Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/16596
DOI URL: http://dx.doi.org/10.21474/IJAR01/16596

RESEARCH ARTICLE

AN INNOVATIVE DEVICE FOR TMJ VIBRATION ANALYSIS

Shayistha M.U[1], Dr. Vivek V. Nair[2], Karunkaran Harshakumar[3] and Rajagopal Ravichandran[4]

1. Junior Resident, Department of Prosthodontics and Crown & Bridge Government Dental College, Thiruvananthapuram, Kerala.
2. Professor, Department of Prosthodontics and Crown & Bridge Government Dental College Thiruvananthapuram, Kerala.
3. Professor & Head, Department of Prosthodontics and Crown & Bridge Government Dental College, Thiruvananthapuram, Kerala.
4. Professor, Department of Prosthodontics and Crown & Bridge Government Dental College, Thiruvananthapuram, Kerala.

Manuscript Info

Manuscript History
Received: 31 January 2023
Final Accepted: 28 February 2023
Published: March 2023

Key words:-
Temporomanibular Joint Vibration, Energy Analysis, Temporomandibular Disorder, Temporomanibular Joint Sounds

Abstract

Temporomandibular joint (TMJ) sounds are an important sign of temporomandibular disorder. Vibrations of different frequencies have been linked to certain types of disorders of the TMJ. Commercially available instrumentsemployed to record the vibrations of the TMJ are expensive and impractical to purchase in a clinical setup or for educational purposes. This article describes the development of a novel, innovative and inexpensive device using a pair of accelerometers, microphones and smartphones along with a developed software for the purpose of recording and analysing the recorded data from the TMJ.

Introduction:-

Temporomandibular disorder (TMD) is a multifactorial functional disturbance of the temporomandibular joint (TMJ). The presenting symptoms of TMD include soreness of the jaw, headaches, pain spreading behind the eyes, shoulder, neck or/and back, earaches, clicking or popping of the jaw, locking of the jaw, limited mouth opening, clenching or grinding of the teeth, dizziness, sensitivity of the teeth without the presence of an oral health disease.[1]TMD can be classified into three major groups: pain-related; intra-articular; and degenerative joint disease and subluxation disorders.[2] Within the intra-articular group, disc displacement with reduction defines a subgroup in which diagnosis has often been based on clinical finding of joint sounds.[3]Diagnosis of TMD is mainly by proper detailed history and physical examination. Various imaging techniques also serve as an important diagnostic aid.Human joints in proper biomechanical relationship, in theory, should produce little friction and little vibration;[4, 5, 6] surface changes within the joint could cause greater friction and greater vibration. It has been postulated that different disorders can produce different vibration patterns or signatures in joint including the TMJs.[7, 8, 9] Vibration analysis of the TMJ is thus a quantitative process that measures the absolute intensity and frequency distribution of vibratory waves emanating from the joint during jaw motion.Intra articular vibrations can be studied to give an insight into the status of the joint. Joint Vibration Analysis (JVA) is one of the most important diagnostic tools to study the intra articular vibrations. Since the cost of this device makes it a difficult purchase for most of the practicing dentists, few inexpensive devices consisting of microphones, accelerometers, stethescopeswere developed and have been reported in the literature for recording the TMJ vibrations but without comparing its recording values with that of a Bio JVA. In this context, an attempt is made to developan inexpensive, affordable instrument

Corresponding Author:- Shayistha M U
Address**:-** Junior resident, Department of Prosthodontics and Crown & Bridge Government Dental College, Thiruvananthapuram, Kerala.

comprising of a pair of accelerometer and microphone. Additionally, a software was developed to record the vibrations from the accelerometers. The vibrations from the microphones were recorded in a commercially available sound recording software RecForge II.

Technique:-

Twenty sixsubjects between the age group of 18 and 75 years, regardless of the presence or absence of symptoms of TMD were selected. The subjects provided their informed consent after receiving a detailed explanation of the purpose of the study, its scope and the method of recording.

Device and software development

An accelerometer is an electromechanical device that can sense and measure vibrations or acceleration of an object. In the present study, two triaxial Micro-electromechanical (MEM) accelerometers (**Figure 1)** (InvenSense MPU6050) were used to record the vibrations of TMJs. The accelerometers were enclosed in an acrylic box and mounted on a headphone band **(Figure 2).** A 32 bit microprocessor module, ESP8266, is the soul of this device which can sample the data from accelerometers and send to the computer. The output of the microprocessors were fed to a computer using USB cable and recorded using a developed software which can plot the data in real time. The software is a data logging software developed using JAVA. **Figure3**demonstrates the setup of the developed instrument.In addition to the accelerometer sensors, a pair of lavalier microphones placed in the external auditory meatus were also used for recording the vibrations of the TMJ.

The accelerometers cannot differentiate between acceleration due to motion or vibration and acceleration due to gravity. The compensation of gravity and the acceleration reading due to movement of patient’s head while recording were nullified inside the microcontroller for each sampling. The microcontroller code developed for this device can filter out the noise readings due to head movement while recording the TMJ vibrations. The accelerometer sensors were calibrated for null reading before mounting on the head band.

Data recording

The procedure of recording the vibrations was carried out in a sound proof room. TMJ vibrations of the subjects were recorded using both BioJVA and developed device.

Two accelerometer sensors of the developed device were placed bilaterally on the skin over the TMJ to record vibration waveforms in the time domain from the joints. Vibrations were recorded bilaterally during the maximal opening and closing with rhythmic speed of 1.8 seconds/cycle. Subjects were instructed to follow a sinusoidal wave on the screen in order to keep the pace of opening and closing cycle **(Figure 4).**Simultaneously, signals from the microphones placed bilaterally in external auditory meatus of the subject were recorded using a voice recorder (RecForge II) installed in two separate smartphones for each microphone
(Figure 5).

In order to validate the readings from the developed instrument, commercially available Bio JVA (Bio Research Inc., Milwaukee, USA) was used to record vibrations from the same subjects **(Figure 6**) and the results were compared.

Processing and assessment of recorded signals

The accelerometers can provide the vibration data in m/s^2 about two axes, X and Y for each joint. Even though these accelerometers can sample the measurements in 1 kHz speed, on-board Digital Motion Processor algorithm was used to filter noises while reading the sensor data. This algorithm can sample the sensor data to a maximum speed of 188 Hz only. The acceleration data from sensors recorded in time domain provides the measures of amplitude versus duration. Fast Fourier Transform (FFT) was used to plot the recorded data in frequency domain, which gives the indication of frequency pitch and harmonics.An FFT analysis converts a signal into individual spectral components (sine wave components) having frequency on x-axis and corresponding amplitude on y-axis. The FFT distribution was plotted for selected vibration spikes of the recorded signal, shown using yellow and blue strips **(Figure 7)**. The area (total integral) under frequency-amplitude curve (FFT plot) gives the energy of vibration (**Figure 8).**It is the mean summation of all of the intensities at every frequency recorded and can be understood as a loudness parameter. Condenserlavalier microphones placed at external auditory meatus of subjects were capable to capture clicking sounds of TMJ with a flat response between 20 Hz and 20000 Hz. Vibration sounds in the mandibular movement cycles were recorded as electrical signals from microphone with a sample rate of 44100Hz, at a bit rate of 16 bits.

That means, quantization was 16 bit linear, which means the analogue to digital conversion resolution was 16-bit. The 16 bit recorder can digitize the analogue signal from the microphone as binary value ranging from -32767 to +32767 depending upon the input vibration/sound from joints. The amplitude of the waveform corresponds to the loudness of the sound. The sound pressure captured by the microphone depends on the environment, reflecting surfaces, distance from the source. Since the microphone was not calibrated to the known loudness of sound samples, to the environmental condition and to the microphone-source distances; the binary reading from the microphone were directly used for the analysis, without converting it to sound pressure level in decibels (dB). The recorded 16 bit data were normalized in time domain to the maximum possible value of 32767, as shown in Figure 6. The digitized analogue data of the TMJ sounds were transformed from the time domain to the frequency domain in order to calculate the total energy and peak frequency of vibration.

Discussion:-

The study group comprised of fifteen females and eleven males (n=26), between the age group of 18 and 75 years, regardless of the presence or absence of TMD symptoms. Vibrations were recorded using accelerometer during the maximal opening and closing of mouth as in Figure 5. The signals traced from the microphones placed in external auditory meatus of the subject were recorded in time domain as in Figure 6. The total energy, peak amplitude and the peak frequency of vibrations from recorded signal using accelerometer and microphone of the developed device for each subjects were compared against that from Bio JVA readings. It is worth noting that the sensor reading from BioJVA are expressed as the measure of pressure waves (in Pascals) whereas the developed device records the vibration in m/s^2. The accelerometer and microphone gives the amplitude of vibration as percentage of maximum possible 16 bit recording value of 32767.The recorded accelerometer data and microphone waves were processed using signal processing software (MATLAB) and the total energy, peak amplitude and peak frequency of vibrations for each subjects were tabulated.

The total energy of vibration from accelerometer for left TMJ is compared with that of BioJVA as shown in figure 9. It is evident from the comparison that the trends of hills and valleys of accelerometer readings are exactly matching to the commercially available BioJVA readings. This performance evaluation gives a range to energy levels from the developed device. The energy levels of BioJVA ranges from 3 to 110 whereas the device levels were only from 3 to 32. Similarly, the comparison of total energy of vibration from accelerometer of the right TMJ to that of BioJVA gives a range of 4-35 for the developed device whereas the range is from 2-241 for BioJVA.The observed range of total energy, peak amplitude and peak frequency of left and right TMJ for the device and for BioJVA are tabulated in Table 1.

	Developed Instrument						BioJVA	
	Accelerometer				Microphone		Left	Right
	Left		Right		Left	Right		
	X	Y	X	Y				
Total Integral	1 - 20	2 - 14	2 - 26.	2 - 15	14 - 308	9 - 136	3 - 110	3 - 242
Peak Amplitude	0.1 - 1.1	0.09 - 0.33	0.08 - 0.72	0.08 - 0.36	0.14 - 2.6	0.07 - 2.1	0.3 - 13.7	0.2 - 28.5
Peak frequency	9 - 31	8 - 28	3 - 36	9 - 24	73 - 248	65 - 283	17 - 100	17 - 119

Conclusion:-

There is no argument to the fact that Bio-JVA is the most precise device available to assess and record TMJ vibrations. Whilst, the device described in this article was a humble attempt to create a cost effective instrument for recording TMJ vibrations that may prove to be beneficial for academic and clinical purposes. As discussed, the trends of hills and valleys of the accelerometer of the developed device is comparable to that of Bio-JVA. Although the values do not coincide, a comparable range could be derived. The developed computer software provides quick visuals to appreciate the detected sound. The sound detected by the device can be stored in the laptop hard disk, mobile device, and other storage hardwares. The preoperative sounds can be compared with postoperative joint sound. This device may also be useful for community based research and field studies.

Figure 1:- MEM accelerometer.

Figure 2:- Accelerometer attached to a headphone band.

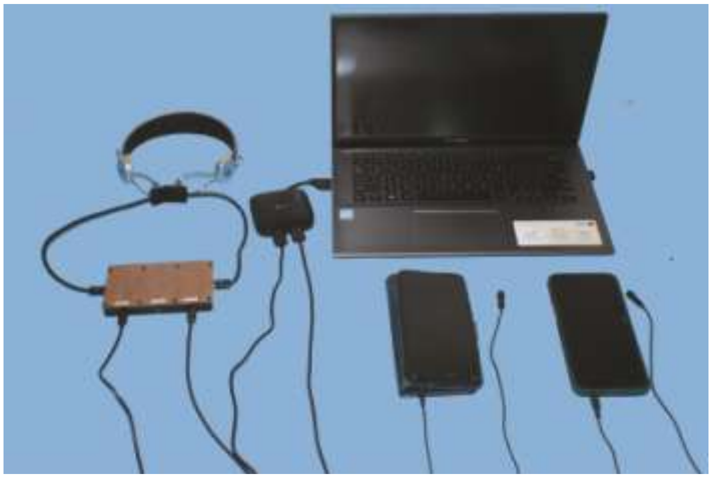

Figure 3:- Set up of the developed instrument.

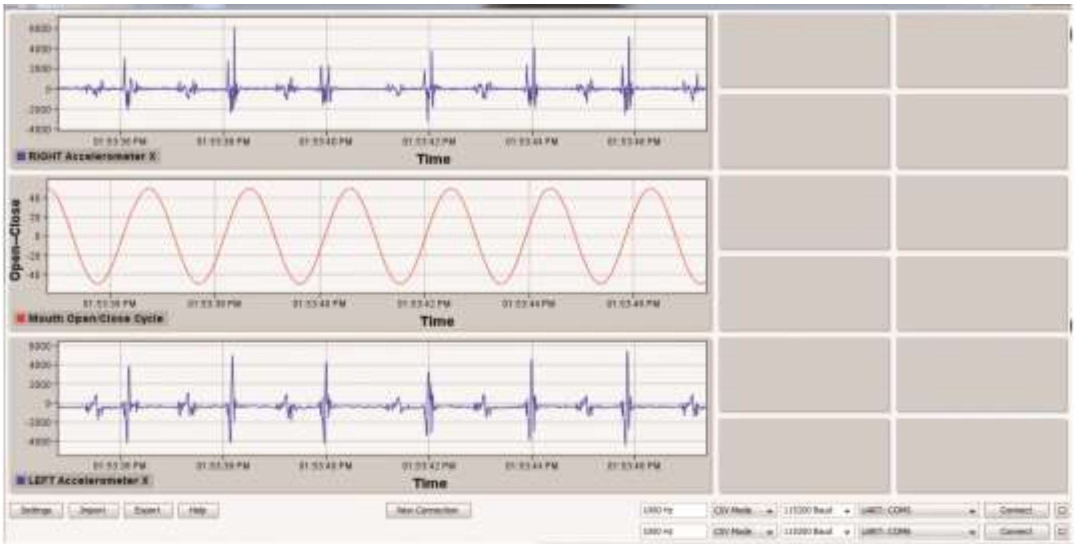

Figure 4:- Sinusoidal wave as seen in the developed software.

Figure 5:- Obtaining recordings from the subject using the developed instrument.

Figure 6:- Obtaining recordings from the patient using Bio JVA.

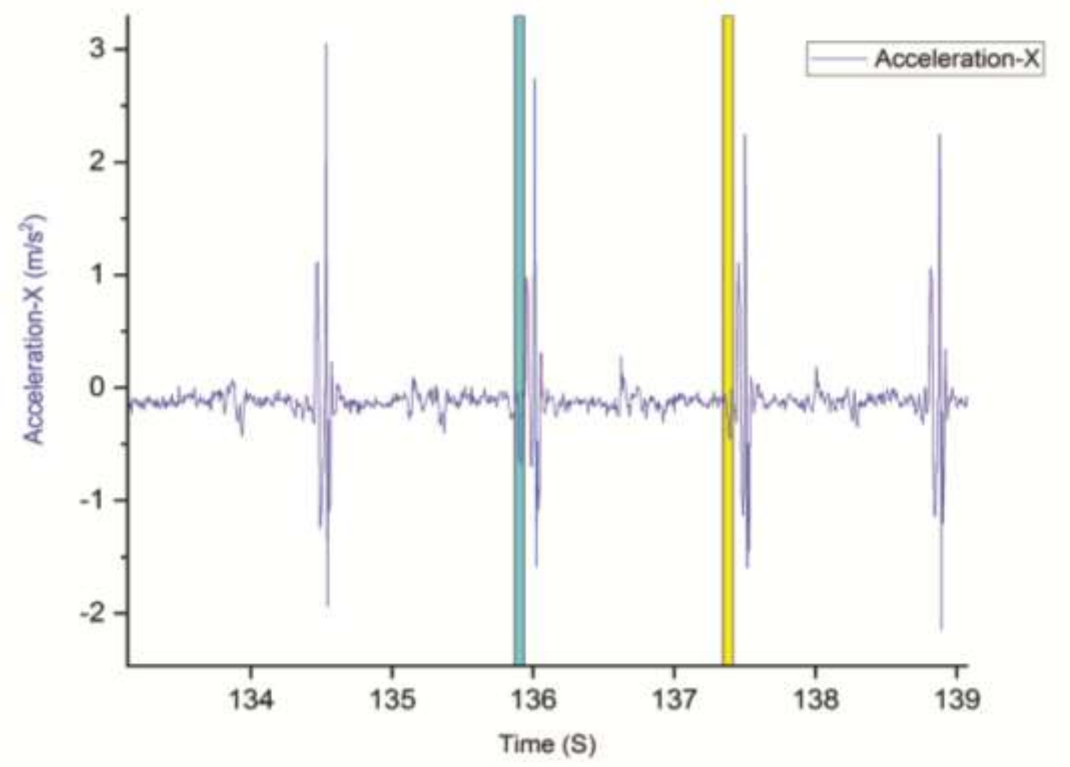

Figure 7:- FFT plot for selected vibration spikes.

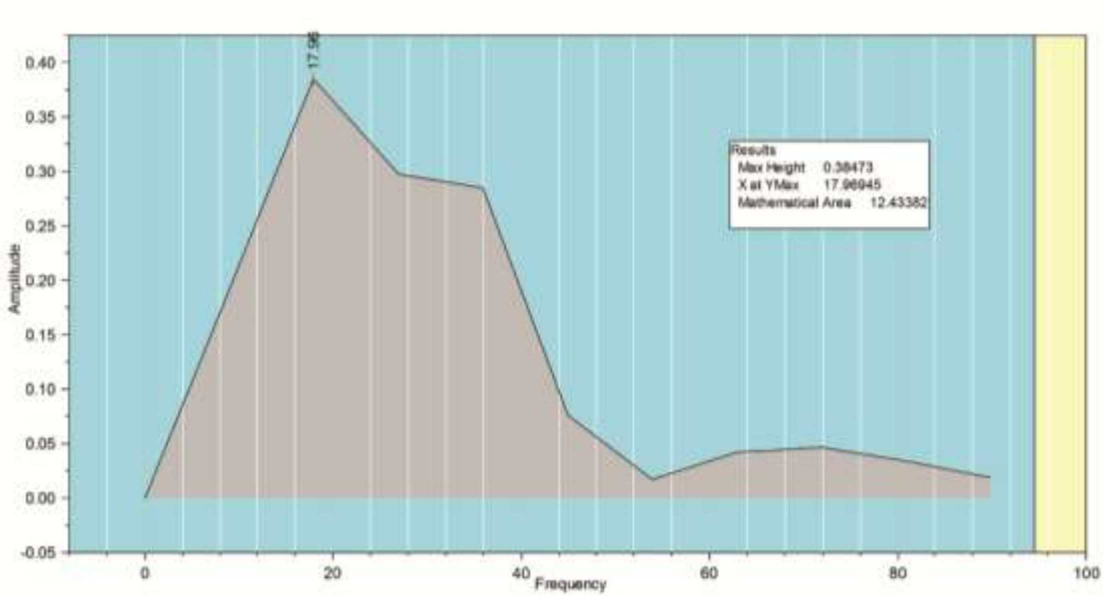

Figure 8:- Total area (energy) under FFT plot.

References:-

1. De Leeuw R, Klasser GD. Temporomandibular disorders. Fifth. Hanover Park: Quintessence Publishing Co; 2013. Guidelines for assessment, diagnosis, and management; pp. 129–204.
2. Chiffman E, Ohrbach R, Truelove E, Look J, Anderson G, Goulet JP, List T, Svensson P, Gonzalez Y, Lobbezoo F, et al. Diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications: recommendations of the international RDC/TMD consortium network and orofacial pain special interest groupdagger. J Oral Facial Pain Headache. 2014;28(1):6–27.
3. Brown DT, Cox LK, 2nd, Hafez AA, Cox CF. “True normal” TMD control subjects: a rare clinical finding. Cranio. 1998;16(2):84–89.
4. Ateshian GA. A theoretical formulation for boundary friction in articular cartilage. J Biomech Eng. 1997;119(1):81–86.
5. Tanaka E, Dalla-Bona DA, Iwabe T, Kawai N, Yamano E, van Eijden T, Tanaka M, Miyauchi M, Takata T, Tanne K. The effect of removal of the disc on the friction in the temporomandibular joint. J Oral Maxillofac Surg. 2006;64(8):1221–1224.
6. Tanaka E, Kawai N, Tanaka M, Todoh M, van Eijden T, Hanaoka K, Dalla-Bona DA, Takata T, Tanne K. The frictional coefficient of the temporomandibular joint and its dependency on the magnitude and duration of joint loading. J Dent Res. 2004;83(5):404–407.
7. Chu M, Gradisar I, Mostardi R. A noninvasiveelectroacoustical evaluation technique of cartilage damage in pathological knee joint. Med BiolEngComput. 1978;16(4):437–442.
8. Chu ML, Gradisar IA, Railey MR, Bowling GF. Detection of knee joint diseases using acoustical pattern recognition technique. J Biomech. 1976;9(3):111–114.
9. Chu ML, Gradisar IA, Railey MR, Bowling GF. An electro-acoustical technique for the detection of knee joint noise. Med Res Eng. 1976;12(1):18–20.