CHAPTER II

LITERATURE REVIEW

2.1 Anatomy of TMJ

The Temporomandibular Joint (TMJ) is a ginglymoarthrodial joint. It is derived from ginglymus, which means a hinge joint, and arthrodia. Where it means that a joint of which permits a gliding motion of the surfaces. Similar to the knee articulation, both right and left TMJ form a bicondylar articulation and ellipsoid variety of the synovial joints (Alomar et al., 2007).

TMJ, it functions simultaneously. It is a joint that regulated mandibular movement where there is a connection between the mandible and the skull. It is also a bi-condylar joint at the two ends of the mandible (Ingawalé & Goswami, 2009). A ligament that forms the joint capsule held the two bones together which surround the TMJ completely. Furthermore, a fibrocartilage is a disc that lies between the condyle and the articular fossa. It acts as a cushion when the mouth opens and closes by absorbing stress and allows the condyle to be move easily (Goswami et al., 2009).

There are two compartments that divide the joint cavity by the disc, which consists of superior and inferior. They provide lubrication and nutrition to the joint structures. The disc too reduces the contact stresses and prevents the
maximum bone-on-bone contact and the chances of wearing of the head of condyle and the articular fossa (Goswami et al., 2009).

First and foremost, TMJ consists of the articular surface that includes mandibular component, cranial component, articular disk, and fibrous capsule. Besides that, there is also temporomandibular ligaments complex, muscular component, blood supply, teeth and occlusion, and the lubrication of joint (Alomar et al., 2007).

Mandibular component consists of an ovoid condylar process at the top narrow mandibular neck. It is 15 to 20 mm side to side and 8 to 10 mm from front to back. Nevertheless, if there will be a medially extension on the long axis of two condyles, they will meet at the base on the anterior limit of the foramen magnum, forming an angle of 145 degree to 160 degree that opens toward the front ranging. The lateral side of the condyle is basically rough, bluntly pointed, and extend moderately from the plane of ramus. Meanwhile, the medial pole extends sharply inward. The articular surface lies on its anterosuperior aspect, thus facing the posterior slope of the articular eminence of the temporal bone. When the jaw is held in an occluded position, it further continues medially down and around the medial pole of the condyle to face the entoglenoid process of the temporal bone (Alomar et al., 2007).
Figure 2.1 The Anatomy Of TMJ. *ACL*, Anterior Capsular Ligament; *AS*, Articular Surface; *IC*, Inferior Joint Cavity; *ILP*, Inferior Lateral Pterygoid Muscles; *IRL*, Inferior Retrodiscal Lamina; *RT*, Retrodiscal Tissues; *SC*, Superior Joint Cavity; *SLP*, Superior Lateral Pterygoid Muscles; *SRL*, Superior Retrodiscal Lamina (Okeson, 2008).

The appearance of the mandibular condyle however differs from one individual to another including their age grouping. Morphologic changes may occur based on their daily habitual towards their simple development variability also the remodeling of the condyle to accommodate developmental variations, malocclusion, trauma, and other abnormalities (Alomar et al., 2007).

As for the cranial component, the articular surface of the temporal bone is located on the inferior aspect of temporal squama, which is anterior to the tympanic plate. The cranial component consist of, one, the articular eminence, where its articular surface is most heavily traveled by the condyle and disk as they move forward and backward in normal jaw function (Alomar et al., 2007).
The articular tubercle is a small, raised, rough, bony knob on the outer end of the articular eminence. It extends below the level of the articular surface and serves to attach the lateral collateral ligament of the joint. However, there is also a plane called the preglenoid plane. Where this plane is slightly hollowed, slightly horizontal as well, and the articular surface continuing anteriorly from the height of the articular eminence (Alomar et al., 2007).

### 2.2 Physiology of TMD

The physiology of TMJ occurs over highly adverse articular surfaces and limited contact areas. If the load were not influence by the TMJ disc, the non-uniform distribution of mechanical stress during jaw movements would be reflected directly over the articular surfaces, leading to cartilage damage. Peak loads are normally absorbed by local deformations of the disc, occurring in the contact areas with the articular surfaces. As the movement of the TMJ proceeds, these deformations involve progressively different portions of the disc. The result is a dynamic structural adaptation that spreads the mechanical stress over larger surfaces. The nature and extent of this adaptive response depend on the biomechanical properties of the disc and the forces acting on its molecular structure which may lead to TMD (Molinari et al., 2007).

Besides that, the physiology of TMJ includes the movement of the TMJ itself. The movements consist of osteokinematics, they are depression, elevation,
lateral deviation, protrusion and retraction. Other than that, there is also
arthrokinematics, which explains what osteokinematics (Lippert L.S, 2006).

Depression, it is basically includes two types of movements. One, anterior
rotation on the disk of mandibular condyle, two, the movement of gliding
anteriorly and inferiorly of the condyle and disk over the temporal bone’s articular
tubercle. However, elevation is the reverse action of depression. As for the
protrusion and retraction, rotation will not happen. Instead, mandible moves in the
transverse plane either anteriorly and posteriorly where both mandibular condyle
and disk move against the articular fossa as one unit. The lateral deviation
normally occurs on opposite sides. For instance, to move the mandible to the
right, the right condyle rotates around a vertical axis and the left condyle will
glide anteriorly. Lateral deviation occurs in the transverse plane. Therefore, TMD
relates to the excess movement or pressure that occurs in either one of the
movements that can be classified into few dysfunctions (Lippert L.S, 2006).

The physiology of TMD, it starts with the signs and symptoms that may
include pain, impaired jaw function, malocclusion, deviation or deflection, limited
range of motion, joint noise, bruxism and locking. Besides that, there are
headache, tinnitus, visual changes, and other neurologic complaints that may also
accompany TMDs. TMDs can be subdivided into muscular and articular
categories. Differentiation between the two is sometimes difficult because muscle
disorders may mimic articular disorders, and they may coexist (Herb et al., 2006).

Overloading will normally triggered the initial adaptive response of the
TMJ. It induces the structural changes in the TMJ. Nevertheless, the process of
modeling the elements of TMJ takes a very long time, but it will be a continuous process within tissue-specific limits. Decreased vascularity and extensive fibrous transformation in the retrodiscal tissue is for continuous compression and shear. These adaptive changes influences the mechanical implications as well, normally on the articular disc behavioral. As long as the system maintains the ability to adapt to the new functional status, the altered mechanical loading will adapt by the TMJ remodeling structure. At this stage, the patient will be asymptomatic although the coordination of the disc-condyle complex may be lost (Molinari et al., 2007).

However, when exhaustion of the reserve adaptive response occurs, the changes taking place in the TMJ are known as regressive remodeling like maladaptation. At this stage, damage and decompensated morphologic changes are usually accompanied with pain and other clinically evident signs and symptoms of the TMD (Molinari et al., 2007).

2.3 The Classifications of TMD

Temporomandibular disorders are classified into myofascial pain, myofascial pain with limited opening, disk displacement with reduction, disk displacement without reduction with limited opening, disk displacement with reduction with intermittent locking, disk displacement without reduction without limited opening, arthralgia, osteoarthritis of the TMJ, and osteoarthrosis of the TMJ (Greenberg, 2008).
Myofascial pain is the pain at the muscle origin, where it includes complaint of pain combines with the localized areas of tenderness to palpation in muscle. Normally, patients will complaint of pain or ache in jaw, temples, face, preauricular area, or inside ear at rest or while moving. Besides that, pain also produces during palpation in three or more muscles sites (Greenberg, 2008). Disk displacement with reduction, it is where the retrodisca tissue will stretch excessively and bear with the repetitive loading force from the mandibular condyle that may lead to the reduction of the condyle. This tissue has the capacity to withstand and adapt to these forces and may transformed into a “pseudosic”. Nevertheless, the TMJ will produce sound or noise like clicking or popping and the condyle will have a full translation movement. However, a correlative click during mandibular closure shows the condyle returning to the retrodisca tissue, and the disc returns to an anterior position (Greenberg, 2008).

Disk displacement with reduction is a biomechanical intracapsular disorder that involves the condyle-disc complex. The disc is in an anterior position accordingly to the condylar head when the mouth is in closed position. When the mouth is opened, the disc will reduce simultaneously. However, this also will be accompanied with clicking, popping, or snapping sounds. Displacement in medial and lateral direction of the disc may also be present (Schiffman et al., 2014).
Figure 2.2 Temporomandibular Disorder, A Pathologic Mandibular Condyle Image, Antero-Oblique View. An Extensive Remodeling (Solid White Arrow) Due To A Depression Below The Articulating Portion Of The Condyle (Heffez, 1995).

As for the disk displacement with reduction with intermittent locking, it is also consider an intra-capsular biomechanical disorder. Similar to disk displacement with reduction, one thing that they differentiate one another is that when reduction does not occur with mouth opens, the mandibular opens with only an intermittent limit. A movement may be needed when limited opening occurs in order to unlock the TMJ (Schiffman et al., 2014).
The disk displacement without reduction without limited opening also explains that when the mouth is closed, the disc is in an anterior position relative to the head of condyle. As for this case, the condylar head will not reduce when opening the mouth. In fact, there will be a very wide opened of the mouth due to the unassociated limited opening. There will also be a passive stretch with more than 4cm (Schiffman et al., 2014).

Disk displacement without reduction with limited opening also known as closed lock where the forward translation of the condyle is limited by the position of the disc anteriorly and is unable to reduce onto the disc. The movement that involve is only rotational movement and not together translation movement. Limitation in opening the jaw accompanies with sudden pain and inability to open more than 20 to 30 mm. Besides that, joint noise too can be heard with the onset of the signs and symptoms. Clinically, the deviations of the mandible during opening showed the sides of the affected area while the unaffected joint has the ability to translate well (Greenberg, 2008).

Osteoarthritis produces a grating sound that is produced by friction between the bone and cartilage, which is called Crepitus. It has a very limited range of motion causes deviation to the affected side when opening the jaw. Nevertheless, osteoarthritis is quite similar to osteoarthrosis. On the other hand, it produces more Crepitus or multiple joint noises. Besides that, the presence of pain is with the function due to inflammation and the tenderness can be felt during palpation (Goswami et al. 2009).
Arthralgia is defined as joint pain that will cause discomfort. This can be related to one of the classifications of TMD that may cause joint pain to the TMJ. It has been compared with the healthy control subjects based on the mobility, the pressure pain threshold (PPT), maximum jaw opening, and bite force. Nevertheless, arthralgia showed a lower result of mobility, PPT, maximum jaw opening and bite force as compared to the normal ones. It also produces a long duration of chewing cycles. The bite force and jaw opening in patients were significantly correlated with the PPT. Jaw opening and bite force were found to be more severe in patients that suffer inflammatory disorders than the patients with disc derangement or osteoarthritis. Therefore, the most impeded jaw function can be seen at the most severe TMJ tenderness, which is at the lowest point of PPT (Goswami et al., 2009).

2.4 Imaging Technique For The Head of Condyle

2.4.1 Alternatives Imaging for Condylar Morphology

The correct diagnosis of TMJ dysfunctions cannot be based on clinical examination only. However, among the basic examinations for TMD are: X-ray examination (RTG), panoramic radiography, arthrography, computer tomography (CT) and magnetic resonance imaging (MRI) (Tvrdy, 2007).

Radio-diagnostic examination or also known as X-ray examination still being used especially in panoramic projection where it shows that X-ray is still necessary in making the correct diagnosis. For example, this is still applied in
examine TMJ traumatic disorders. The configuration joint of the structures can be seen correctly at least perpendicularly in two different views. However, X-ray is best showing the positional, structural and functional changes of the TMD. Besides that, lateral view is the most common part to be observed clinically (Tvrdy, 2007).

As for the panoramic technique, both TMJ and other jaw and tooth structures are best to be viewed using this method. Other than that, panoramic also provide a convenient projection of both joints with the mouth opened or closed in one film for the diagnosis of the TMD. Examination of condylar fractures too is an alternative method for the X-ray (Tvrdy, 2007).

Arthrography however, is the only technique that provides information on the condition of the cartilage and the joint disc. It is also the most accurate method in certifying an anterior dislocation of the joint disc when MRI is not available. Its accuracy is 84–100 %. To identify an articular perforation and intra-articular adhesion are best to be identified using this technique (Tvrdy, 2007).

Diagnosing disc dislocation, condylar fractures, degenerative bone changes and ankylosis is often used by CBCT (Tvrdy 2007). In comparison with multislice CT, CBCT produce substantially lower radiation dose, and provide a high-resolution multiplanar images. However, CBCT too allows in examine the TMJ anatomy and the bone morphology in all three dimensions without any superimposition and distortion in analyzing the bone morphology, joint space and dynamic function (Barghan et al., 2012).
On the other hand, MRI here explains that without any desirable side effects, MRI is the best imaging method in imaging the high-resolution efficacy of the TMD. It also produced more accurate imaging when featuring degenerative bone changes and disc dislocation compared to arthrography and CT pictures. Synovial and subsynovial tissues can be viewed as well. The best method of displaying TMJ hard and soft tissues has been proven by many studies that MRI is the most suitable technique that can be used (Tvrdy, 2007).

2.5 CBCT Radiograph

CBCT is a recent technology. When an X-Ray source and detector are fixed, with the usage of rotating gantry, imaging can be accomplished successfully. On the opposite side of the CBCT, there will be an ionizing radiation source of a divergent pyramidal or cone-shaped is directed through the middle of the area of interest onto an area of x-ray detector. Within the center of the region of interest, the x-ray source and detector will rotate around a rotation fulcrum that has already fixed within it. In a complete, or partial arc of the field of view (FOV) are required during the rotation in the multiple sequential planar projection images. Only one rotational sequence of the plane is needed since CBCT exposure incorporates the entire FOV to achieve enough data for the image reconstruction (Scarfe & Farman, 2008).

CBCT scanners are based on volumetric tomography, using a 2D extended digital array providing an area detector. This is combined with a 3D x-ray beam.
A single 360 degree scan is involved in the cone-beam technique where the detector area and the x-ray source synchronously move around the patient’s head, and it is stabilized by a head holder that attached to it. A “basis” images are required at certain degree intervals where it is also known as single projection images (Scarfe, 2006).

CBCT scanners are based on volumetric tomography. In 1967, Sir Godfrey Hounsfield has developed the CT. However, there has been a gradual transformation to what is currently in use today. There are two types of beams commonly used in CT that includes fan-beam and cone-beam (Figure 2.1). Both can be reconstructed in the axial, coronal and sagittal planes. The cone-beam scanners rotate around the patient by using a cone shaped beam and the reciprocating detector and it will collect the projection data. Nevertheless, a 3D image will be produced by using a back-filtered projection along with the computer software (Praveen BN., 2013).

Figure 2.3 CBCT Machine
(http://www.drhungvu.com/cbct)
2.5.1 Advantages of CBCT Radiograph

CBCT radiograph consists of isotopic volumetric image. This means that it generates equal dimension in all three planes and it can also achieve a voxel size as small as 0.125mm. With that small voxel size and isotropic feature will produce an image of CBCT with high and better resolution, more accurate measurement of thickness of the head of condyle and reproducibility images (Praveen BN, 2013). On the other hand, initially angiography was developed by CBCT. As time goes by, plenty recent medical applications have included radiotherapy guidance and mammography into the CBCT. By using either fan
beam or spiral-scan geometries, the cone-beam geometry was developed as a substitute to the conventional CT, this is to provide more rapid acquisition of the entire data of FOV, and it uses comparatively less expensive radiation detector. Therefore, some advantages of CBCT radiographs are stated as below:

1) Provides a shorter examination time.
2) Increase the sharpness of an image that might caused by the translation and distortion of the patient and internal movement of the patient.
3) Increase the x-ray tube efficiency (Scarfe & Farman, 2008).
4) Has its option in selecting different FOV by exposing only the specific area of interest that will minimize the tissue irradiation.
5) For the dental office comfort, CBCT provides a compact size and affordability setting.
6) The images can be reconstructed into many formats that an oral care provider is familiar with like to a panoramic and cephalometric or bilateral multiple cross-sectional views for an evaluation of anomalies. Therefore, the image can be annotated, assessed, and measured electronically.
7) In relation between the CBCT technology and TMJ/TMD imaging is that it gives a very accurate clinical assessment.
8) It can measure the volume and the height of the head of condylar very accurately.
9) It can provide full information for diagnosis and treatment planning of the hard tissues of the TMJ disease towards the articular eminence and condylar head (Praveen BN., 2013).
2.5.2 Disadvantages of CBCT Radiograph

As for the disadvantages, CBCT has its main disadvantage that cannot distinguish the image accurately. Some of the disadvantages of the CBCT radiograph are:

1) The limitation in image quality especially with a large FOV. This is due to the noise and contrast resolution that has been detected from the large amounts of scattered radiation.

2) Metal restorations and motion artifacts from a patient’s movement still exist on CBCT images even so there were a great improvement that has been made.

3) In evaluating the cartilage and the soft tissue of the TMJ, it has stated that CBCT is definitely not ideal for it. This is because CBCT has limited contrast resolution and cannot distinguish soft tissue densities. However, CBCT (Scarfe & Farman, 2008).

2.5.3 Clinical Indication

The indications in using the CBCT radiographs consist of, visualizing the alveolus in 3 dimensions for implant dentistry and precise measures before surgery, oral and maxillofacial pathology in detecting any cysts or tumors at the region of the maxillofacial for future surgery planning, a treatment planning and diagnosing the temporomandibular disorders, craniofacial surgery, orthognathic surgery, and also identifying impacted teeth (Quereshy et al., 2008).
2.5.4 Components of CBCT Radiograph

One of the components of CBCT radiograph consists of x-ray tube voltage and mAs. The potential difference between anode and cathode during operation is determined by the kilo-voltage of an x-ray tube. However, the energy of the x-ray is produce by the voltage. Therefore, these two components work simultaneously to achieve the right dosage for each patient and the accuracy of the image because, “lower tube voltages give lower energy X-rays and thus increase the dose to the skin of the patient”, and “increasing the kilo-voltage may result in a decrease in skin and effective dose but an increase in scatter” (Horner, 2011).

The next component of the CBCT radiograph would be FOV and collimation. FOV works in determining the shape and size of the reconstructed image and it has a cylindrical volume. It also may vary in few centimetres to achieve a full head reconstruction and the range of FOV in some CBCT units offered an adjustment to it. Nevertheless, in order to get the image of the area of interest, several CBCT machines give an option to collimate the beam to the size that is needed. Bear in mind, the value of the radiation dose correlates with the size of FOV (Horner, 2011).

Filtration however is also one of the CBCT radiograph’s components. It is an aluminium filtration that reduces the radiation dose. It normally removes the lower energy of the X-ray photons which then gives a result in contrast loss and skin dose (Horner, 2011).
The next component is the digital detector, where every dental CBCT units are equipped with digital receptors where the image is captured and formed. In dental CBCT units, there will always be two types of digital detectors that have been used, one is the conventional image intensifier, and the other one is the flat panel detector. This digital receptor is very important in CBCT because the spatial and contrast resolution influence the image quality (Horner, 2011).

Voxel size, represents a three-dimensional (3D) image in CBCT. The quantity data of the volume element can be pictured as a 3D pixel in the radiograph itself. Smaller voxel size will obtain a better spatial resolution but a higher radiation dose will be produce and affect the patient. The size however may vary from less than 0.1 mm to above 0.4mm (Horner, 2011).

Besides that, there is also the number of projections that is listed in the components of the CBCT radiograph. Multiple projection images tend to be produced when the detector and the x-ray tube rotates and surround the patient’s head. The radiation dose correlate with the increasing number of projection, spatial and contrast resolution of the image and towards the patient (Horner, 2011).

![Figure 2.5 Illustration Of The Imaging Field In CBCT (Yang, Meng, & Gong, 2012)](image-url)