We are IntechOpen, the world’s leading publisher of Open Access books
Built by scientists, for scientists

6,600
Open access books available

177,000
International authors and editors

195M
Downloads

154
Countries delivered to

TOP 1%
Our authors are among the most cited scientists

12.2%
Contributors from top 500 universities

WEB OF SCIENCE™
Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com
Abstract

The temporomandibular joint (TMJ), being an almost well-known anatomical structure but its diagnosis may become difficult due to sounds accompanying joint movement. One example is temporomandibular joint hypermobility (TMJH), which still requires comprehensive study. TMJH is a rare disorder; however, its prevalence at the level of around 4% is still significant. We propose a diagnostic method of TMJH based on the digital time-frequency analysis of sounds generated by TMJ. The volunteers were diagnosed using the RDC/TMD questionnaire and auscultated with the Littmann 3200 electronic stethoscopes on both sides of the head simultaneously. Recorded TMJ sounds were transferred to the computer via Bluetooth® for numerical analysis. The research reveals characteristic time-frequency features in acoustic signals which can be used to detect TMJH. This can help differentiate other disc displacements from joint hypermobility.

Keywords: temporomandibular joint, hypermobility, joint auscultation

1. Introduction

Following the survey carried out in Germany in 2017, the number of cases with temporomandibular joint dislocation as hypermobility movement accounts for 3% of all documented dislocation, which means at least 25 cases per 100,000 inhabitants each year [1]. Following European Commission rules, it could be classified as a rare disease – affecting fewer than 5 people in 10,000 are considered to be so. It is also reported to represent 3% of all dislocated joints cases in the human body. On the other hand, dislocation of temporomandibular joint occurs in up to 7% of people during their lifetime [2]. Shorey and Campbell [3] referred to Sir Astley Cooper’s research from the year 1832, who proposed principles for diagnosis and treatment of lower jaw dislocations and introduced nomenclature of joints hypermobility: 'complete dislocation' as luxation and 'imperfect dislocation' as subluxation. The incidences of subluxation are estimated to occur in about 70% of the population based on clinical and radiographic analysis [4]. In new classification proposed by Akinbami [5], three types of dislocation based on clinic-radiological evaluation were presented: type I – the head of condyle directly below the tip of the eminence; type II – the head of condyle in the front of the tip of the eminence; type III – the head of condyle located high up...
in the front of base of the eminence. Two types of dislocation with a possibility to self-reduce the hypermobility can be distinguished - subluxation – with, or luxation – without self-reducing.

From The Glossary of Prosthodontic Terms [6], the definition of temporomandibular joint condylar subluxation is: ‘self-reducing incomplete or partial dislocation of the condyle’, and of incomplete dislocation is: ‘a border position of the disk-condyle complex out of the physiological end of movement position in relation to articular eminence’. Partial dislocation is explained in the glossary [6] as a ‘displacement of the articular disk resulting in a seriously impaired disk-condyle complex function’. Condylar dislocation [6] is defined as ‘a non-self-reducing displacement of the mandibular condyle usually forward of the articular eminence’.

For the condylar displacement, the definition stands as follow – it is when the condyle stands out of the articular eminence in maximal jaw opening position. However, definitions confuse subluxation, luxation and disk displacement. From the clinical point of view, subluxation occurs when the opening of patient’s mandibular ends with disk-condyle complex position forward to the articular eminence, which is self-reducing [3]. It means that the patient can close the mandible without any assistance, only by repositioning the mandibular into the disk-condyle complex. It usually concerns joint on one side. With both sides affected it could be more difficult to close the mouth, but patients can usually manage with that on their own. This concerns especially patients with general joints hypermobility, like the Ehlers-Danlos syndrome [7]. They may be frightened or disoriented when it happens for the first time i.e. during yawning. If there is a problem with self-healing and the patient is looking for medical help it could be named as joint dislocation, complete dislocation or luxation. When the dislocation concerns both joints, it looks very dramatic, because patient is unable to speak, swallow and of course, close the mouth. Such cases require medical help, whereas in recurring cases surgical treatment should be considered. It is compatible with Cooper and other authors who followed him, that suggest calling it habitual or recurrent dislocation in cases with more frequent incidents of dislocation and when it is going progressively wrong [3, 8, 9].

As with the other temporomandibular disorders, joint dislocation is often reported by females, especially in recurrent cases. Tendency to dislocation is associated with the shape of anatomical elements like the condyle, glenoid fossa and articular eminence. The pathogenesis is multifactorial, however, for almost 60% of cases, a preceding trauma has been indicated. The mechanism of dislocation also contributes: age, dentition and neurological or neuromuscular diseases. The older the patient, the more he/she is exposed. Lack of posterior teeth support, correlated with advanced tooth loss or edentulous arches without the denture is regarded as favorable to develop joint dislocation. As a recurrent problem for older people with multimorbidity, it significantly reduces their quality of life.

2. Anatomy and physiology

The ‘displacement of the articular disk’ which is ‘non-self-reducing’ is usually understood as a pathological position of the disk in relation to the condyle. That pathology is explained as a forward movement of the disk in relation to the condyle (non-reducing), which results in limitations of condylar head movements, and it is often called ‘disk lock’ or ‘disk displacement without reduction’. The main symptoms of that pathology are sudden disappearance of joints sounds, limitation in jaw
Temporomandibular Joint Hypermobility Examination through Differentiation of Sounds
DOI: http://dx.doi.org/10.5772/intechopen.103955

opening, and lateral jaw displacement during movement, and usually acute pain from
the joint region. The above symptoms are opposite to suspected joint subluxation.

From the anatomy of the temporomandibular joints’ point of view, it is well
known that these joints are extremely complex synovial articulations. In the distal
part of the joints — which is in the backside of the disk — exists a bilaminar zone,
named also retro-articular structure or hydrodynamic retral pad or retrodiscal tissue
[10, 11]. It is a mass of loose, highly vascularized and innervated, connective tissue
attached to the posterior edge of the articular disk which extends and fills the loose
folds of the posterior capsule of the temporomandibular joint [6]. It changes its posi-
tion simultaneously with all the disk moves and protects the joints against posteriorly
oriented trauma [12]. Although the research of Schmolke [13] carried out on human
cadavers has concluded, that it was not possible to distinguish the distal disk as a part
of a separated structure, Merida-Velasco et al. [10] reported that after examination
of 20 cadavers they have identified two separated laminae and retroarticular region
filled with venous plexus. The authors confirmed the presence of discomalleolar
ligaments in that region and agreed with suggestion about limitation of the range of
opening function by those ligaments [14]. Apparently, that part of the joint capsule is
still not fully explored.

During the jaw function, both left and right joints move and they are in mutual
interdependence. Going again to the anatomy, joints are divided by the disk into
two compartments — the upper and the lower. In that two compartments, different
movements take place. The movement in the upper one is mostly translational. In the
lower compartment movements are mostly rotational. One of the joint’s functions is
to connect the mandibular condyle movements in relation to the articular fossa of the
temporal bone with the temporomandibular disk interposed. The disk itself is con-
ected with the joint capsule. The capsule is constructed from fibrous ligaments that
enclose the joint and limit its motion [15]. It is lined with the synovial membrane.

In order for the movement to be smooth and free of any sound, each surface of the
joints, the disks and condylar heads as well as the articular fossae should be sleek and
moistened. The articular surfaces are covered by synovial membrane and moistened
by synovial fluid. That fluid is produced by specialized endothelial cells capable of
producing synovial fluid. It fills all joints’ cavities surrounded by the membrane. For
proper joints movements, the capsules need to be flexible enough and tight to keep
joints parts together during all joints positions [11].

The joints’ shifting results in opening, closing, forward, backward and lateral
movements of the mandible. During the first four movements, both joints work
simultaneously, in mirror reflection. Yet, in the lateral movements, the movement
made by the side joint is smaller than the one made by the opposite joint. When one
moves, it always results in the movement of the other. That relationship — where one
bone (the mandible) moves between two joints, which are mutually dependent on
each other — is specific in human skeleton and occurs only in that very specific joints.

Movements are related to joints disks position, capsules and ligaments tension and
muscle function. Muscles that are involved in the temporomandibular joint functions
are mainly the temporal, masseter, digastricus, medial and lateral pterygoid. From
contemporary anatomy, we know that some fibers of temporal, masseter and upper
head of lateral pterygoid muscle penetrate to the joint capsule and even to the joint
disk [11, 16]. This can result in disk movements, but in the case of muscle hyperactivity
could cause disk displacement.

The physiological joints opening movement starts with condyles located in the
higher position in relation to the glenoid fossa with the disk between them in the
Temporalmandibular Joint - Surgical Reconstruction and Managements

uppermost position. Then, the condyle's head makes a rotation movement in relation to the disk in the lower joint compartment, and the disk translates down and forward in relation to the glenoid fossa and the articular eminence, as a movement in the upper jaw compartment. At the end of the movement, the condyle head is covered by the disk and located on the top of the articular eminence in its lowest possible position. This movement is limited by the joint capsule tension and the ligaments. The bilaminar zone tissues are maximally stretched. In the physiological movement of the joints, the relation between the condyles and the eminences is expected to be the same during the entire action of the opening and closing of the lower jaw. That condyle head position in relation to the fossa and the eminence can be visualized by pantomographic x-ray examination [17].

3. Temporomandibular joint examination opportunities

The diagnostic methods of temporomandibular joint hypermobility are various and there is a possibility to use non-invasive methods such as clinical examination, auscultation, ultrasonography (USG) or magnetic resonance imaging (MRI). It can be also diagnosed by some invasive methods such as X-ray or computed tomography (CT). Clinical examination, X-rays and auscultation are more convenient for the patients and they give enough medical data for proper diagnoses, so there is no need to buy advanced equipment.

Firstly, the clinical examination should be carried out in a repetitive way at every patient [18]. To realize the assumptions a way of examination was thoroughly described in the validated international protocol Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) [19]. It helps to make the examination in a repeatable way and find a proper diagnosis. The stethoscopes are the main instruments for joint auscultation, their advantage is their vast accessibility [20, 21]. The researchers used various modifications of stethoscopes for joints auscultation [22]. The use of a stethoscope, especially an electronic one for examination allows sending the signal via Bluetooth to the computer for further analysis. That tool was used in the research by Wiedmann et al. [23]. Such a method could also help an inexpericenced dentist to consult the cases with a specialist. USG of joints region, especially made by an experienced person allows detecting the position of the disk-condyle complex in a dynamic, real way during the test [24]. It informs about the muscle tension, shape of joints compartments and the amount of synovial fluid. This method is non-invasive, repetitive and gives a satisfying amount of information. MRI, belonging also to the non-invasive examination methods, requires dedicated tools and an experienced person for proper interpretation of the results. It can help to detect disc position, the amount of joint fluid and present the bones structures, yet this technique is the most expensive of the non-invasive methods [25].

Computed tomography (CT) belongs to the invasive examination methods and the radiation dose is the biggest. The advantage of this examination is the very precise detection of the properties of the osseous components of the temporomandibular joints [26]. A much lower radiation dose and sufficient amount of clinical data are obtained from an x-ray examination from pantomographs. Currently, they are the very basic equipment of almost all dental offices so diagnostic technic seems to be very easy and common. As the result of that examination, we receive four pictures, two of each side of the face. Two of them present the mandible in the state of closing and the other two in the maximal opening position. The analysis of both sides
is possible and easy. Not too many anatomical structures disturb the image. The example of that x-ray is presented in Figure 1.

That examination informs us about condyle bone structure, shape and relation to the fossae in maximal intercuspal position and at the end of opening movement. The result of such an x-ray should be compared with patient’s clinical status. It is important to analyze the opening and closing jaw movements in relation to upper and lower incisor midline positions during all the movements. The range of openings should be measured between the incisal edges. Then palpation in temporomandibular joints region during mandibular movements and auscultation of that region would be crucial [27].

3.1 Symptoms and diagnosis

Signs and symptoms of acute or chronic dislocation as hypermobility are the same and include temporary inability to close the mouth, preauricular depression of the skin, excessive salivation, tense, spastic muscle of mastication and pain of temporomandibular joint. At the time of a wide opening, specific sounds may appear. It would happen during excessive mouth opening such as yawning, eating, singing or vomiting. The people who are most vulnerable are the ones who suffer from generalized joint hypermobility as Ehlers-Danlos syndrome or Marfan syndrome as well as neurodegenerative/neurodysfunctional diseases or muscle dystrophies [28, 29]. In the described groups of patients, that symptom could be physiological and often that joint hypermobility is painless. Very characteristic in that cases of hypermobility movement are self-reducing, but sometimes the patients are afraid about complications. The problem could also appear after intubation in general anesthesia too. Repeated episodes of subluxation may result in the lengthening of the capsule ligaments or

![Figure 1.](image)

*Right (two left pictures) and left temporomandibular joints in opening (outer images) and closing position with physiological relation of joints elements.*
cause damage to the joint capsule. To make the proper diagnosis clinical examination with joint auscultation and x-ray examination are required.

The clinical examination includes the measurement of jaw abduction, lateral movements and protrusion. The symmetry of movements and their straight direction inform us about their proper function. Then the palpation of jaw movement muscle is required. During the examination, muscles should be in the relaxed position. Before palpation, the stretch of the muscle should be investigated. We are expecting symmetrical contraction in the muscles on both sides during the opening and closing of the mandible. Similarly during forward and backward movement. At that moment the tendons and muscle bodies are palpated, especially temporalis, masseter and digastricus. Those muscles are suitable for direct palpation. Lateral pterygoid muscle can be examined using indirect movements. In such a case the examiner’s hands should block patient’s forward and lateral jaw movements and the doctor should ask the patients about the pain in the region of the joints. The appearance of pain informs about muscle dysfunction, hyperfunction or overactivity [30].

During physiological jaw movements, neither sound nor noises from joints region are expected. If they appear, some disturbances occur i.e. in relation between disk and condylar head or between disk-condyle complex and fossa to articular eminence. The joint dysfunction might be differentiated by sound and it requires auscultating them. Typical sound associated with joints dislocation correlated with hypermobile movement appears at the end of the movement, usually when the mouth is being opened. Subluxation sounds are very specific. Using two electronic stethoscopes the examination takes place during opening and closing movements. That examination is safe for the patient and is easy even for inexperienced doctors. The measured signals from electronic stethoscopes are sent to the computer and the signals are analyzed [31].

3.2 Material and method

In our examination the patients with temporomandibular disorders were included based on our national version of The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) as well as a group of patients without diagnoses but with symptoms and sounds from the joints region [32, 33]. After clinical examination, the auscultation procedure takes place. Patients with diagnoses based on RDC/TMD with sounds from temporomandibular joints and that those with joints sounds who did not receive the diagnoses were taken to the analyzes. All patients with other diagnoses without joints sounds were excluded from the study. After sound differentiation, the group suspected hypermobile joints were selected and an x-ray as confirmation was recommended.

3.2.1 Auscultation technic

Two electronic stethoscopes (Littmann Model 3200 Manufacturer 3 M Health Care, St. Paul, MN, USA) were used for the examination. Patients were asked to open and close the mouth 5 to 8 times. The auscultation of the temporomandibular joints region was carried out on both sides simultaneously. Electronic stethoscopes convert analogue signals to digital domains and make it possible to analyze about 15 s sounds. Stethoscopes provide a 4000 Hz sampling rate that ensures possibilities to reproduce sound components up to 2000 Hz. The measured sounds were sent to the computer to analyses the recorded signals. The representation of the signal in the frequency domain was computed with the use of the Numpy library and the fast
Fourier transform algorithm. In order to achieve local spectral representation, we split the signal into atomic sections with the Blackman window of 512 samples length and 256 samples overlapping. The frequencies below 80 Hz were removed from spectrograms to emphasize higher harmonics that were responsible for the effect of clicking [31]. Usage of two independent stethoscopes is beneficial in terms of capability of identification which joint generates sounds but on the other hand, makes difficulties in interpretation. Vibrations are conducted by bone and tissues therefore to differentiate where the origin of sound is located signals recorded by stethoscopes have to be synchronized. This feature is based on an external synchronization system. Small actuators placed on stethoscopes generate synchro beep sound and are triggered by physician during auscultation using a footswitch [34]. Promising results were achieved by signal analysis in time-frequency domain. This representation provides both information, when acoustic event occurred and which frequency components are present. Artificial intelligence-based approach seems to be the most appropriate in terms of mentioned signal analysis. Dedicated algorithms are still being developed. One of the main challenges is signal identification and segmentation [35]. Only when the auscultation signals will be split into parts corresponding to each jaw movement there will be possible to provide comprehensive automatic signals recognition algorithms.

3.3 Results

Totally 120 patients participated in the study. For sounds analyses were qualified 40 persons, in that group 32 were women. Hypermobile sounds were recognized in 4 patients (2 men and 2 women) based on lack of RDC/TMD diagnoses, sound analyses and x-ray confirmation.

From our research, we have very characteristic results for hypermobile joints in relation to the healthy one and with disk displacement with reduction, which is presented in Figures 2–4.

The sound record from a healthy temporomandibular joint presented in Figure 2 concerns the time representation. The record representation is obtained from the serving program from electronic stethoscope Littmann 3200. It is worth mentioning that both joints do not present pathological sounds. Graphs represent a sound that indicates the correct movement of the structures of the temporomandibular joints during opening and closing.

In Figure 3, there is the signal representation from software Littmann 3200 from patient with disk displacement with reduction in both joints.

The signal time representation in Figure 4 is characteristic for a person with subluxation in both joints.

Figure 2.
The signal traces recorded on both sides in time domain in healthy joints.
Another helpful auscultation result is presented as time-frequency domain in the form of spectrograms (Figures 5–7).

As a complementary examination x-ray of the joints was required. The results are very characteristic in hypermobile jaw movements patients with a subluxation in one or both joints. For example, in Figure 8 the position of the condyles in the front of the articular eminence was visible.

3.4 Discussion

The presented method of examination in the group of patients with temporomandibular joints region sounds is easy, inexpensive and gives possibility for future...
Temporomandibular Joint Hypermobility Examination through Differentiation of Sounds
DOI: http://dx.doi.org/10.5772/intechopen.103955

Figure 6.
The signal traces are recorded on the STFT representation of a disk displacement with reduction in both joints.

Figure 7.
Signal traces were recorded on the STFT representation of a hypermobile joints as subluxation.

Figure 8.
An example of both sides subluxation x-ray. From left to right: Right side joint in wide jaw open position (the condyle head in the front of articular eminence), right side joint in maximal intercuspation position (the condyle head in glenoid fossa), left side joint in maximal intercuspation position (the condyle head in glenoid fossa) and left side joint in wide jaw open position (the condyle head in the front of articular eminence).
development. It takes the way for telemedicine as remote consultation. It allows enlargement of patients’ medical data for monitoring present status and progress of treatment. Hypermobile jaw sounds are rare problem in a group of patients with temporomandibular disorders. In our group, it was 3.3% of examined patients which was correlated with the literature [2]. Although the problem affects a relatively small group of patients, it should not be underestimated. It is worth searching for simple solutions for diagnosis. It is possible that the lack of diagnosis is associated with the difficulty and no additional equipment. There is an alternative tool- BioJVA (BioResearch Associates, Inc. Milwaukee WI USA) that can be used to diagnose patients with temporomandibular disorders and for joints sounds analysis [36–38]. It is non-invasive diagnostic equipment, supplementing the basic clinical examination that can help to observe the present status and the effectiveness of the therapy. The use of this device is not common, it usually occurs in research medical centres due to very high prices and lack of knowledge of how to interpret diagnostic results. The use of a stethoscope could be a common examining method performed by every practising dentist.

4. Conclusion

As the summary about hypermobile temporomandibular jaw movements, it is important to know, that in all cases with subluxation the appearing sounds are frightening, and sometimes the doctors are more surprised than the accustomed patient. The associated unexpected jaw movements which are correlated with the thud sound in relation to inexperienced dentists would lead to a patient becoming sick. On the other hand, subluxation in some cases would lead to luxation and the patients may require surgery which is at risk of multiple complications. So the necessary recommendations for patients with hypermobile joints with the subluxation are to avoid wide mouth opening during yawning, eating or singing. The most difficult is to control jaw opening during yawning. Our recommendation is to bend your head to the chest and protect jaw opening by neck spine. Another possibility is to suction the tongue to the palate during yawning and protect wide opening by tongue frenulum. In addition, physiotherapeutic procedures are required, to strengthen the muscle for joints protection.
Author details

Jolanta E. Loster* and Justyna Grochala
Department of Prosthodontics and Orthodontics, Jagiellonian University in Kraków, Medical College, Dental Institute, Kraków, Poland

*Address all correspondence to: jolanta.loster@uj.edu.pl

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. [BY]
References


Comparison of the outcomes of dynamic/static tests and palpation tests in TMD-pain patients. Journal of Oral Rehabilitation. 2018;45:185-190


