Int. J. Morphol.,
42(6):1550-1559, 2024.

Revisiting the Anatomical Features of the Temporomandibular Joint and their Association with Temporomandibular Disorder: A Narrative Review

Revisitando las Características Anatómicas de la Articulación Temporomandibular y su Asociación con el Trastorno Temporomandibular: Una Revisión Narrativa

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LAPPANAKOKIAT, N.; KIM, J. E.; PARK, J. Y. & PARK, Y. S. Revisiting the anatomical features of the temporomandibular joint and their association with temporomandibular disorder: A narrative review. *Int. J. Morphol., 42(6)*:1550-1559, 2024.

SUMMARY: The temporomandibular joint (TMJ) is a complex structure relying on bones, muscles, ligaments, and an articular disc for smooth functioning. Temporomandibular disorders (TMDs) development can be attributed to changes in TMJ anatomy. Several factors, including age, gender, chewing side preference, dentition status, cephalometric relationship, and orthodontic treatment or orthognathic surgery, contributed to the structural and positional changes of the TMJ components. This review article summarizes the association between TMDs and the changes in morphology and position of the mandibular condyle, articular eminence, and glenoid fossa from various factors. Extensive electronic search was performed in PubMed and Scopus databases with appropriate search filters. After the deduplication process and screening of titles, abstracts, and full texts, sixty studies underwent a thorough full-text reading process and were included in this review. Patients with TMDs symptoms tend to have flattened and angled condylar shapes and frequently exhibit a posteriorly positioned condylar head. The steeper inclination of the articular eminence appears to be a notable characteristic of certain TMDs. However, given the multifactorial nature of TMDs, determining a single factor as a primary cause can be challenging. Therefore, recognizing all potential risk factors beyond anatomy-related factors is crucial for accurate diagnosis and successful management of TMDs.

KEY WORDS: Anatomy; Articular disc; Temporal bone; Temporomandibular disorders; Temporomandibular joint.

INTRODUCTION

Temporomandibular disorders (TMDs) affect the temporomandibular joint (TMJ), a complex joint responsible for essential jaw movements such as eating and speaking. TMDs are relatively prevalent disorders that can significantly affect the patient's quality of life. Based on a recent meta-analysis, the incidence of TMDs worldwide is 34 %, with individuals aged 18 to 60 years being the most susceptible. The prevalence of TMDs may also be influenced by geographical location, as evidenced by the significantly higher prevalence in South America (47 %) compared to Asia (33 %), Europe (29 %) and North America (26 %) (Zielinski, Pajak-Zielinska, & Ginszt, 2024).

TMDs cause a range of symptoms and pathological changes. As per The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), the assessment of TMDs comprises two components: axis I and axis II. Axis I further categorizes TMDs into three groups: group I (muscular disorders), group II (disc displacement), and group III (arthralgia, osteoarthritis, osteoarthrosis) (Schiffman *et al*., 2014). Most TMDs cases are either asymptomatic or mildly symptomatic, with only a small percentage of affected individuals seeking or requiring treatment. However, some patients experience more severe symptoms, and the chronic nature of TMDs can lead to prolonged physical and

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FUNDED. This research was supported by the Korea Medical Device Development funded by the Ministry of Science and ICT, the Ministry of Trade, Industry and Energy, the Ministry of Health & Welfare, and the Ministry of Food and Drug Safety (Project Number: 1711134912, RS-2020-KD000002) and Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2021R1I1A2048516).

Received: 2024-07-24 Accepted: 2024-08-23

psychological suffering (Ohrbach & Dworkin, 2016; Valesan *et al*., 2021).

TMDs have been the subject of numerous studies to understand their etiology and contributing factors. Anatomical factors, such as mandibular condyle position and structure (Ramachandran *et al*., 2021; Mohamed *et al*., 2022), articular eminence inclination (Al-Rawi *et al*., 2017; Ma *et al*., 2021; Alhammadi, 2022) and glenoid fossa morphology (Li *et al*., 2023) are among the several factors associated with TMDs occurrence and progression. Age (Mathew *et al*., 2011; Li & Zhang, 2023) gender (Liu *et al*., 2018; Yasa & Akgül, 2018; Seo *et al*., 2021; Daneshmehr *et al*., 2022; Li & Zhang, 2023; Paknahad *et al*., 2023), preferred mastication side (Jiang *et al*., 2015; Jeon *et al*., 2017; Ma *et al*., 2021, 2022), cephalometric relationship (Fichera *et al*., 2021; Noh *et al*., 2021; Soni *et al*., 2022; Türker & Öztürk Yasar, 2022; Yan *et al*., 2022), dentition status (Paknahad *et al*., 2023; Zheng *et al*., 2023), use of orthodontic treatment (Dibbets & van der Weele, 1992; Zurfluh *et al*., 2015; Kaur *et al*., 2018; Michelotti *et al*., 2020) and orthognathic surgery (Ding *et al*., 2022; Han, 2022; Kaur *et al*., 2022; Toh & Leung, 2022), could affect these factors. However, the results from various studies on this topic remain inconclusive and subject to controversy. While presenting some noteworthy aspects, a clear consensus has yet to be reached.

In recent decades, numerous review articles have been published about TMDs. However, most of these articles have focused on treatment options for TMDs, such as orthognathic surgery (Abdul & Minervini, 2023) and orthodontic treatment (Alam *et al*., 2023; Aldayel *et al*., 2023). Some have also covered topics related to imaging techniques used in diagnosing TMDs (Xiong *et al*., 2021; Dhabale & Bhowate, 2022; Gharavi *et al*., 2022; Maranini *et al*., 2022), advanced technologies for treating TMDs (Almubarak *et al*., 2020; Kapos *et al*., 2020; Wadhokar & Patil, 2022) and the association of specific syndromes or conditions with TMDs (Nicot *et al*., 2020; Militi *et al*., 2023; Minervini *et al*., 2023). Fewer articles have focused on the connection between the anatomical aspects of the TMJ structures and TMDs. As a result, the number of review articles on this specific association remains limited. Therefore, this narrative review aims to consolidate information from previous research and review papers regarding the association between TMDs and the changes in morphology and position of the mandibular condyle, articular eminence, and glenoid fossa from various factors.

MATERIAL AND METHOD

The scope of the search was limited to English-written studies that involved human subjects published from October 1977 to June 2024. A search was conducted using Medical Subject Headings terms as well as general keywords, such as "temporomandibular joint," "temporomandibular disorder," "condyle morphology," "anatomy," "condyle position," "articular eminence," and "glenoid fossa" along with appropriate search filters in PubMed and Scopus databases.

The search results revealed 172 and 329 studies, respectively. The EndNote program was used to duplicate the literature. After the deduplication process, the titles, abstracts, and full texts of the studies were screened, which identified 60 studies that underwent a thorough full-text reading process (Fig. 1).

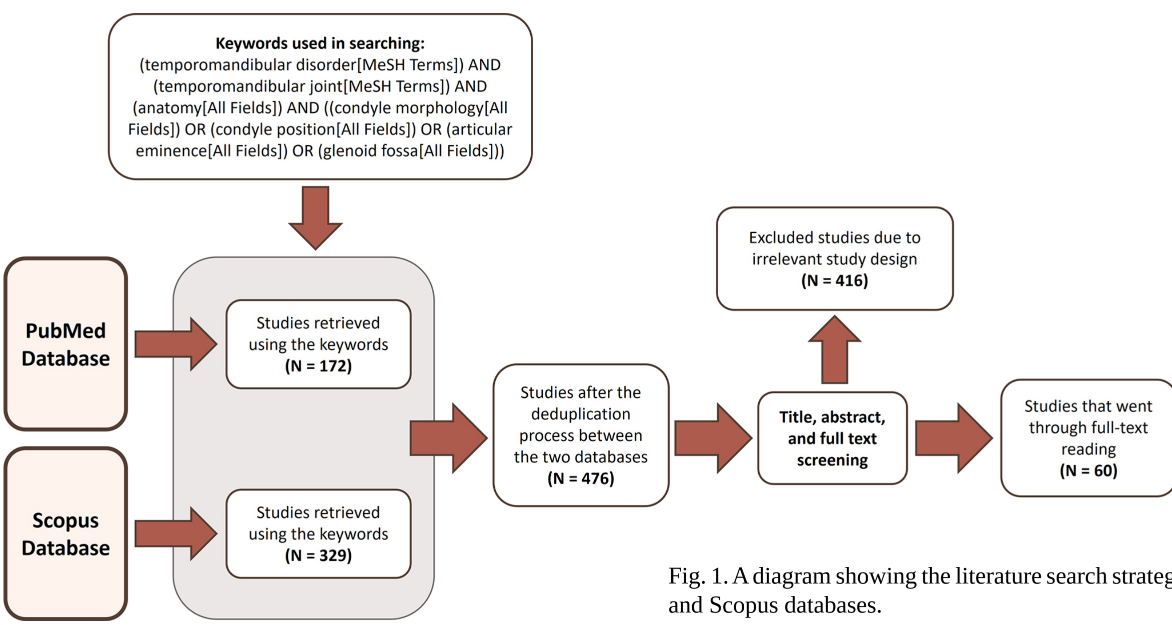

Fig. 1. A diagram showing the literature search strategy in PubMed and Scopus databases.

TMDs and TMJ morphology

Normal TMJ morphology. The TMJ is widely recognized as one of the most intricate joints in the human body. It comprises a complex interplay of both osseous and non-osseous components (Kaur *et al*., 2018).

The articular eminence and glenoid fossa are parts of the temporal bone and are crucial in determining condylar head rotation within the glenoid fossa during the rotation phase and the condylar path during the translation phase of mandibular movement. The articular eminence, a bony protrusion, marks the foremost boundary for the condylar head movement. Positioned behind the eminence is the glenoid fossa, serving as an enclosure for the articular disc and condylar head (Ma *et al*., 2021). Furthermore, the medial third of the glenoid fossa exhibits relatively greater thickness, enhancing its capacity to withstand elevated pressure (Ramachandran *et al*., 2021). Between the glenoid fossa and mandibular condyle lies the articular disc, a fibrocartilaginous pad with a biconcave shape in the sagittal view and thinnest at the center portion (Basit *et al*., 2024) The anatomical illustration of the TMJ is depicted in Figure 2.

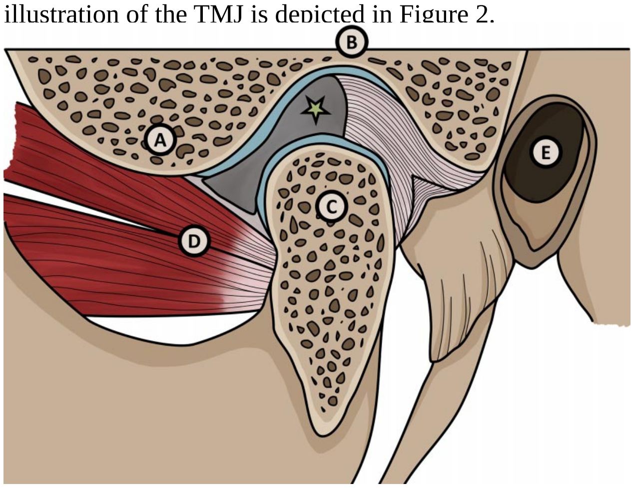

Fig. 2. Anatomy of the TMJ. A, articular eminence; B, glenoid fossa; C, mandibular condyle; D, lateral pterygoid muscle with a superior and an inferior head; and E, external acoustic meatus. The articular disc (star) divides the joint space into superior and inferior compartments (blue areas).

Association between condylar morphology and TMDs. The human mandibular condyle demonstrates a diverse range of basic shapes, as observed by Yale *et al*. (1966) They conducted a thorough examination of a series of dry mandibles to classify condylar shapes into four distinct types: Type A, characterized by a flattened superior surface; Type B, featuring a convex superior surface with a radius of curvature greater than one-half of the axial length; Type C, demonstrating an angled superior surface; Type D, exhibiting a rounded superior surface with a radius of curvature similar to one-half of the axial length (Fig. 3). The classification system has gained wide acceptance, and numerous researchers have incorporated it into their studies on condylar morphology (Yasa & Akgül, 2018; Hegde *et al*., 2021; Mohamed *et al*., 2022).

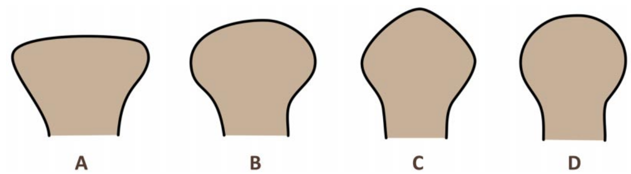

Fig. 3. Morphological type of the mandibular condyle in the coronal view (A) flat type (B) oval type (C) angled type, and (D) round type.

Evaluating the condyle's normalcy includes scrutinizing its associated characteristics and morphological aspects. The cortical bone surrounding the condyle should demonstrate uniform thickness without discontinuities. Any signs of surface erosion, osteophyte subcortical cysts, or generalized sclerosis indicate anomalies within the joint (Li & Zhang, 2023; Paknahad *et al*., 2023).

When degenerative changes occur in the area, the condylar head is initially eroded and cannot sit securely in the fossa. If this condition persists, the body will attempt to compensate for the instability by initiating a regeneration process to increase stability. This frequently causes osteophyte formation, which is the marginal expansion of the joint surface to provide stability under a power load. Such osteophytes are prevalently observed in patients with long-term degenerative joint disease (Seo *et al*., 2021).

The above mentioned changes contribute to the prevalence of flattened and angled condylar shapes among individuals with TMDs (Yasa & Akgül, 2018; Çamlıdag *et al*., 2022; Mohamed *et al*., 2022). Another study revealed that anterior disc displacement with reduction is highly correlated with subchondral cyst and bone edema, while patients with anterior disc displacement without reduction showed a higher prevalence of generalized condyle sclerosis (de Souza-Pinto *et al*., 2023).

The stability of the TMJ during functioning also depends on the proper sizing of the condyle and glenoid fossa. A larger condyle fits more effectively in a glenoid fossa of the same size, mitigating the likelihood of disc displacement compared with smaller condyles (Noh *et al*., 2021). One study found that TMJs exhibiting anterior disc displacement demonstrated reduced anteroposterior dimensions compared to normal joints (Çamlıdag *et al*., 2022) This correlation affects the distribution of force in the fossa, resulting in morphological variations among individuals (Noh *et al*., 2021).

Association between the articular eminence and glenoid fossa morphology and TMDs. Various studies have classified the shape of the glenoid fossa in corrected sagittal images, identifying four distinct types: triangular, trapezoid, oval, and round (Çaglayan *et al*., 2014; Choudhary *et al*., 2020) Other studies, while adopting a similar categorization, introduced an additional type, including triangular, trapezoid, oval, angled, and other shapes (Yasa & Akgül, 2018; Derwich *et al*., 2020) However, study outcomes can differ due to variations and overlapping definitions in categorization methods, making it difficult to compare results between studies.

Similar to other bones, the articular eminence and glenoid fossa can undergo remodeling in response to functional forces. This can lead to changes in the articular eminence inclination and glenoid fossa depth (Çaglayan *et al*., 2014).

A steeper articular eminence leads to greater vertical movement of the condyle during mouth opening and closing, increasing the risk of disc entrapment and potential displacement during jaw movement. The research conducted by Ma *et al*. (2021) indicates that an increased inclination of the articular eminence results in a wider range of motion for the disc and condylar process. Furthermore, another study suggests that men with disc displacement or joint inflammation tend to have a higher articular eminence angle compared to women (Al-Rawi *et al*., 2017).

On the other hand, the relationship between the depth of the glenoid fossa and the occurrence of TMDs remains inconclusive. One study indicates that TMDs patients experiencing joint pain or sounds exhibit a greater depth of the glenoid fossa compared to the control group (Ma *et al*., 2021). However, another study utilizing 3D models found no significant differences in glenoid fossa volume between TMDs patients and non-patients (Li *et al*., 2023).

Therefore, while the inclination of the articular eminence appears to be a significant characteristic of certain TMDs, the association between the glenoid fossa and the occurrence of TMDs may not be definitively established.

TMDs and condylar position

Normal condylar position. The optimal condyle position in the glenoid fossa remains a topic of debate among researchers in symptomatic and asymptomatic individuals (Lelis *et al*., 2015; Al-Rawi *et al*., 2017; Vankadara *et al*., 2021; Alhammadi, 2022; Alhammadi *et al*., 2023; Li & Zhang, 2023; Li *et al*., 2023). An imaging modality capable of envisioning soft tissues, such as Magnetic Resonance Imaging (MRI), is preferred to ensure that the condylar head, articular disc, and glenoid fossa are optimally aligned (Gharavi *et al*., 2022). Further, Computed Tomography (CT) and Cone-beamed Computed Tomography (CBCT) are suitable for visualizing the bony structure's integrity and identifying the condylar head's position with the glenoid fossa (Ikeda & Kawamura, 2009; Li & Zhang, 2023) A healthy connection between the condylar head and the articular disc is indicated by the posterior band of the disc being positioned at the 12 o'clock mark when the mouth is closed, with a permissible deviation of 30 degrees (Gharavi *et al*., 2022; Ananthan *et al*., 2023). The thinnest intermediate portion of the disc should be situated directly above the condylar head with no signs of displacement when the mouth is fully open (Fig. 4).

Association between condylar position and TMDs. Several studies have indicated that individuals with anterior disc displacement with reduction are more likely to exhibit posterior condylar positioning compared to those without. In such cases, the articular discs are displaced toward the front during mouth closure and then return to the top of the condyle as the joint begins to translate from the glenoid fossa. This causes the condyle to be pushed backward during mouth closure (Ikeda & Kawamura, 2013; Yasa & Akgül, 2018; Alhammadi, 2022; Mohamed *et al*., 2022; Alhammadi *et al*., 2023; Li & Zhang, 2023) Additionally, Cho & Jung (2012) discovered that patients with TMDs with joint noise, which is typically associated with anterior disc displacement, demonstrate a posterior condyle position, whereas other TMDs symptoms, such as joint pain, exhibit no significant correlation with the condyle position.

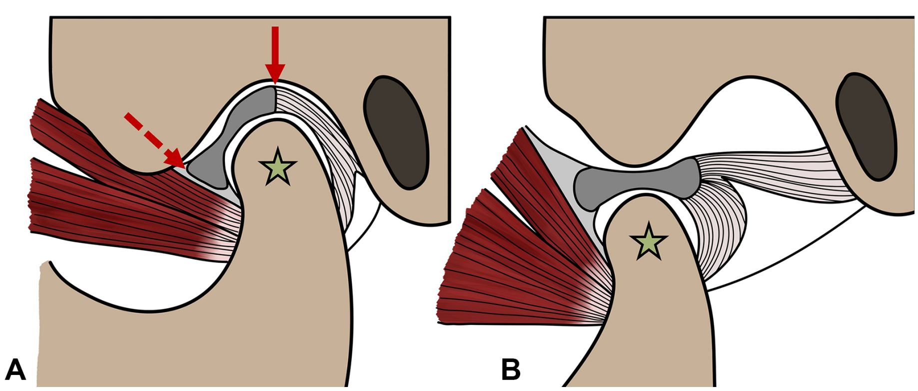

Fig. 4. TMJ with a normal internal connection (A) TMJ in the closed-mouth position, with the anterior band (dashed arrow) and posterior band (solid arrow) of the articular disc indicated by two arrows. Note the positional relationship between the posterior band and the condylar head (star) (B) TMJ in the open-mouth position. Note the relationship between the condylar head (star) and the thinnest intermediate part of the articular disc.

If left untreated, this chronic condition can lead to remodeling of the glenoid fossa, ultimately allowing the condylar head to return to its central position over time (Ma *et al*., 2022) However, other studies have shown that using deprogramming splints as a treatment for TMDs patients with specific symptoms can help shift the condylar head toward the anterior region (Ramachandran *et al*., 2021). This finding confirms the correlation between an overly posterior position of the condylar head and certain TMDs.

Factors affecting TMJ anatomical features and their association with TMDs.

Various factors can influence the morphology and position of the condylar head, as well as the morphologies of the articular eminence and glenoid fossa. These factors may be related to TMDs to varying degrees. The following factors regarding anatomical changes in the TMJ are explored: patient age, gender, preferred chewing side, cephalometric relationship, dentition status, experience with orthodontic treatment, and orthognathic surgery.

Age. The morphology of the condylar head varies with age. Children typically have round-shaped condyles, while adults commonly develop convex and oval-shaped condyles (Hegde *et al*., 2021; López Ramírez *et al*., 2023). Additionally, the inclination of the articular eminence is steeper in adults than in children. In asymptomatic individuals, the eminence height is lowest in the 16–20 age group, peaks at 21–30 years old, and becomes relatively flatter in those aged over 30 (Yasa & Akgül, 2018) Despite these changes, the structures of the articular eminence and glenoid fossa tend to stabilize after full development, occurring between the ages of 20 and 30 (Ma *et al*., 2021).

Different individuals display varying adaptive responses to TMJ changes. Extended exposure to factors predisposing individuals to TMDs is necessary to surpass these natural adaptive capabilities and allow for detectable spatial or morphological TMJ changes (Lelis *et al*., 2015; Fichera *et al*., 2021; Paknahad *et al*., 2023). TMDs are more commonly found in individuals aged 20–40 (Valesan *et al*., 2021). Research comparing asymptomatic and symptomatic TMJs also revealed that individuals aged 19 and older face twice the risk of developing TMDs (Li & Zhang, 2023). Notably, significant morphological changes in the condylar head occur more frequently in individuals aged over 61, with flattening of the condylar head being the most prevalent feature (Mathew *et al*., 2011).

Sex. There are conflicting findings on the effects of sex on the predisposition of TMDs. Some studies suggest that females have a higher prevalence of TMDs and, therefore, seek treatment more than males, with a gender ratio of 3.3 (Manfredini *et al*., 2011; Valesan *et al*., 2021). Another study has shown a positive association between condylar changes and female gender (Liu *et al*., 2018). However, other studies have found no significant relationship between these variables (Seo *et al*., 2021; Li & Zhang, 2023; Paknahad *et al*., 2023). Some studies even suggest that males have more morphological alterations of the mandibular condyle and clinical findings compared with females (Daneshmehr *et al*., 2022). The most recent meta-analysis conducted on the global prevalence of TMDs has revealed a higher incidence of TMDs in women as compared to men. Nevertheless, the female-to-male ratio varies from 1.09 to 1.56 across different continents (Zielinski *et al*., 2024), indicating that gender may not be a strong predisposing factor for TMDs.

The morphology of TMJ can be influenced by sex hormones, with differences becoming more pronounced after adolescence. Generally, males tend to have larger cranial structures than females, which include wider condyles, greater condylar volume, and stronger chewing forces, resulting in a higher eminence height compared to females (Liu *et al*., 2018; Yasa & Akgül, 2018). In females, estrogen, a predominant female sex hormone, can influence the metabolism of bone and cartilage in the TMJ. Some animal studies suggest that estrogen could lead to degenerative remodeling of the TMJ, reduced bone volume, and the formation of osteophytes. An increase in estrogen receptors may lead to an amplified response to joint loading (Kobayashi *et al*., 2012).

Chewing-side preference. Chewing-side preference (CSP) refers to an individual consistently chewing on one side of the dentition and while CSP alone may not be directly responsible for causing TMDs, it may contribute to their development (Jeon *et al*., 2017; Ma *et al*., 2022). Unilateral chewing can result in excessive functional load on one side, potentially causing changes to the structure of the articular eminence and glenoid fossa in the jaw. Ma *et al*. (2021) compared articular eminence inclination and glenoid fossa depth among patients with TMDs symptoms and asymptomatic individuals, revealing that patients with TMDs and CSP had a steeper articular eminence slope and deeper glenoid fossa compared to those without. Some researchers suggest using the term "habitual chewing side syndrome" to describe the symptoms of TMDs resulting from a patient's repetitive unilateral chewing behavior. This syndrome presents with a steeper condylar path, flatter lateral anterior guidance, and a tendency to chew habitually on the side where the symptoms are felt (Santana-Mora *et al*., 2013).

Having CSP can also influence the position of the condylar head on the preferred side. Research has indicated that, during mastication, condyles on the chewing side move toward the back more often than the nonchewing side in healthy young adults (Tomonari *et al*., 2017). Those with CSP exhibit a repetitive pattern of this movement, causing posterior displacement of the condylar head over time. A study involving normal subjects revealed that the preferred side in a CSP group exhibited diminished posterior and supero-posterior joint spaces, indicating a posteriorly displaced position (Jiang *et al*., 2015). If the condyle is pushed excessively beyond the articular disc area, the force generated during mandibular movement may result in inflammation and pain in the retrodiscal tissue, which possesses a lower force-bearing capability compared with the articular disc (Ma *et al*., 2022).

Cephalometric relationship. The developmental process of a person's facial skeleton can be broadly categorized into vertical and anteroposterior growth. Vertical skeletal growth can be further classified into three types based on the angle between the inclination of the mandibular plane and the cranial base plane. Individuals with a normal angle fall into the normodivergent category, while those with a low angle are classified as hypodivergent, and those with a high angle as hyperdivergent (Türker & Öztürk Yas¸ar, 2022) On the other hand, the anteroposterior relationship between the jaws is categorized as Class I, II, or III, depending on the relative position of the maxilla and mandible (López Ramírez *et al*., 2023).

Cephalometric relationships, both in terms of vertical and anteroposterior dimensions, can influence the structure of the TMJ. In cases of excessive anteroposterior growth, often seen in patients with skeletal Class III relationships, there is typically a greater condylar width and height compared to those with skeletal Class II relationships (Noh *et al*., 2021). Studies on skeletal vertical analysis have shown that individuals with a hyperdivergent skeletal pattern tend to have a lower condylar volume but greater fossa length and height (Türker & Öztürk Yasar, 2022).

Craniofacial morphology can also impact condylar position. Although this altered position may not be a direct cause of TMDs, it could be a predisposing factor (Fichera *et al*., 2021). Skeletal Class II relationships are characterized by a retrognathic mandible, in which the condylar head is more posteriorly positioned compared with a normal skeletal relationship. Research has indicated that in a group with Class I skeletal relationships, condyles are primarily located within the 4/7 position on Gelb's grid. In comparison, condyles in groups with Class II and Class III skeletal relationships tend to be located in the more posterior 5/8 position (Soni *et al*., 2022). A pilot study with a limited sample size found significant differences in the skeletal classification distribution between TMDs and non-TMDs groups. Skeletal Class II was the most prevalent relationship in the TMDs group, followed by Class III and Class I. In contrast, skeletal Class I was most common in those without TMDs symptoms, followed by Class II and III (Fichera *et al*., 2021). Another study with more participants demonstrated that patients with TMDs symptoms tend to have a higher ANB angle, indicative of a skeletal Class II relationship (Yan *et al*., 2022). Additionally, patients with a hyperdivergent profile exhibit a significantly smaller superior joint space width, indicating a more superior condyle position (Noh *et al*., 2021).

Dentition status. Various studies have employed Eichner's index or the Kennedy classification to explore the tooth loss phenomenon (Singh *et al*., 2020; Sreekumar *et al*., 2021; Leal *et al*., 2023; Paknahad *et al*., 2023). Eichner's index, widely used in dental epidemiological studies, categorizes patients into Groups A–C based on the number of occluding pairs among posterior teeth by dividing the occlusal support area of these teeth into four zones. The Kennedy classification categorizes patients into Class I–IV based on tooth loss patterns.

The influence of tooth loss on morphological and positional changes in the TMJ area is a topic of ongoing discussion, with numerous studies presenting conflicting results. Some researchers argue that the absence of posterior teeth may disrupt the balance of occlusal forces during chewing, leading to structural remodeling and degenerative changes as the jaw adapts to changes in occlusal function (Zheng *et al*., 2023). It has also been suggested that individuals without posterior teeth may compensate by relying more on their anterior teeth during chewing, causing the mandible to shift posteriorly due to the inclination of these teeth (Paknahad *et al*., 2023). Additionally, another study indicated that a greater loss of tooth-supporting zones is linked to posterior and inferior displacement of condylar heads (Tabatabaei *et al*., 2024). However, one study has reported that the glenoid fossae of completely edentulous patients are positioned more anteriorly than those of patients with teeth (Raustia *et al*., 1998).

Despite the observed structural and positional changes in individuals with tooth loss, it has been suggested that these changes may not be significant enough for tooth loss to be a major predisposing factor for TMDs. This assertion is supported by a recent systematic review that underscores the lack of scientific evidence linking tooth loss to the prevalence of TMDs (Leal *et al.*, 2023).

Orthognathic surgery. Changes in the morphology and position of the TMJ can be observed following orthognathic surgery. However, these minor alterations are generally not considered to be a significant factor in the development of

TMDs. In rare instances, certain orthognathic surgical techniques may result in torque and malpositioning of the condyle, placing increased stress on the TMJ structure. This can lead to permanent changes in the shape of the condylar head, resulting in a reduction in volume and a decrease in ramus height, a condition known as progressive condylar resorption. The diminished blood supply and soft tissue tension due to mandibular advancement contribute to this resorption, as tension causes the condyle to be retracted forcefully into the fossa, exerting pressure on the condylar head (Kaur *et al*., 2022; Kobayashi *et al*., 2012).

Early responses at the site of surgery, such as intra-articular edema or masticatory muscle and temporomandibular ligament stretching, may cause temporary positional changes, but orthognathic surgery does not significantly shift the condylar head's position (Ding *et al*., 2022). Research on condylar position post orthognathic surgery revealed notable changes after 15 days with mandibular counterclockwise rotation (Méndez-Manjón *et al*., 2016). However, a study conducted six months after surgery revealed only minor forward and inward condyle movements (Kaur *et al*., 2022). A follow-up study performed 1 year after surgery found that the condyle's long axis had axially rotated inward, tilted forward, and tilted inward, although these modifications were also deemed nonsignificant (Han, 2022).

The primary goal of orthognathic surgery is to correct skeletal deformities, although symptoms of TMDs may present prior to the surgical intervention (Abrahamsson *et al*., 2009). The impact of orthognathic surgery on individuals with pre-existing TMDs symptoms can vary. While positive outcomes are possible, there is also a chance of negative effects or the development of new symptoms. A recent study reported an increased risk for progressive condylar resorption in individuals with prior condylar erosions and/or deformities following orthognathic surgery. Therefore, mandibular advancement surgery is only recommended for those with stable pre-operative condylar positions as determined by radiographs. Additionally, caution should be exercised when performing surgery on patients with pre-existing TMDs. These high-risk patients require careful attention to postoperative mechanical loading on the TMJ (Kobayashi *et al*., 2012). Another 1-year follow-up study found that around 50 % of patients showed no TMJ status changes, but 12.5 % developed TMDs symptoms post-surgery (Toh & Leung, 2022) Patients with symptom resolution showed significantly improved joint disorders, suggesting that despite minimal changes in linear distance and angular tilt, orthognathic surgery can restructure the TMJ's internal components, resulting in healthier condyle and articular disc relationships (Ding *et al*., 2022).

Orthodontic treatment. Various intraoral and extraoral devices are employed during orthodontic treatment. However, none of these devices are considered direct causes of TMDs (Kaur *et al*., 2018). Extraoral appliances, such as chin-cups and reverse pull headgear, are thought to shift the mandible and condyle more posteriorly, but the temporomandibular ligament, particularly the horizontal part, can resist the force. Research on chin-cups has indicated that they do not hinder mandibular growth but alter its direction, resulting in a shift in mandibular shape with minor morphological changes (Zurfluh *et al*., 2015). Clear aligners, another popular appliance, may induce muscle soreness due to increased activity, but this effect is typically temporary and rarely progresses to noticeable TMDs symptoms (Michelotti *et al*., 2020).

A long-term study monitoring patients undergoing orthodontic treatment for 20 years found no causal relationship between orthodontic treatment or tooth extraction and TMDs symptoms or signs, regardless of the method employed (Dibbets & van der Weele, 1992) Thus, correctly completed orthodontic treatment, when the forces applied remain within the patient's adaptive capability, should not contribute to TMDs. Overall, the scientific evidence connecting orthodontic treatment to an increased risk or prevention of TMDs is insufficient.

Similar to orthognathic surgery, patients seeking orthodontic treatment often have pre-existing skeletal abnormalities and may experience TMDs symptoms before the procedure. Orthodontists must identify any existing TMDs concerns to establish an effective treatment strategy, and it is advisable to defer treatment until the patient is pain-free or has pain under proper management (Michelotti *et al*., 2020). Certain authors have suggested that functional mandibular advancement should not be considered contraindicated in cases of total disc displacement, with or without reduction. However, caution should be exercised in patients with pathological changes in the condyle, as they are considered high-risk patients, and the use of such treatment requires careful attention (Ding *et al*., 2022).

CONCLUSION

The TMJ is a complex structure relying on bones, muscles, richly vascularized and innervated capsules, ligaments, and an articular disc for smooth functioning. The alteration of its anatomy under an inadequate function may contribute to TMDs development. Previous studies have indicated that reduced fitness of the condylar head in the glenoid fossa, resulting from morphological changes and excessively posterior positioning of the condyle, are potential factors contributing to TMDs. The steepness of articular eminence inclination appears to be a notable characteristic of certain TMDs. However, the correlation between the glenoid fossa with TMDs occurrence may not be robust, and discrepancies in findings could be attributed to humans' adaptive capacity.

This study acknowledges several limitations within its scope. TMDs encompass a broad range of symptoms related to the TMJ, including orofacial pain originating from muscular components. While our investigation primarily centers on factors influencing the osseous components of the TMJ—specifically, the condyle, articular eminence, and glenoid fossa—TMDs stemming from muscular origins are not extensively addressed. Furthermore, it is essential to recognize that structures external to the TMJ region may also exert significant influence on TMJ structure and function, highlighting the complexity of TMDs etiology beyond the confines of discussed factors. Given the multifactorial nature of TMDs, determining a single primary cause can be challenging. Therefore, recognizing all potential risk factors beyond anatomy-related factors is crucial for accurate diagnosis and successful management of TMDs. This complex condition warrants further standardized studies to deepen our understanding.

ACKNOWLEDGMENTS

This research was supported by the Korea Medical Device Development funded by the Ministry of Science and ICT, the Ministry of Trade, Industry and Energy, the Ministry of Health & Welfare, and the Ministry of Food and Drug Safety (Project Number: 1711134912, RS-2020-KD000002) and Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2021R1I1A2048516).

LAPPANAKOKIAT, N.; KIM, J-E.; PARK, J-Y. y PARK, Y-S. Revisitando las características anatómicas de la articulación temporomandibular y su asociación con el trastorno temporomandibular: Una revisión narrativa. *Int. J. Morphol., 42(6)*:1550-1559, 2024.

RESUMEN: La articulación temporomandibular (ATM) es una estructura compleja que depende de huesos, músculos, ligamentos y un disco articular para su adecuado funcionamiento. El desarrollo de los trastornos temporomandibulares (TTM) se puede atribuir a cambios en la anatomía de la ATM. Varios factores, entre ellos la edad, el sexo, la preferencia del lado de masticación, el estado de la dentición, la relación cefalométrica y el tratamiento de ortodoncia o la cirugía ortognática, contribuyen a los cambios estructurales y posicionales de los componentes de la ATM. Este artículo de revisión resume la asociación entre los TTM y los cambios en la morfología y la posición del cóndilo mandibular, la eminencia articular y la fosa glenoidea debido a varios factores. Se realizó una búsqueda electrónica exhaustiva en las bases de datos PubMed y Scopus con los filtros de búsqueda apropiados. Después del proceso de deduplicación y la selección de títulos, resúmenes y textos completos, sesenta estudios se sometieron a un proceso de lectura de texto completo exhaustivo y se incluyeron en esta revisión. Los pacientes con síntomas de TTM tienden a tener formas condilares aplanadas y anguladas y con frecuencia presentan una cabeza condilar posicionada posteriormente. La inclinación más pronunciada de la eminencia articular parece ser una característica notable de ciertos TTM. Sin embargo, dada la naturaleza multifactorial de los TTM, determinar un solo factor como causa primaria puede ser un desafío. Por lo tanto, reconocer todos los factores de riesgo potenciales más allá de los factores relacionados con la anatomía es fundamental para el diagnóstico preciso y el manejo exitoso de los TTM.

PALABRAS CLAVE: Anatomía; Disco articular; Hueso temporal; Trastornos temporomandibulares; Articulación temporomandibular.

REFERENCES

Abdul, N. S. & Minervini, G. Prevalence of temporomandibular disorders in orthognathic surgery patients: a systematic review conducted according to PRISMA guidelines and the Cochrane Handbook for Systematic Reviews of Interventions. *J. Oral. Rehabil., 50(10)*:1093-100, 2023.

Abrahamsson, C.; Ekberg, E.; Henrikson, T.; Nilner, M.; Sunzel, B. & Bondemark, L. TMD in consecutive patients referred for orthognathic surgery. *Angle Orthod., 79(4)*:621-7, 2009.

Al-Rawi, N. H.; Uthman, A. T. & Sodeify, S. M. Spatial analysis of mandibular condyles in patients with temporomandibular disorders and normal controls using cone beam computed tomography. *Eur. J. Dent., 11(1)*:99-105, 2017.

Alam, M. K.; Abutayyem, H.; Alzabni, K. M. D.; Almuhyi, N. H. S.; Alsabilah, K. A. S.; Alkubaydan, F. S. T.; Alswairki, H. J.; Hajeer, M. Y. & Awawdeh, M. A. The impact of temporomandibular disorders on orthodontic management: a systematic review and meta-analysis. *Cureus, 15(8)*:e44243, 2023.

Aldayel, A. M.; AlGahnem, Z. J.; Alrashidi, I. S.; Nunu, D. Y.; Alzahrani, A. M.; Alburaidi, W. S.; Alanazi, F.; Alamari, A. S. & Alotaibi, R. M. Orthodontics and temporomandibular disorders: an overview. *Cureus, 15(10)*:e47049, 2023.

Alhammadi, M. S. Dimensional and positional characteristics of the temporomandibular joint of skeletal class II malocclusion with and without temporomandibular disorders. *J. Contemp. Dent. Pract., 23(12)*:1203-10, 2022.

Alhammadi, M. S.; Almashraqi, A. A.; Thawaba, A. A.; Fayed, M. M. S. & Aboalnaga, A. A. Dimensional and positional temporomandibular joint osseous characteristics in normodivergent facial patterns with and without temporomandibular disorders. *Clin. Oral. Investig., 27(9)*:5011-20, 2023.

Almubarak, S. M.; Ashour, L. M.; Aleissa, Z. H.; Alotaibi, A. M.; Mortaga, R. M.; Khulaifi, R. K. a.; Hunaish, A. A.; Addin, B. S. & Noureddin, M. A. Current concepts about temporomandibular joint disorders: a review article. *J. Res. Med. Dent., 8*:471-9, 2020.

Ananthan, S.; Pertes, R. A. & Bender, S. D. Biomechanics and derangements of the temporomandibular joint. *Dent. Clin. North Am., 67(2)*:243-57, 2023.

Basit, H.; Tariq, M. A. & Siccardi, M. A. *Anatomy, Head and Neck, Mastication Muscles.* Web Site. StatPearls, StatPearls Publishing, 2024.

Çaglayan, F.; Sümbüllü, M. A. & Akgül, H. M. Associations between the articular eminence inclination and condylar bone changes, condylar movements, and condyle and fossa shapes. *Oral Radiol., 30(1)*:84-91, 2014.

Çamlıdag, I.; Sayıt, A. T. & Elmalı, M. Is condyle morphology a factor for anterior temporomandibular disc displacement? *Turk. J. Med. Sci., 52(5)*:1609-15, 2022.

Cho, B. H. & Jung, Y. H. Osteoarthritic changes and condylar positioning of the temporomandibular joint in Korean children and adolescents. *Imaging Sci. Dent., 42(3)*:169-74, 2012.

Choudhary, A.; Ahuja, U. S.; Rathore, A.; Puri, N.; Dhillon, M. & Budakoti, A. Association of temporomandibular joint morphology in patients with and without temporomandibular joint dysfunction: A cone-beam computed tomography based study. *J. Dent. Res., 17(5)*:338-46, 2020.

Daneshmehr, S.; Razi, T. & Razi, S. Relationship between the condyle morphology and clinical findings in terms of gender, age, and remaining teeth on cone beam computed tomography images. *Braz. J. Oral Sci., 21(00)*:e226611, 2022.

de Souza-Pinto, G. N.; Herreira-Ferreira, M.; Grossmann, E.; Brasil, D. M.; Hara, G. F.; Groppo, F. C. & Iwaki, L. C. V. Assessment of temporomandibular joint bone changes associated with anterior disc displacement: An MRI cross-sectional study. *J. Stomatol. Oral Maxillofac. Surg., 124(6S2)*:101657, 2023.

Derwich, M.; Mitus-Kenig, M. & Pawlowska, E. Temporomandibular joints' morphology and osteoarthritic changes in cone-beam computed tomography images in patients with and without reciprocal clicking—A case control study. *Int. J. Environ. Res. Public Health, 17(10)*:3428, 2020.

Dhabale, G. S. & Bhowate, R. R. Cone-beam computed tomography for temporomandibular joint imaging. *Cureus, 14(11)*:e31515, 2022.

Dibbets, J. M. & van der Weele, L. T. Long-term effects of orthodontic treatment, including extraction, on signs and symptoms attributed to CMD. *Eur. J. Orthod., 14(1)*:16-20, 1992.

Ding, L.; Chen, R.; Liu, J.; Wang, Y.; Chang, Q. & Ren, L. The effect of functional mandibular advancement for adolescent patients with skeletal class II malocclusion on the TMJ: a systematic review and meta-analysis. *BMC Oral Health, 22(1)*:51, 2022.

Fichera, G.; Ronsivalle, V.; Santonocito, S.; Aboulazm, K. S.; Isola, G.; Leonardi, R. & Palazzo, G. Class II skeletal malocclusion and prevalence of temporomandibular disorders. an epidemiological pilot study on growing subjects. *J. Funct. Morphol. Kinesiol., 6(3)*:63, 2021.

Gharavi, S.; Qiao, Y.; Faghihimehr, A. & Vossen, J. Imaging of the temporomandibular joint. *Diagnostics (Basel), 12(4)*:1006, 2022.

Han, Y. Changes in condylar position within 12 months after bilateral sagittal split ramus osteotomy with and without Le Fort I osteotomy by using cone-beam computed tomography. *J. Oral Maxillofac. Surg., 80(1)*:162-73, 2022.

Hegde, R.; Shigli, A.; Gawali, P.; Krishnan, A.; Jadhav, G. & Raheja, S. Morphological variations of the condylar head among children aged 4-15 years: A panoramic study. J. *Indian Soc. Pedod. Prev. Dent., 39(4)*:353-7, 2021.

Ikeda, K. & Kawamura, A. Assessment of optimal condylar position with limited cone-beam computed tomography. *Am. J. Orthod. Dentofacial Orthop., 135(4)*:495-501, 2009.

Ikeda, K. & Kawamura, A. Disc displacement and changes in condylar position. *Dentomaxillofac. Radiol., 42(3)*:84227642, 2013.

Jeon, H. M.; Ahn, Y. W.; Jeong, S. H.; Ok, S. M.; Choi, J.; Lee, J. Y.; Joo, J. Y. & Kwon, E. Y. Pattern analysis of patients with temporomandibular disorders resulting from unilateral mastication due to chronic periodontitis. *J. Periodontal Implant Sci., 47(4)*:211-8, 2017.

Jiang, H.; Li, C.; Wang, Z.; Cao, J.; Shi, X.; Ma, J. & Liu, H. Assessment of osseous morphology of temporomandibular joint in asymptomatic participants with chewing-side preference. *J. Oral Rehabil., 42(2)*:105-12, 2015.

Kapos, F. P.; Exposto, F. G.; Oyarzo, J. F. & Durham, J. Temporomandibular disorders: a review of current concepts in aetiology, diagnosis and management. *Oral Surg., 13(4)*:321-34, 2020.

Kaur, A.; Rattan, V.; Rai, S.; Singh, S. P.; Kalra, P. & Sharma, S. Changes in condylar position after orthognathic surgery and its correlation with temporomandibular symptoms (TMD) - a prospective study. *J. Craniomaxillofac. Surg., 50(12)*:915-22, 2022.

Kaur, R.; Munjal, S.; Singh, S.; Natt, A. & Singh, H. Temporomandibular joint and orthodontics: a review article. *J. Appl. Dent. Med. Sci., 4(1)*:128-35, 2018.

Kobayashi, T.; Izumi, N.; Kojima, T.; Sakagami, N.; Saito, I. & Saito, C. Progressive condylar resorption after mandibular advancement. *Br. J. Oral Maxillofac. Surg., 50(2)*:176-180, 2012.

Leal, M.; Castro, M. M. L. & Sosthenes, M. C. K. Updating the general practitioner on the association between teeth loss and temporomandibular disorders: a systematic review. *Eur. J. Dent., 17(2)*:296-309, 2023.

Lelis, É. R.; Guimarães Henriques, J. C.; Tavares, M.; de Mendonça, M. R.; Fernandes Neto, A. J. & Almeida, G. A. Cone-beam tomography assessment of the condylar position in asymptomatic and symptomatic young individuals. *J. Prosthet. Dent., 114(3)*:420-5, 2015.

Li, C. & Zhang, Q. Comparison of imaging findings of 714 symptomatic and asymptomatic temporomandibular joints: a retrospective study. *BMC Oral Health, 23(1)*:79, 2023.

Li, C. X.; Liu, H.; Gong, Z. C.; Liu, X. & Ling, B. Effects of osseous structure based on three-dimensional reconstructive imaging evaluation in the assessment of temporomandibular joint disc position. *Clin. Oral Investig., 27(4)*:1449-63, 2023.

Liu, Q.; Wei, X.; Guan, J.; Wang, R.; Zou, D. & Yu, L. Assessment of condylar morphology and position using MSCT in an Asian population. *Clin. Oral Investig., 22(7)*:2653-61, 2018.

López Ramírez, J. C.; Mariel Cárdenas, J.; Gutiérrez Cantú, F. J.; Salas Orozco, M. F.; Sr.; Medina-Solís, C. E.; Hernández Molinar, Y.; Trejo Rivero, E. & Patiño-Marín, N. Association between gender, age, and skeletal class with mandibular condyle morphology: a retrospective study. *Cureus, 15(11)*:e49043, 2023.

Ma, J.; Wang, J.; Huang, D.; Wang, Z.; Hu, M.; Liu, H. & Jiang, H. Cone-beam computed tomographic assessment of the inclination of the articular eminence in patients with temporomandibular disorders and chewing side preference. *BMC Oral Health, 21(1)*:396, 2021.

Ma, J.; Wang, J.; Huang, D.; Wang, Z.; Hu, M.; Liu, H. & Jiang, H. A comparative study of condyle position in temporomandibular disorder patients with chewing side preference using cone-beam computed tomography. *J. Oral Rehabil., 49(2)*:265-71, 2022.

Manfredini, D.; Guarda-Nardini, L.; Winocur, E.; Piccotti, F.; Ahlberg, J. & Lobbezoo, F. Research diagnostic criteria for temporomandibular disorders: a systematic review of axis I epidemiologic findings. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod., 112(4)*:453-62, 2011.

Maranini, B.; Ciancio, G.; Mandrioli, S.; Galiè, M. & Govoni, M. The role of ultrasound in temporomandibular joint disorders: an update and future perspectives. *Front. Med. (Lausanne), 9*:926573, 2022.

Mathew, A. L.; Sholapurkar, A. A. & Pai, K. M. Condylar Changes and Its Association with Age, TMD, and Dentition Status: A Cross-Sectional Study. *Int. J. Dent., 2011*:413639, 2011.

Méndez-Manjón, I.; Guijarro-Martínez, R.; Valls-Ontañón, A. & Hernández-Alfaro, F. Early changes in condylar position after mandibular advancement: a three-dimensional analysis. *Int. J. Oral Maxillofac. Surg., 45(6)*:787-92, 2016.

Michelotti, A.; Rongo, R.; D'Antò, V. & Bucci, R. Occlusion, orthodontics, and temporomandibular disorders: Cutting edge of the current evidence. *J. World Fed. Orthod., 9(3s)*:S15-S18, 2020.

Militi, A.; Bonanno, M. & Calabrò, R. S. It is time for a multidisciplinary rehabilitation approach: a scoping review on stomatognathic diseases in neurological disorders. *J. Clin. Med., 12(10)*:3528, 2023.

Minervini, G.; Marrapodi, M. M.; Tirupathi, S.; Afnan, L.; Ronsivalle, V.; Cervino, G. & Cicciù, M. Prevalence of temporomandibular disorders (TMD) in bleeding disorders: A systematic review with meta-analysis. *J. Oral Rehabil., 50(12)*:1535-43, 2023.

Mohamed, H. N.; Ashmawy, M. S.; Ekladious, M. E. Y. & Farid, M. M. Analysis of the relationship between condylar changes and anterior disc displacement with reduction: a preliminary study. *Oral Radiol., 39(1)*:154-63, 2022.

Nicot, R.; Raoul, G.; Ferri, J. & Schlund, M. Temporomandibular disorders in head and neck cancers: Overview of specific mechanisms and management. *J. Stomatol. Oral Maxillofac. Surg., 121(5)*:563-8, 2020.

Noh, K. J.; Baik, H. S.; Han, S. S.; Jang, W. & Choi, Y. J. Differences in mandibular condyle and glenoid fossa morphology in relation to vertical and sagittal skeletal patterns: A cone-beam computed tomography study. *Korean J. Orthod., 51(2)*:126-34, 2021.

Ohrbach, R. & Dworkin, S. F. The evolution of TMD diagnosis: past, present, future. *J. Dent. Res., 95(10)*:1093-1101, 2016.

Paknahad, M.; Khojastepour, L.; Tabatabaei, S. & Mahjoori-Ghasrodashti, M. Association between condylar bone changes and eichner index in patients with temporomandibular dysfunction: a cone beam computed tomography study. *J. Dent (Shiraz), 24(1)*:12-8, 2023.

Ramachandran, A.; Jose, R.; Tunkiwala, A.; Varma, R. B.; Shanmugham, M. A.; Nair, P. K.; Kumar, K. S. & Sam, L. M. Effect of deprogramming splint and occlusal equilibration on condylar position of TMD patients – A CBCT assessment. *Cranio, 39(4)*:294-302, 2021.

Raustia, A. M.; Pirttiniemi, P.; Salonen, M. A. & Pyhtinen, J. Effect of edentulousness on mandibular size and condyle-fossa position. *J. Oral Rehabil., 25(3)*:174-9, 1998.

Santana-Mora, U.; López-Cedrún, J.; Mora, M. J.; Otero, X. L. & Santana-Penín, U. Temporomandibular disorders: the habitual chewing side syndrome. *PLoS One, 8(4)*:e59980, 2013.

Schiffman, E.; Ohrbach, R.; Truelove, E.; Look, J.; Anderson, G.; Goulet, J. P.; 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 Group. *J. Oral Facial Pain Headache, 28(1)*:6-27, 2014.

Seo, B. Y.; Huh, K. H.; An, J. S.; Chang, M. S. & Ahn, S. J. Relationship of computed tomography-verified degenerative condylar morphology with temporomandibular joint disk displacement and sex. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol., 132(1)*:93-103, 2021.

Singh, B.; Kumar, N. R.; Balan, A.; Nishan, M.; Haris, P. S.; Jinisha, M. & Denny, C. D. Evaluation of normal morphology of mandibular condyle: a radiographic survey. *J. Clin. Imaging Sci., 10*:51, 2020.

Soni, D.; Khanna, R.; Tikku, T.; Maurya, R. P.; Verma, S. & Srivastava, K. Evaluation of mandibular condylar position in different malocclusion with Gelb's grid. IP Indian *J. Orthod. Dentofacial Res., 8(3)*:161-5, 2022.

Sreekumar, S.; Janakiram, C. & Mathew, A. Effects of Prosthetic Rehabilitation on Temporomandibular Disorders: Protocol for a Randomized Controlled Trial. JMIR Res. Protoc., 10(12):e33104, 2021.

Tabatabaei, S.; Paknahad, M. & Poostforoosh, M. The effect of tooth loss on the temporomandibular joint space: A CBCT study. *Clin. Exp. Dent. Res., 10(1)*:e845, 2024.

Toh, A. Q. J. & Leung, Y. Y. The effect of orthognathic surgery on temporomandibular disorder. *J. Craniomaxillofac. Surg., 50(3)*:218-24, 2022.

Tomonari, H.; Kwon, S.; Kuninori, T. & Miyawaki, S. Differences between the chewing and non-chewing sides of the mandibular first molars and condyles in the closing phase during chewing in normal subjects. *Arch. Oral Biol., 81*:198-205, 2017.

Türker, G. & Öztürk Yasar, M. Evaluation of associations between condylar morphology, ramus height, and mandibular plane angle in various vertical skeletal patterns: a digital radiographic study. *BMC Oral Health, 22(1)*:330, 2022.

Valesan, L. F.; Da-Cas, C. D.; Réus, J. C.; Denardin, A. C. S.; Garanhani, R. R.; Bonotto, D.; Januzzi, E. & de Souza, B. D. M. Prevalence of temporomandibular joint disorders: a systematic review and meta-analysis. *Clin. Oral Investig., 25(2)*:441-53, 2021.

Vankadara, S.; Akula, B. & Nissi, K. Assessment and comparison of condylar position based on joint space dimensions and gelb 4/7 grid using CBCT. *J. Indian Acad. Oral Med. Radiol., 33(1)*:6-11, 2021.

Wadhokar, O. C. & Patil, D. S. Current trends in the management of temporomandibular joint dysfunction: a review. *Cureus, 14(9)*:e29314, 2022.

Xiong, X.; Ye, Z.; Tang, H.; Wei, Y.; Nie, L.; Wei, X.; Liu, Y. & Song, B. MRI of Temporomandibular Joint Disorders: Recent Advances and Future Directions. *J. Magn. Reson. Imaging, 54(4)*:1039-52, 2021.

Yale, S. H.; Allison, B. D. & Hauptfuehrer, J. D. An epidemiological assessment of mandibular condyle morphology. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol., 21(2)*:169-77, 1966.

Yan, Z. B.; Wan, Y. D.; Xiao, C. Q.; Li, Y. Q.; Zhang, Y. Y.; An, Y. & Xiong, X. Craniofacial morphology of orthodontic patients with and without temporomandibular disorders: a cross-sectional study. *Pain Res. Manag., 2022*:9344028, 2022.

Yasa, Y. & Akgül, H. M. Comparative cone-beam computed tomography evaluation of the osseous morphology of the temporomandibular joint in temporomandibular dysfunction patients and asymptomatic individuals. *Oral Radiol., 34(1)*:31-9, 2018.

Zheng, H.; Shi, L.; Lu, H.; Liu, Z.; Yu, M.; Wang, Y. & Wang, H. Influence of edentulism on the structure and function of temporomandibular joint. *Heliyon, 9(10)*:e20307, 2023.

Zielin´ski, G.; Paja˛k-Zielin´ska, B. & Ginszt, M. A meta-analysis of the global prevalence of temporomandibular disorders. *J. Clin. Med., 13(5)*:1365, 2024.

Zurfluh, M. A.; Kloukos, D.; Patcas, R. & Eliades, T. Effect of chin-cup treatment on the temporomandibular joint: a systematic review. *Eur. J. Orthod., 37(3)*:314-24, 2015.

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