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Vibration Analysis of the Temporomandibular Joint Sounds

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측두하악 관절잡음의 진동 분석

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국문 초록

측두하악 관절잡음의 진동 분석

정 다 운

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관절잡음의 발생은 TMJ의 구조적, 기능적 이상의 징후로 여겨져왔다. 이러한 관절잡음을 평가하는데 청진과 촉진은 주관적이고 부정확한 방법으로 평가되어 좀 더 과학적이고 객관적인 방법으로 electrovibratography(EVG)가 제시되어 왔다. 기존의 연구에서 EVG는 관절잡음을 평가하는데 가장 비침습적이고 신뢰할만한 방법이라고 하였으며 EVG의 사용으로 관절잡음의 진동수와 진폭 및 전체 에너지 양상을 숫자화하고 도식화 하는 것이 가능하게 되었다. 기존의 연구에서 증상군의 진동에너지가 무증상군보다 높다는 것이 발표되어 왔으며 frequency spectrum의 양상을 분석하는 등 여러 가지 관절잡음의 양적, 질적 분석이 시도되어 왔다. 이번 연구의 목적은 frequency spectrum pattern을 integral>300Hz/<300Hz ratio와 함께 분석하는 것이다.

본 실험에서는 Joint Vibration Analysis (the BioPAK® system, BioResearch Inc., USA)를 사용하여 촉진으로 관절잡음이 느껴지지 않고 TMD증상이 없는 10명의 대조군(Group I)과 관절잡음과 동통이 있으나 개구제한을 보이지 않는 정복성 관절원판 변위의 범주에 있는 20명의 실험군(Group II)에서 관절진동을 분석하였으며 관절진동 기록 시에 JT-3(Jaw tracker, the BioPAK® system, Bioresearch, Inc, USA)를 함께 사용하여 개폐구시 관절잡음 발생의 위치를 감별하고 치아접촉음을 배제하여 관절잡음을 분석하였다. Group II 의 frequency spectrum pattern에 따라 실험군을 4가지 subgroup으로 나누어 분석하였다.

실험 결과 Group I 과 Group II ; subdivision 1에서 유사한 frequency spectrum pattern과 ratio범위를 보였으며 Group II ; subdivision 2,3,4 에서는 더 불규칙한 에

너지 양상을 보이는 frequency spectrum pattern과 더 큰 ratio가 관찰되었다.

이번 연구를 통해 JVA가 악관절 진동의 특성을 감별하는데 유용함을 알 수 있었고 JVA를 이용한 지속적인 진동 분석이 환자 교육뿐 아니라 성공적인 턱관절 기능이상의 진단과 치료에 유용할 것으로 사료된다.

Ⅰ. *INTRODUCTION*

The phenomenon of temporomandibular joint(TMJ) noise, such as a clicking or crepitus, has long attracted the attention of clinical researchers. Studies on the etiology of joint sounds suggest that the sounds can originate from an incorrect relationship between condyle and disk.[1,2] But in most studies of TMJ joint epidemiology, the presence of TMJ sounds is not correlated with diagnostic imaging.[3-11] Ishigaki et al., reported nearly one half of symptomatic patients unmanageable by conservative therapy had confirmed internal derangements.[12] In addition, other studies have reported an incidence of disk displacement approaching 20% in asymptomatic subjects.[13]

Several qualitative and quantitiative classification methods have been suggested for classification of TMJ sounds, and electro-acoustical system for recording and characterizing the sounds objectively have been introduced. Furthermore, several authors have associated different power spectra with various pathologies.[14] Some authors previously reported that the joint vibration analysis using electrovibratography(EVG) is most reliable than physical examination alone and can serve as a non-invasive method for screening patients with internal derangements.[15]

Using electrovibratography, It is possible to identify and show: 1. The frequencies (in Hertz), as well as the amplitude of the vibration can be expressed mathematically. i.e., Numeric analysis; 2. The visualization of the types of waves created by the sound. i.e., Graphic analysis; 3. The precise moment that the sound happens in the opening and closing cycles.

We used Joint vibration analysis(JVA) in the BioPAK system(Bioresearch, Inc, Milwaukee, USA) as the electrovibratography, and Jaw tracker(JT)-3 device in the BioPAK system (Bioresearch, Inc, Milwaukee, USA). Using JT-3 deivce allowed the computer to estimate where a joint vibration occurs in the open/close cycle and let us distinguish tooth contact from joint sound precisely. JVA provides excellent conduction of subtle vibrations (tissue borne vibration) for its density of silicone while sonography increases recording of room nose(air borne vibration). furthermore no magnet in sensors allows it to be used with jaw tracker for accurate timimg evaluations.

The vibratory energy in the symptomatic group was higher than in the asymptomatic group which agrees with the observations of several studies.[16,17,18] This is because the highest amount of vibration happens in the articular structures because of lubrication deficiency,[19] lengthening of the ligaments[20] and an alteration in the relationship of the condyle/disk[21,2] or spasms of the lateral pterygoid muscle.[22] Ishigaki et al. suggested that when using total power density only(total integral), EVG is useful in the separation of meniscal displacement.[6] Gallo et al. reported healthy TMJs produced sounds which were distinctly different from baseline and background noise at lower frequencies. Ishigaki et al. reported a disc displacement with reduction generates a "click" in the lower frequencies(under 300Hz)[23]and a degenerative condition generates "crepitus" in the higher frequencies(over 300Hz).[24]

However, despite all these attempts to quantify, qualify, and use joint sounds for diagnosis of joint pathologies, we found few studies based on the frequency spectrum patterns associated with integral >300Hz/<300Hz ratio. The aim of this study was to examime the TMJ sounds with repect to integral >300 Hz/<300Hz ratio and frequency spectra pattern in subjects showing Disc displacement with reduction.

Ⅱ. *MATERIALS AND METHODS*

This study was done using 30 individuals whose ages ranged from 23 to 33 years with a mean average of 26.2 years. Through palpation and auscultation of the TMJs during maximum active mouth opening/closing, subjects were examined for the clinical presence/absence of TMJ noises. While subjects showed absence of TMJ noises, pain at palpation (any of the masseter, temporalis, pterygoid, digastric muscles) and jaw movement or chewing, we screened out which agreed with objective EVG findings. They were 9 male and 1 female, designated as our control material. Group II designated as our experimental material, showed presence of TMJ noises, normal range of jaw movement during opening and pain at palpation and jaw movement of chewing. So they could be differentiated as disc displacement with reduction.

In each subject, EVG analysis were performed three times. The magnet was attached to the labial surface of mandibular incisors of the subjects in order to bring the midline of the magnet with the labial frenum and locate the groove of the magnet to the left side to the subjects. If the subject tends to have deep bite so that it is impossible to attach the magnet, it can be considered to attach to the labial gingival surface or lingual tooth surface. one transducer was placed on the skin over the right TMJ, and the other over the left TMJ. and then JT-3 device was set to the subjects. Once, the horizontal and vertical standard point were set, and we controlled them to fit with the subjects' heads. It should be controlled that the bar of the front side is paralleled to the interauditory axis and the lateral side to the Frankfort Horizontal plane. The accessory bar for approaching to the magnet was fixed temporally and operated in order to set the exact midline. (Fig. 1)

As the subject performed metronome-guided maximun active opening/closing with JVA , the condyles rub against the various surface in the joint creating characteristic vibrations which are then, in turn, detected by the accelerometers.

They convert those specific vibrations in to an electronic signal. The signal from the accelerometers is amplified by a small, light-weight amplifier which is placed around the patient's neck. The amplified signals are then transmitted to the PC computer where they are recorded and analyzed with a software program designed and then displayed on CRT. After the best performed recording was selected from three recordings, vibrations showing highest amplitude were screened priorly. When tooth contact exculded precisely, reproducible joint sound was analyzed for each opening & closing cycle. Finally averaged episode was detected in each subjets.

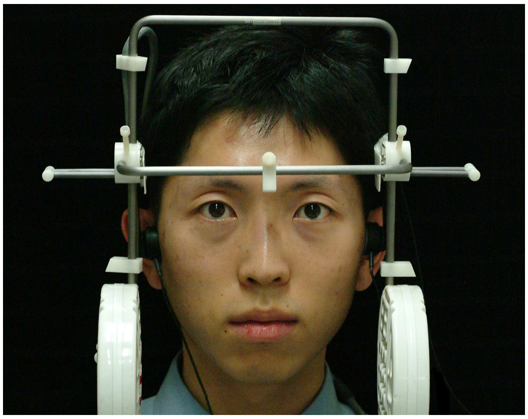
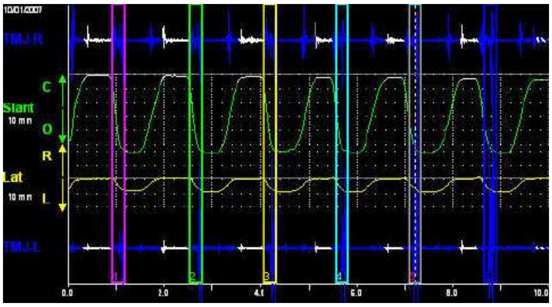
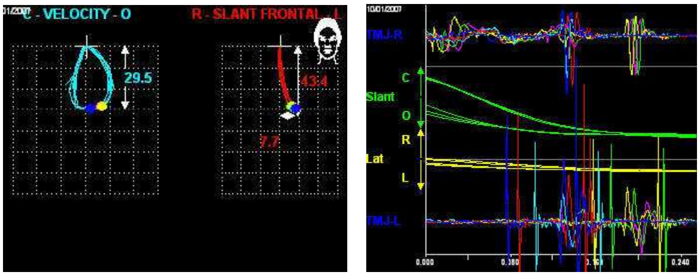


Fig. 1. JVA and JT-3 device placed on the subjects.
(BioPAK system®, Bioresearch Inc., USA)

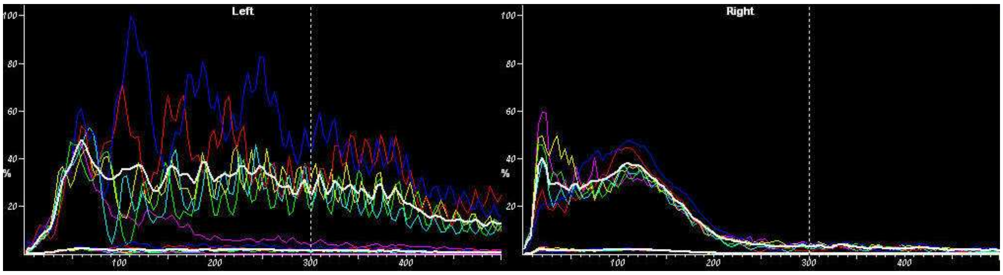
They convert those specific vibrations in to an electronic signal. The signal from the accelerometers is amplified by a small, light-weight amplifier which is placed around the patient's neck. The amplified signals are then transmitted to the PC computer where they are recorded and analyzed with a software program designed and then displayed on CRT. After the best performed recording was selected from three recordings, vibrations showing highest amplitude were screened priorly. When tooth contact exculded precisely, reproducible joint sound was analyzed for each opening & closing cycle. Finally averaged episode was detected in each subjets. (Fig. 2)



(a)



(b)



(c)

Help / Narrative	Average Left	Average Right	Window 1 Left	Window 1 Right	Window 2 Left	Window 2 Right	Window 3 Left	Window 3 Right
Total Integral	69.5	32.7	24.6	33.6	58.5	31.4	67.4	34.9
Integral <300Hz	47.4	30.1	21.3	31.2	37.9	28.7	44.2	31.9
Integral >300Hz	22.1	2.6	3.3	2.5	20.5	2.8	23.3	3.0
>300/<300 Ratio	0.47	0.09	0.15	0.08	0.54	0.10	0.53	0.10
Peak Amplitude	2.5	2.1	2.5	3.2	2.5	2.4	2.4	2.6
Peak Frequency	60	21	60	21	48	17	221	21
Med. Frequency	221	111	107	103	232	107	236	103
Slant Distance	40.5	40.5	38.2	38.5	42.1	37.5	41.1	38.4
Velocity	78.6	79.4	122.2	119.1	57.0	127.5	74.2	129.8
Max. Slant	43							

(d)

Fig. 2. Graph of the registration of joint vibrations occurs at the late of the mandibular opening(a) and superimposed amplitude and duration data from 6 open/close cycles.(b) Frequency spectrum computed from fast Fourier transform algorithm. The thick line represents the average spectrum of all the marked vibrations' spectra.(c) Numerics of JVA summary view based upon absolute frequency spectra.(d)

Ⅲ. *RESULT*

Joint vibrations are analyzed using a mathematical technique known as the Fast Fourier Transform(FFT). Complex vibrations can be thought of as a sum of fundamental pure sine waves, each with a different pitch(frequency) and loudness(amplitude). The FFT extracts the amplitude of each of these fundamental frequencies to show the frequency spectrum which represents the amplitude(energy) at each frequency. The frequency spectra view plots amplitude(vertical axis) versus frequency(horizontal axis). The height of the curve is directly proportional to the energy of the spectrum at each frequency. The thick line represents the average spectrum of all the marked vibration′ spectra. Two spectra are plotted for each side; the smaller of the two represents the absolute magnitude of the vibrations′ spectra as recorded(N/m^2), the larger one has been scaled to the maximum range(at the recorded amplification) and is known as the relative plot. The relative plot accentuates features that may not be visible in the absolute plot. The numeric values that are calculated and displayed in the JVA summary view are based on the absolute frequency spectra.

For the numerics, the following variables were used. The peak frequency(Hz) was the frequency having the highest amplitude in the frequency spectrum, and the median frequency(Hz) was the frequency dividing the frequency spectrum into two regions with equal power. The total integral(arbitrary units) was the area under the curve of the frequency spectrum. The peak amplitude indicates the highest numeric point of the vibration analyzed expressed in Pascals.

Characteristics of the frequency spectrum was described as the durations(short/long) standardized from below/above 300Hz and the patterns(smooth/irregular) of the relative plot.(Table 3.) The joint has the higher value between the left and right side was selected for description of the frequency spectrum.

In Group I the frequency spectrums(Fig. 3.) showed short duration below 300Hz and smooth pattern. Integral >300Hz/<300Hz ratio ranged from 0.04 to 0.3 variously.

Group II divided in 4 subgroups by the characteristics of frequency spectrum. In Group II 16 subjects showed reciprocal click and integral >300Hz/<300Hz ratio was selected according to the higher value from the reciprocal click as well as the right and left joint vibrations.

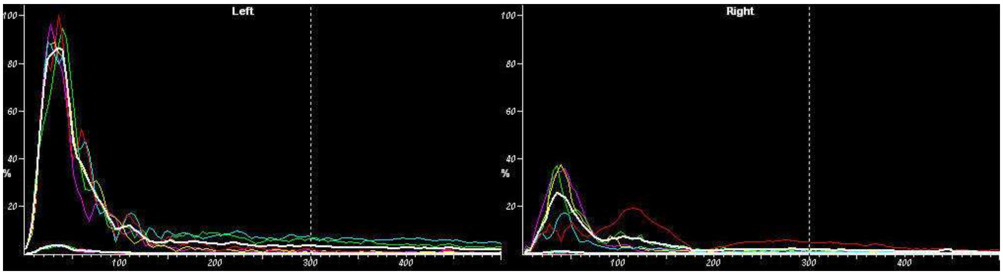


Fig. 3. Frequency spectrum represents Group I . In this subject No.7, integral >300Hz/<300Hz ratio was 0.10 and 0.15 respectively and the right joint was selected for frequency spectrum analysis and characterized as short, smooth pattern.

No.	Lt.ratio	Rt.ratio
1	0.04	0.02
2	0.13	0.13
3	0.07	0.19
4	0.14	0.09
5	0.05	0.09
6	0.13	0.08
7	0.10	0.15
8	0.20	0.30
9	0.17	0.13
10	0.18	0.10

Table 1. Integral>300Hz/<300Hz ratio in Group I .

In subdivision 1 the fruquency spectrums showed short duration below 300Hz and smooth pattern similar to control group. Integral >300Hz/<300Hz ratio varied ranges from 0.05 to 0.31 and 7 subjects were included. In subdivision 2 the frequency spectrums showed short duration below 300Hz and irregular pattern had Integral >300Hz/<300Hz ratio ranged from 0.12 to 0.19 with a mean average of 0.16 and 4 subjects were included. In subdivision 3 the frequency spectrums showed short, irregular pattern below 300Hz is accompanied by simultaneous long duration, lower amplitude pattern. Integral >300Hz/<300Hz ratio ranged from 0.23 to 0.42 with a mean average of 0.31 and 7 subjects were included. Subdivision 4 showed long duration, irregular pattern had integral >300Hz/<300Hz ratio ranged from 0.43 to 0.47 with a mean average of 0.45 and 2 subjects were included.

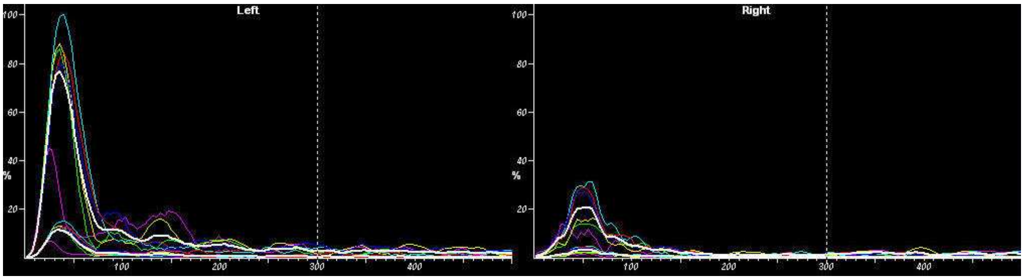


Fig 4. – Frequency spectrum represents GroupⅡ; subdivision 1. In this subject No.3, integral >300Hz/<300Hz ratio was 0.11 and 0.24 respectively and the right joint was selected for frequency spectrum analysis and characterized as short, smooth pattern.

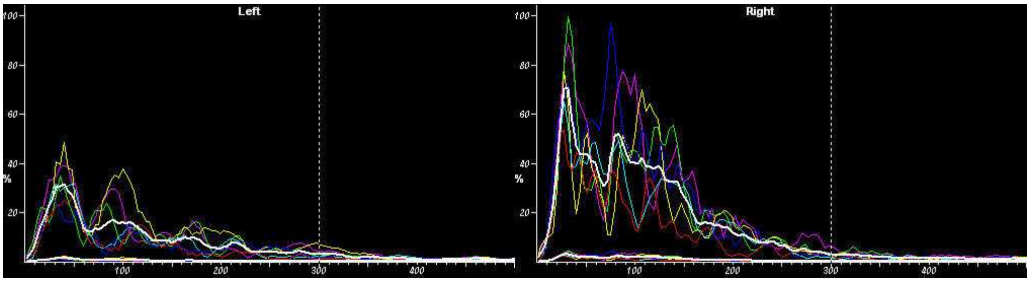


Fig. 5. Frequency spectrum represents Group II; subdivision 2. In this subject No.8, integral >300Hz/<300Hz ratio was 0.17 and 0.04 respectively and the left joint was selected for frequency spectrum analysis and characterized as short, irregular pattern.

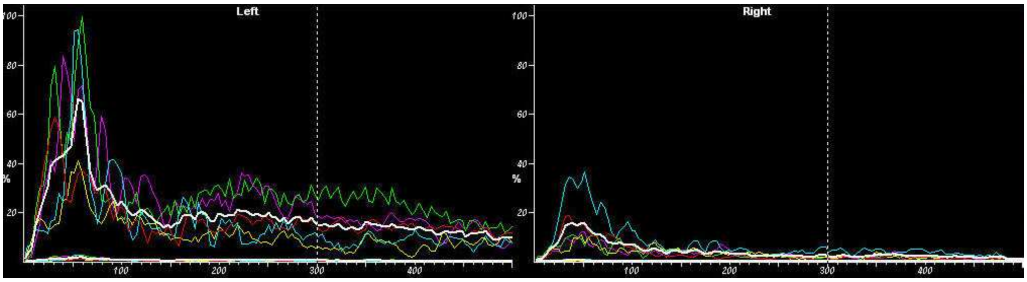


Fig. 6. Frequency spectrum represents Group II; subdivision 3. In this subject No.18, integral >300Hz/<300Hz ratio was 0.38 and 0.26 respectively and the left joint was selected for frequency spectrum analysis and characterized as short, irregular pattern accompanied by lower amplitude, long and irregular pattern.

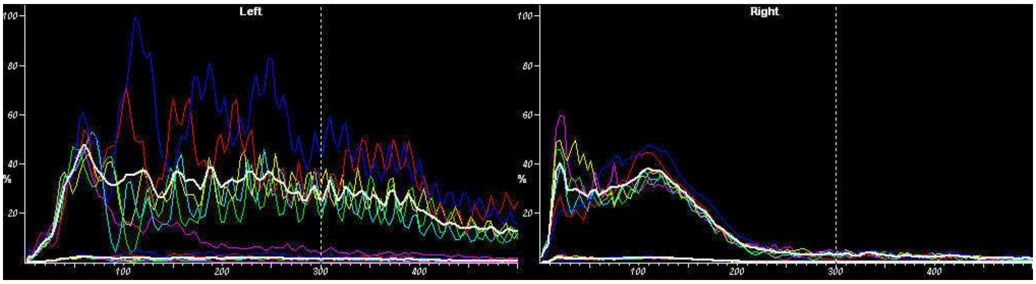


Fig. 7. Frequency spectrum represents GroupⅡ; subdivision 4. In this subject No.20, integral >300Hz/<300Hz ratio was 0.47 and 0.09 respectively and the left joint was selected for frequency spectrum analysis and characterized as long, irregular pattern.

No.		Lt. ratio	Rt. Ratio
1	subdivision 1	0.31	0.17
2		0.06	0.26
3		0.11	0.24
4		0.02	0.09
5		0.05	0.06
6		0.08	0.09
7		0.05	0.04
8	subdivision 2	0.19	0.04
9		0.16	0.19
10		0.17	0.04
11		0.07	0.12
12	subdivision 3	0.27	0.25
13		0.25	0.07
14		0.14	0.23
15		0.27	0.34
16		0.27	0.32
17		0.24	0.42
18		0.38	0.26
19	subdivision 4	0.43	0.15
20		0.47	0.09

Table 2. Integral >300Hz/<300Hz ratio in GroupⅡ.

	Group I (10)	Group II (20)			
		subdivision1 (7)	**subdivision2 (4)**	**subdivision3 (7)**	**subdivision4 (2)**
duration	short	short	short	short&long	long
pattern	smooth	smooth	irregular	irregular	irregular
range of ratio	0.04-0.3	0.05-0.31	0.12-0.19	0.23-0.42	0.43-0.47
mean ratio	**0.152**	**0.157**	**0.167**	**0.316**	**0.45**

Table 3. Description of frequency spectrum as the duration (short/long) standardized from below/above 300Hz, and the patterns (smooth/irregular).

Ⅳ. *DISCUSSION*

Like all wave energy, the joint vibration wave has both amplitude and frequency. As a sound wave moves through a medium, each particle of the medium vibrates at the same frequency. These frequencies are commonly referred to as the pitch of a sound. A low pitch sound corresponds to a low frequency and a high pitch sound corresponds to a high frequency. The human ear can detect sound wave with a wide range of frequencies ranging between approximately 20Hz to 20,000Hz. The quality of loudness is an expression of the vibration wave amplitude. The greater the amplitude of vibrations, the greater the rate at which energy is transported through it and the more intense that the sound wave is. And we often note where the sound occurs in the patient's open-close cycle. This is defining location.

Joint vibrations are analyzed using a mathematical technique known as the Fast Fourier Transform (FFT) extracts the amplitude of each of these fundamental frequencies to show the fruquency spectrum which represents the amplitude(energy) at each frequency. Integral is the amount of vibration energy from each joint and the area under the curve of the frequency spectrum expressed in % power times Hertz.

The soft tissue vibrations generally has frequencies below 300Hz and the hard tissues vibrations will generally has frequencies above 300Hz. Likewise the low integral indicates energy below 300Hz and the High integral indiocates energy above 300Hz. Ishigaki et al reported a disc displacement with reduction generates a "click" in the lower frequencies(under 300Hz)[23]and a degenerative condition generates "crepitus" in the higher frequencies(over 300Hz)[24] With regard to the ratio between intergals above and below 300Hz provides information on the relative distribution of high and low vibration frequencies, it is conceivable that the higher integral >300Hz/<300Hz ratio number, the more advanced degenerative condition could exist.

In this study GruopⅠ and GroupⅡ; subdivision1 represented similar frequency spectrum pattern and showed variable range of integral >300Hz/<300Hz ratio ranged from 0.04 to 0.3 and 0.05 to 0.31 respectively. While GroupⅡ; subdivision1, 2 and 3 represented irregular energe pattern and showed higher integral >300Hz/<300Hz ratio relatively. Furthermore GroupⅡ; subdivision 3 and 4 could be suggested being on the degenerative condition. So normal healthy joint could be differentiated from those in degenerative condition by analysis of clinical examinations along with integral >300Hz/<300Hz ratio and patterns of frequency spectrum.

SUMMARY

We used Joint vibration analysis(JVA) in the BioPAK system(Bioresearch, Inc, Milwaukee, USA) as the electrovibratography, and Jaw tracker(JT)-3 device in the BioPAK system (Bioresearch, Inc, Milwaukee,USA) for distinguish tooth contact from joint sound precisely. The aim of this study was to examime the TMJ sounds with repect to integral >300 Hz/<300Hz ratio and frequency spectra pattern in subjects showing Disc displacement with reduction.

This study was done using 30 individuals whose ages ranged from 23 to 33 years with a mean average of 26.2 years. Group I was 10 subjects had an absence of subjective TMJ complaints(noises and pains) while showed objective EVG findings. GroupII was 20 subjects showed symptoms of disc displacement with reduction. In each subject EVG analysis were performed three times and the best performed recording was selected from three recordings. Screening out vibrations showing highest amplitude priorly tooth contact exculded and reproducible joint sound was analyzed for each opening & closing cycle. Finally averaged episode was detected in each subjets.

Joint vibrations are analyzed using a mathematical technique known as the Fast Fourier Transform(FFT). The frequency spectra view plots amplitude(vertical axis) versus frequency(horizontal axis). The soft tissue vibrations generally has frequencies below 300Hz and the hard tissues vibrations will generally has frequencies above 300Hz. With regard to the ratio between intergals above and below 300Hz provides information on the relative distribution of high and low vibration frequencies, it is conceivable that the higher integral >300Hz/<300Hz ratio number, the more advanced degenerative condition could exist.

In this study Gruop I and Group II; subdivision1 represented similar frequency spectrum pattern and showed variable range of integral >300Hz/<300Hz ratio ranged from 0.04 to 0.3 and 0.05 to 0.31 respectively. While Group II; subdivision1, 2 and 3 represented irregular energe pattern and showed higher

integral >300Hz/<300Hz ratio relatively.

Since the clinical examination alone is not entirely accurate, an alternative cost-effective technique must be found. Through constant observations, it could be suggested clinicians consider using this JVA protocol to differentiate the characteristics of TMJ sound. And JVA will be provided the clinician with the visible patterns of TMJ sound for patient management.

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	영문 : Vibration Analysis of the Temporomandibular Joint Sounds				

본인이 저작한 위의 저작물에 대하여 다음과 같은 조건아래 조선대학교가 저작물을 이용할 수 있도록 허락하고 동의합니다.

- 다 음 -

1. 저작물의 DB구축 및 인터넷을 포함한 정보통신망에의 공개를 위한 저작물의 복제, 기억장치에의 저장, 전송 등을 허락함
2. 위의 목적을 위하여 필요한 범위 내에서의 편집・형식상의 변경을 허락함. 다만, 저작물의 내용변경은 금지함.
3. 배포・전송된 저작물의 영리적 목적을 위한 복제, 저장, 전송 등은 금지함.
4. 저작물에 대한 이용기간은 5년으로 하고, 기간종료 3개월 이내에 별도의 의사 표시가 없을 경우에는 저작물의 이용기간을 계속 연장함.
5. 해당 저작물의 저작권을 타인에게 양도하거나 또는 출판을 허락을 하였을 경우에는 1개월 이내에 대학에 이를 통보함.
6. 조선대학교는 저작물의 이용허락 이후 해당 저작물로 인하여 발생하는 타인에 의한 권리 침해에 대하여 일체의 법적 책임을 지지 않음
7. 소속대학의 협정기관에 저작물의 제공 및 인터넷 등 정보통신망을 이용한 저작물의 전송・출력을 허락함.

동의여부 : 동의(0)　 반대(　)

2008년　2월　25 일

저작자:　 정 다 운　　　(서명 또는 인)

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