group (≥ 500 Hz) and the low-frequency group (< 500 Hz) was observed (Table 4).

For joint sounds that occurred during the closing movement, a significant difference in the history of subjective joint sounds was observed between the groups with a wave duration of less than and more than 40 s (Table 5). There were no significant differences in the peak frequency and the limits of maximal frequency of the power spectrum (Tables 6 and 7).

Figure 4 shows a scattergram of the peak frequencies of the opening click in 15 joints, which were divisible into two groups, one around 70 Hz (A) and the other around 800 Hz (B). The time frequency distributions for each subject were calculated and displayed as the sonogram. In typical contour-plots (sonogram) of TMJ sounds, varied features were observed. As the frequency component changes were observed with time in group A, high-frequency components were synchronized with the maximal amplitude of the wave, and low-frequency components were carried to the latter half of the wave (Fig.5). The sonogram for group B (Fig.6) showed an obscure picture indicating no significant features of temporal change in the frequency component.

Table 2 Association between duration of the wave and diagnostic information

- Opening click -

		Duration of the wave		sig.*
		$< 40 \mu s$	$\geq 40 \mu s$	
Maximal distance between opening curve & closing curve	mean	1.1	1.3	-
	S.D.	0.5	0.5	
The bulge on axiographic tracing		29%	63%	-
History of subjective joint sounds	mean	7.3	5.4	-
	S.D.	6.3	5.0	
Existence of restricted condylar movement in clinical history		14%	63%	-
Transformation of the condyle		57%	13%	-

* Student's t test

Table 3 Association between peak frequency and diagnostic information

- Opening click -

		Peak frequency		sig.*
		$\geq 500\text{Hz}$	$< 500\text{Hz}$	
Maximal distance between opening curve & closing curve	mean	0.8	1.4	5%
	S.D.	0.3	0.5	
The bulge on axiographic tracing		0%	64%	-
History of subjective joint sounds	mean	10.8	4.6	5%
	S.D.	6.1	4.6	
Existence of restricted condylar movement in clinical history		0%	55%	-
Transformation of the condyle		100%	9%	1%

* Student's t test

Table 4 Association between limits of maximum frequency and diagnostic information

- Opening click -

		Limits of maximum frequency		sig.*
		$\geq 500\text{ Hz}$	$< 500\text{ Hz}$	
Maximal distance between opening curve & closing curve	mean	1.1	1.3	-
	S.D.	0.5	0.4	
The bulge on axiographic tracing		29%	63%	-
History of subjective joint sounds	mean	7.0	5.6	-
	S.D.	6.6	4.8	
Existence of restricted condylar movement in clinical history		14%	63%	-
Transformation of the condyle		57%	13%	-

* Student's t test

Table 5 Association between duration of the wave and diagnostic information

- Closing click -

		Duration of the wave		sig.*
		< 40 μ s	$\geq$ 40 μ s	
Maximal distance between opening curve & closing curve	mean	1.1	1.4	-
	S.D.	0.6	0.5	
The bulge on axiographic tracing		25%	50%	-
History of subjective joint sounds	mean	7.5	1.0	5%
	S.D.	7.5	1.0	
Existence of restricted condylar movement in clinical history		25%	0%	-
Transformation of the condyle		25%	0%	-

* Student's t test

Table 6 Association between peak frequency and diagnostic information

- Closing click -

		Peak frequency		sig.*
		$\geq$ 500 Hz	< 500 Hz	
Maximal distance between opening curve & closing curve	mean	0.7	1.3	-
	S.D.	0.4	0.6	
The bulge on axiographic tracing		0%	42%	-
History of subjective joint sounds	mean	4.0	4.8	-
	S.D.	0.1	7.0	
Existence of restricted condylar movement in clinical history		0%	17%	-
Transformation of the condyle		0%	17%	-

* Student's t test

Table 7 Association between limits of maximum frequency and diagnostic information

- Closing click -

		Limits of maximum frequency		
		≥ 500 Hz	< 500 Hz	sig.*
Maximal distance between opening curve & closing curve	mean	1.0	1.3	-
	S.D.	0.6	0.5	
The bulge on axiographic tracing		0%	50%	-
History of subjective joint sounds	mean	8.5	3.2	-
	S.D.	6.7	5.8	
Existence of restricted condylar movement in clinical history		25%	10%	-
Transformation of the condyle		25%	10%	-

* Student's t test

Fig. 4 Scattergram of peak frequency of the opening click

Fig. 5 Time frequency distribution from group A joint with clicking during opening

Fig. 6 Time frequency distribution from group B joint with clicking during opening

Discussion

In order to develop a diagnostic method for TMJ disorders, it is important to differentiate between sounds that indicate pathology and those that do not. A number of studies have attempted to characterize certain variations in TMJ sounds, and the analog forms of TMJ sounds have been recorded by many researchers^[5-9]. However, it is difficult to interpret variations in these analog forms. In order to analyze TMJ sounds quantitatively, it is necessary to separate the signals into their spectral components. Recently, many researchers^[10-16] have carried out acoustic analysis of joint sounds, but a clear understanding of its diagnostic value has not yet been obtained.

When our present subjects were divided into two groups at a boundary peak frequency of 500 Hz, significant differences were observed in the maximal distance between the opening and closing curves, the history of subjective joint sounds and the incidence of condylar transformation. The group with a low peak frequency (< 500 Hz) showed a larger maximal distance, a shorter history and a lower incidence of transformation than the group with a high peak frequency (≥ 500 Hz). TMJ sounds due to slipping of articular discs were recognizable by the presence of irregular jaw movement, a short history and lack of condylar transformation. If the peak wave frequency of the TMJ sound was low, then slipping of the articular discs might be suspected. Conversely, a long history, with the presence of condylar transformation due to injury of the articular disks or retrodiscal ligaments might be associated with a high peak frequency.

Only in the duration of the wave during jaw closing was a significant difference observed; the group with a duration of less than $40 \mu\text{s}$ showed a longer history of subjective TMJ sounds than the group with a duration of more than $40 \mu\text{s}$. It is considered that the amplitude of signals during closing sounds can be smaller than those during opening sounds, and thus it is difficult to extract pure signals of small sounds from the signal to noise ratio.

The distribution of the peak values for opening sounds allowed the subjects to be divided into two groups; an approximately 70 Hz group (A) and an 800 Hz group (B)(Fig.4). Group A had a shorter history and a lower incidence of condylar transformation than group B. Therefore, measurement of the peak frequency of TMJ sounds might help to clarify their cause. If the sounds are caused by slipping of the articular discs during opening movement, the frequency peak would be around 70 Hz, whereas if the sounds are due to perforation of the discs or retrodiscal pad, the frequency peak would be approximately 800 Hz. Considering the sonogram of TMJ sounds in group A, high-frequency components were synchronized with the maximal amplitude of the wave. However, low-frequency components left their traces in the latter half of the wave. This feature of the time frequency distribution may be important for finding the characteristic sounds resulting from slippage of the articular discs. The sonogram for group B had no significant feature related to changes in the frequency component with time.

Conclusions

1. Acoustic analysis of joint sounds during opening
When the present subjects were divided into two groups according to the peak frequency at 500 Hz, there were significant differences in the maximal distance between the opening and closing axiographic curves, the history of subjectives joint sounds and the transformation of the condyle. No significant difference was observed in other measurements.
2. Acoustic analysis of joint sounds during closing
A significant difference was observed only between the groups with a wave duration of more than or less than $40 \mu\text{s}$ and in the history of joint sounds.
3. The scattergram of the peak frequencies was divisible into two groups; one of approximately 70 Hz (A) and one of about 800 Hz (B), and the time frequency of distribution was calculated and displayed on a sonogram. The results suggest that the time frequency distributions may be important for finding the characteristic sounds of TMJ dysfunction.

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