A STUDY OF SOUND ANALYSIS OF TEMPOROMANDIBULAR JOINT

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CONTENTS

Ⅰ. INTRODUCTION

Temporomandibular joint(TMJ) sounds are the most frequent of all signs and symptoms within the broad spectrum of craniomandibular disorders(CMD) in nonpatient groups and patients with CMDs[1-4]. TMJ sounds can be perceived by placing the finger tips over the lateral surfaces of the joint and having the patient open and close the mouth. Often they may be felt by the fingertips[5]. Despite the simplicity and ease, the accuracy and interexaminer and/or intraexaminer reliability of clinical sound perception have been a subject of controversy[6]. Methods and criteria for recording joint sounds differ in the various reports, and this, combined with natural fluctuations, is possibly the reason for the wide range of TMJ sounds that appear[2].

The etiology of clicking is not clearly understood : Uncoordinated muscle function of the lower and upper part of the lateral pterygoid muscles[7], specific internal derangement of the articular disk[5,8], and morphologic variation of the condylar head[9,10] have been suggested as etiologic factors. TMJ clicking has been proposed by some authors to be a progressive disturbance[11]. Accordingly, a number of different treatment modalities have been advocated[2]. But some authors didn't agree to treatment of the only click without other dysfunctional symptoms. Crepitation from TMJ is often associated with degenerative joint diseases such as arthrosis or rheumatoid arthritis[12].

Truelove et al.[6] suggested that reliability for recording TMJ sounds might be confused by untrained examiners and non-systematic changes in joint sounds that occurred with repeated observations. They also found even trained examiner pairs agreed only on 69% of trials of listening joint sounds with stereo stethoscopes. Roberts et al.[4] found most of the clinical signs and symptoms investigated were not sufficiently reliable in themselves to permit prediction of the condition of the disc.

Some terminologies used for TMJ sound discription have sometimes vague definitions. Watt[13] discussed the problem of the terms 'early, middle or late' for the description of timing in opening or closing joint sounds, and he proposed the terms 'near', 'middle' and 'wide' according to their positions when the sounds occurred. But even his classification lacked

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quantified standard and has left the chance of misunderstanding by other examiners.

A number of studies have sought to quantify TMJ sounds and to relate them to possible dysfunctions[14-25,33,34]. Agerberg et al.[14], Bush et al[15], Vincent et al.[16] developed methods based upon clinical informations. Isberg-Holm et al.[17] conducted extensive autopsy studies with arthrography and cineradiography, and Wilkes[18,19], Dolwick et al.[20], Oster et al.[21] used arthrogram. Ciancaglini et al.[22] used phoncardiography transducer in acoustical analysis. Watt et al.[13,33,34], Ouellette[23], Heffez et al.[24], Lee at al.[35], Christensen [36-38],Wabeke et al.[39] and Ishigaki et al.[40] investigated the joint sounds with sonogram.

The major interest in this study is in the sound energy ratio and peak amplitude of the sound recorded and analysed simultaneously from both TMJ. The purpose of this study is to estimate clinical adaptability of SonoPAK (Bioresearch, Inc USA), a computerized sound power-spectrum analyser, to record the raw data obtained, and to classify the patient group according to the power spectra and peak amplitude ranges of the TMJ sound. Transcranial TMJ projection series and orthopantomogram results are compared with cases of certain joint sound frequencies.

Ⅱ. MATERIALS AND METHODS

1. Subjects.

106 patients with craniomandibular disorder who complained of temporomandibular joint sounds were selected(table 1).

2. Methods

SonoPAK(Bioresearch, Inc. USA) procedure was done for all the subjects. Each subject sat infront of the computer installed with SonoPak program in a quiet room. Headphone-like SonoPAK sensors were placed over both right and left temporomandibular joints. The right SonoPAK sensor was plugged into channel 5 of the Bio EMG and the left sensor was plugged into channal 8. The subject was explained about what he or she should do and when he or she opened wide and closed, the sounds generated from both TMJs were recorded and analyzed simultaneously and automatically. All other procedures were done according to manufacturer's instruction. Zoomed window was used to find the occurence of meaningful sound.

The complete SonoPAK printout is composed of raw data(all TMJ sounds plus jaw movement recorded), zoomed data(enlarged view of data located inside zoom window), location of sound (in relation to open/close cycle), sound analysis of right and left joint and numerical values (both right and left 0-300Hz integral, Above 300Hz integral, $\Sigma(>300Hz)/\Sigma(<300Hz)$ ratio, peak freguency, peak amplitude) (fig.1 to fig.4). All the subjects were taken both right & left transcranial TMJ series(at maximum articulation, one inch opening between upper & lower incisors, and wide opening possible) and orthopantomogram. Any changes in hard tissue integrities in temporomandibular joint were recorded.

3. Statistical analysis

The data of age, gender, radiologic assessment, right(left) opening/closing frequency radio, right(left) opening/closing peak amplitude of 106 patients were computed into a personal computer and frequencies, mean values and standard deviations of variables were attained using SPSS Pc+(Microsoft corp.). Statistical analysis was performed with student's t-test.

Ⅲ. RESULTS

A total of 106 patients, 210 sound occurrence cases were examined and analyzed for this study. Age and sex distribution of patients are illustrated in table 1. Distribution of reciprocal, opening and closing TMJ sound is illustrated in table 2. Incidence of opening joint sound(35.2 %) was more frequent to that of closing joint sound (22.9%).

Distribution of TMJ sounds according to sound energy ratio(Σ(>300Hz)/Σ(<300Hz)) is illustrated in Table 3. Cases which showed the frequencies solely under 300Hz were 34, and cases which showed frequencies above 300Hz were 176.

The mean values and standard deviations of peak amplitudes of opening and closing sounds among reciprocal sound patients and shown in table 4. Extreme data were not included. we could not find significant differences in mean values between opening peak amplitude and closing peak amplitude($p>0.05$).

Distribution of loudness of TMJ sounds is summarized in table 5. We could classify the joint sound loudness according to degree of peak amplitude. Amplitude range of weak sound was from 0 to 9.9(%). That of moderate and load sound was from 10(%) to 39.9(%) and above 40(%) respectively.

Mean values and standard deviations with skewness of patients with osseous changes in radiologic examination and patients without changes are illustrated in table 6. The average of sound energy ratio in patient group with whom bony changes in transcranial TMJ series

Table 1. Age, Sex Distribution of Patients

Sex	Age	0−19	20−29	30−39	40−49	50−
Male(No.)	48	21	23	1	2	1
%	45.3	19.8	21.7	0.9	1.9	0.9
Female(No.)	58	16	27	9	3	3
%	54.7	15.1	25.5	8.5	2.8	2.8
Sum(No)	106	37	50	10	5	4
%	100	34.9	47.2	9.4	4.7	3.7

Table 2. Distribution of Reciprocal, Opening and Closing TMJ Sounds

Reciprocal	Opening	Closing	Sum
88	74	48	210
41.9	35.2	22.9	100(%)

Table 3. Mean Values and Standard Deviations of Opening and Closing Sound among Reciprocal Sound Patients (n=37)

Opening Sound		Closing Sound		
Mean	S.D.	Mean	D.D.	P>0.05
18.6	15.6	16.6	17.4	

Table 4. Distribution of Peak Amplitude(Loudness) of TMJ Sounds

Peak(%) Amplitude	ROPA	LOPA	RCPA	LCPA	SUM	%
0−9.9	30	29	24	27	110	52
10.0−39.9	19	29	11	20	79	38
40.0−	5	6	5	5	21	10
SUM	54	64	40	52	210	100

ROPA : Right Opening Peak Amplitude
LOPA : Left Opening Peak Amplitude
RCPA : Right Closing Peak Amplitude
LCPA : Left Closing Peak Amplitude

and orthopantomogram result were detected, was 0.387±0.284. On the other hand, 147 patients with the energy ratio above 0.01 but didn't have bony changes detected, had mean value 0.286±0.227.

Table 5. Distribution of TMJ Sounds according to $\Sigma(>300Hz)/\Sigma(<300Hz)$

Ratio	Rt. Opening	Lt. Opening	Rt. Closing	Lt. Closing	Sum
0	6	6	10	12	34
0.01−0.09	8	11	4	10	33
0.10−0.19	9	10	5	7	31
0.20−0.29	12	16	4	6	38
0.30−0.39	6	8	9	7	30
0.40−0.49	6	3	3	1	13
0.50−0.59	2	1	2	4	9
0.60−0.69	1	5			6
0.70−0.79	1		1	3	5
0.80−0.89	1	1	2		4
0.90−0.99				1	1
1.00−1.99	2	1		1	4
2.00−2.99		1			1
3.00−3.99		1			1
Sum	54	64	40	52	210

Table 6. Mean and Standard Deviation with Skewness of Patients with Osseous Changes in Radiologic Examination and Patients without Changes

	Mean	S.D.	Skewness
W.B.C	0.387	0.284	0.885
N.B.C	0.286	0.227	1.634

W.B.C. With Bone Change Detected (n=18)
N.B.C. No Bone Change Detected (n=147)

IV. DISCUSSION

As with table 1, over the 80% of the patients with TMJ sounds were teens and twenties and about 55% of the patients were females. TMJ symptoms are said to be more frequent in women[26]. This has been explained by the fact that women seek treatment for TMJ problems more often than men, as they do for dental treatment in general [14,27].

In the quantitative comparison of the sound power spectra which was facillitated by defining specific parameters for the power−spectrum waveform, Hutta et al.[25] divided the power spectra into low−frequency (0 to 300Hz) and high−frequency(301 to 600Hz) ranges and computed the relative amount of sound energy present in each particular range and the ratio of high−frequency energy divided by lower−frequency energy. And they showed the increase of the ratio in the patient group with disc displacement without reduction. The frequency at which the highest energy level occured was defined as peak frequency. They also examined the power−spectrum wave forms for gross differences in degree of smoothness and number of energy peaks present. The author followed their methodologic criteria.

Complex sounds such as produced by the TMJ can be analyzed in two modes.

1. The time domain gives a measure of total energy versus time and includes vibrations at all frequencies simultaneously.
2. The frequency domain gives the spectum of energy of a given sound partitioned among different frequencies[12]. Most of the studies concerning TMJ sound analysis were focused on the time domain wave form[28-31].

Some of recent studies put interest on frequency domain of sound elicited by the TMJ. Oster and associates[21] study showed in TMJ internal derangement with reduction patients group that the opening click was distinct and louder than the closing click, as shown by amplitude differences, and also observed the opening click generally contained higher frequency oscillations than the closing click. In this study, as illustrated in table 2 and table 4, opening click occurred much frequently than closing click, and average opening peak amplitude was 18.6 (%) while average closing peak amplitude was 16.6(%) though statistical significance could not be found.

The sound energy ratio distribution is shown in table 3. Brooks[32] classified the ratio ranges of the sound energy into tentative four categories such as soft tissue sounds from 0 to 0.29, acute click 0.30 to 0.49, mixed sounds from 0.50 to 0.99 and crepitus from 1.00 to 1.50. He said soft tissue sound and/or click occured mainly below 300Hz, but in degenerative joint disease, crepitus, disc perforation etc, the sound occured in a wide frequency range. However this kind of classification is literally a tentative one. Rather, each sound case should be evaluated according to sound frequency spectra form and ratio, timing of sound occurrence and other corresponding clinical informations collected. For instance, as shown in table 6, despite the presence of crepitus the ratio of energy is far below 1.0.

As the intracapsular disease of the TMJ progresses the peak frequency and the ratio of the energy seems to increase. Roughness or presence of small peaks in the wave form tends to increase accordingly. Some patients showed multiple vibrations of low amplitude and broad range of frequency suggesting the presence of degenerative joint disease.[25]

Typical clicking sound has relatively smooth and usually single episode in frequency domain wave form and is silent before and after the short duration of oscillations of wave in time domain view. Fig. 1 shows SonoPAK pattern of typical click.

Crepitus has jagged wave form which appears distinct in frequency domain window, and energy portion above 300Hz appears more than in click case. The result therefore, is increased $\Sigma(>300Hz)/\Sigma(<300Hz)$ ratio[25]. Fig. 2 shows SonoPAK pattern of crepitus.

Fig. 3 shows mixed more than one sound occurrences. Zoomed window shows two small spikes and right frequency spectum window shows typical saw blade like appearance.

Fig. 4 shows eminence sound which is produced when the condylar head passes over the articular eminence of glenoid fossa. It happens at or near the eminence and typically has gross double ups and downs.

The new instrument gives us new challenges and new possibilities. Further quantitative classification in the TMJ sounds between dysfunction groups through the use of power-spectrum analysis as in this study is needed. There should be further research to correlate specific wave forms with frequency ratio and peak amplitude. And more studies combined with other clinical signs and symptoms to lessen subjective skipping or misinterpretation of the symptom or interexaminer differences are expected.

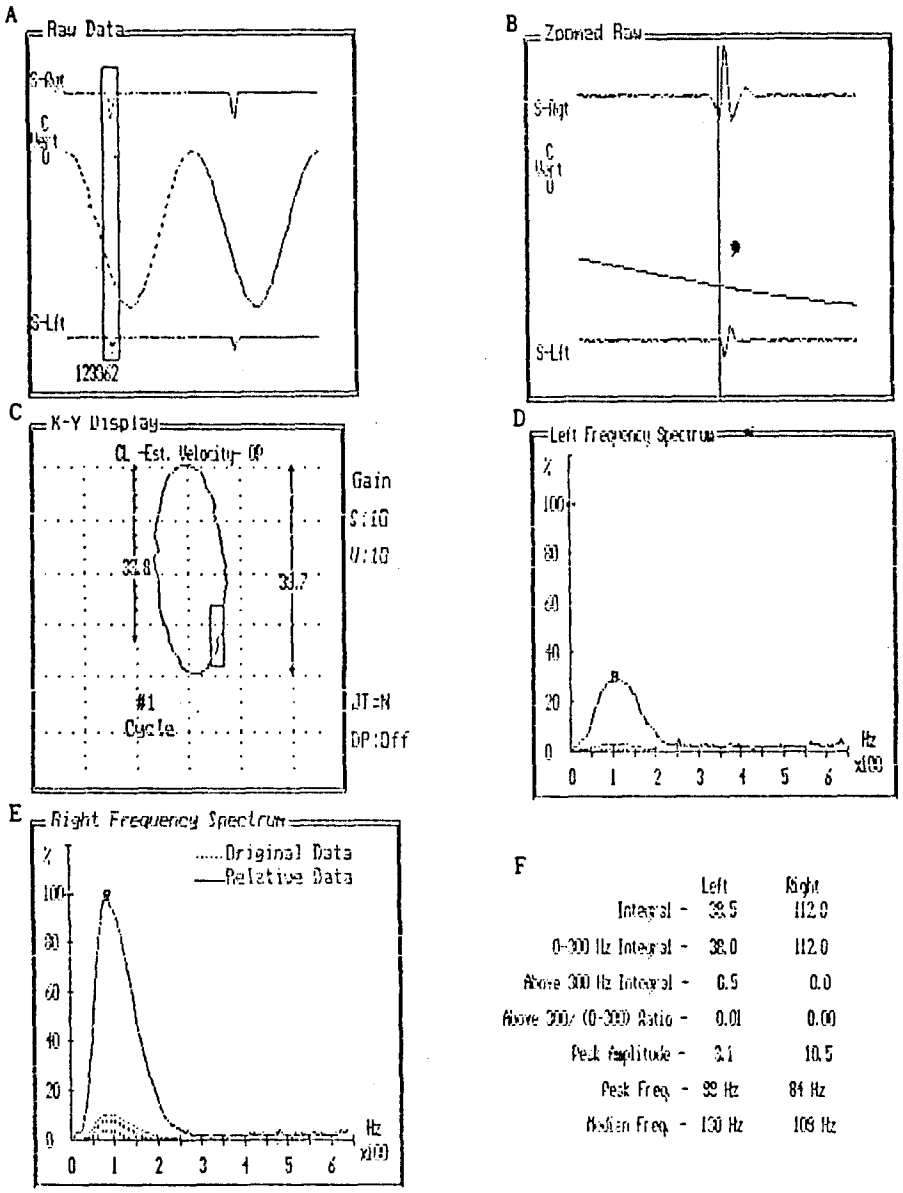

Fig. 1. Click pattern A. Raw Data window shows opening and closing cycles of mouth and apperances of joint sounds from right(s−Rgt) and left(s−Lft) TMJ. B, Zoomed Raw window shows right click and left propagated vibration typically smaller in oscillation and looks like a mirrow image in wave pattern. Vertical incline shows it's in opening phase. C,X−Y Display window shows the occurrence of click in late stage of open phase, maximum of which is 33.7mm. D and E, Frequency Domain window with F,. Numerical data, offers many implications. The frequency pattern in E is smooth and single indicating it is a click wave and relative peak data shows the click site is right TMJ. All the frequencies are below 300Hz, and sound energy ratio is 0.00 which is thought as a soft tissue sound with peak amplitude of 10.5 that is relatively weak to moderate loudness.

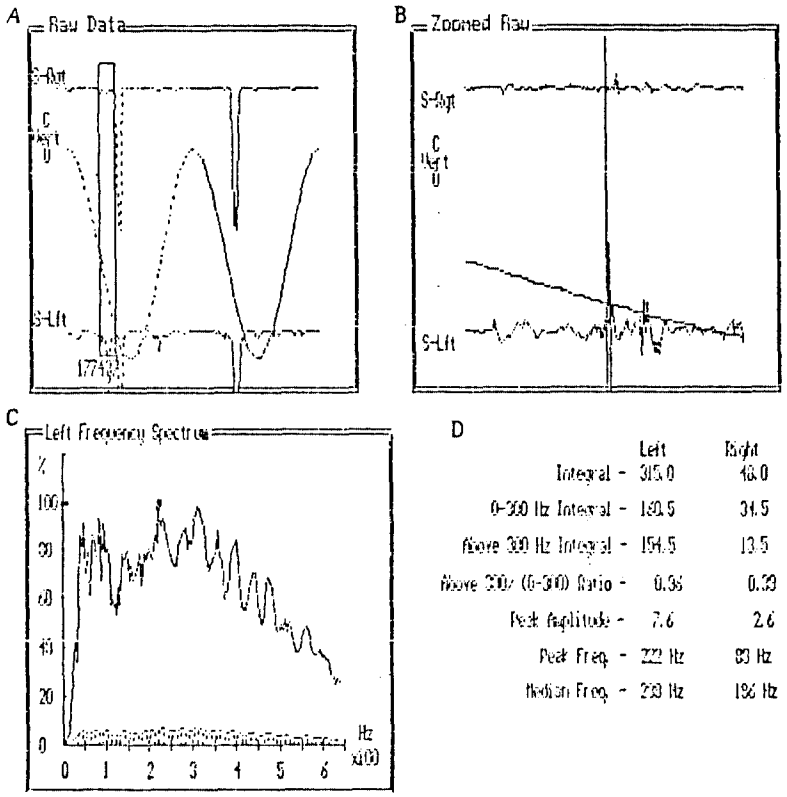

Fig. 2. Crepitus A, Raw data window shows spike in S−LFT B. Zoomed raw window shows left opening multiple oscillation of time domain view, C,D shows jagged frequency spectum with the energy ratio of 0.96 in left joint.

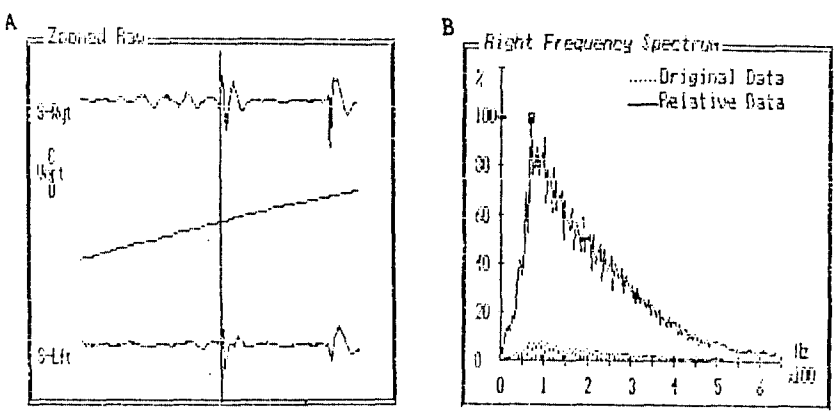

Fig. 3. mixed sound pattern

A. Zoom window shows more than one spike of sound occurrence which is reflected as saw blade appearance of frequency spectra in B.

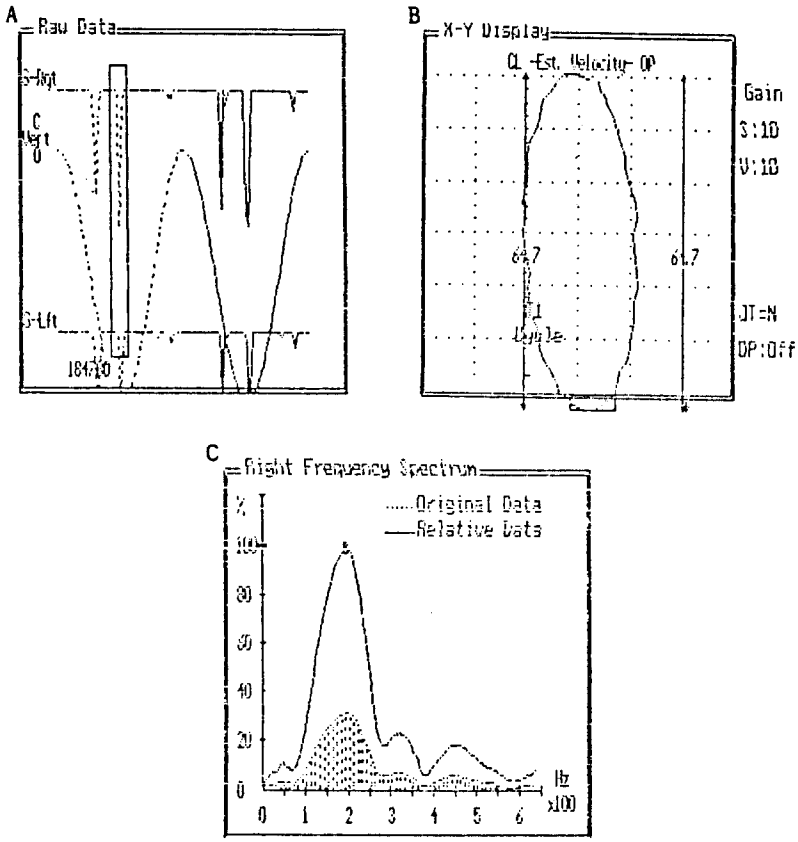

Fig.4. Eminence sound A,B. Raw data window and X−Y display shows the joint sound occurred near the maximum opening(ie, near art articulating eminence) and, C. shows typical double ups and downs of frequency spectra pattern.

V. CONCLUSIONS

Analysis of the TMJ sounds with Computerized sound power−spectrum analyser and comparison with the transcranial TMJ series and orthopantomogram were performed for 106 CMD patients who complained the presence of the joint sounds.

The obtained results were as follows :

1. The records of reciprocal joint sounds, opening and closing joint sounds were 88cases (44 opening & 44 closing), 74 cases and 48cases respectively. The opening joint sounds appeared more frequently than closing sounds.

2. In patients with reciprocal joint sound, mean of opening peak amplitude was 18.6±15.6(%), where as mean of closing peak amplitude was 16.6±17.4(%). There was no significant difference between them($p>0.05$).

3. The loudness of sounds recorded could be classified into 3 groups according to degree of the peak amplitude. Weak sound appeared 110 times, moderate and loud sound appeared 79 and 21 times respectively.

4. All the power−spectra analyzed were sort-

ed according to ratio of $\Sigma(>300Hz)/\Sigma(<300Hz)$. 34 power-spectra showed solely under 300Hz(16.2%). On the other hand, 176 cases presented spectra integral of sounds above 300Hz.

5. The mean of integral above 300Hz divided by integral below 300Hz for 18 cases in which osseous changes were in condylar head upon transcranial TMJ projection series and orthopantomogram reading, was 0.387 ± 0.284. However, 147 patients with the ratio above 0.01 who didn't show bony changes had mean value 0.286 ± 0.227.

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악관절 잡음에 관한 연구

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[국문초록]

저자는 서울대학병원 치과진료부 구강진단과를 내원한 두개하악장애 환자 중, 악관절음이 있음을 호소하는 환자 106명을 대상으로 SonoPAK을 이용하여 악관절음을 분석하고 Transcranial TMJ Series와 파노라마상 판독결과를 종합하여 다음과 같은 결론을 얻었다.

1. SonoPAK에 기록된 210회의 발생 악관절음 중 왕복성 관절음은 44건, 88회 발생하였고, 개구시 관절음은 74회, 그리고 폐구시 관절음은 48회 발생하였으며, 개구시에 관절음이 더 빈번히 나타났다.
2. 왕복성 악관절음이 있다고 인정되는 환자군에서, 개구시 평균 최대 단위는 18.6(%) ±15.6(%), 폐구시 평균 최대 진폭은 16.6(%)±17.4(%)이었으며, 개폐구간 진폭의 차이에는 유의성이 없었다 ($p>0.05$).
3. 악관절음을 미약한 소리, 중간소리, 큰소리로 분류할 수 있었으며 각각 110, 79, 21회의 발생을 기록하였다.
4. $\Sigma(>300Hz)/\Sigma(<300Hz)$의 비율이 0인 경우는 34회 였고, 300Hz 이상의 주파수가 관찰된 경우는 176회였다.
5. Transcranial TMJ projection series와 파노라마상의 판독 결과 하악과두의 골 변화가 인정된 환자군에서 SonoPAK기록의 평균 주파수 비율($\Sigma(>300Hz)/\Sigma(<300Hz)$은 0.387±0.284이었고 골 변화가 인지되지는 않았으나 주파수 비율이 0.01 이상인 환자군의 평균은 0.286±0.227이었다.

주요어 : 악관절음, 최대진폭, 컴퓨터화한 음향 분석기, 두개하악장애