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Temporomandibular Joint Ankylosis: A Comprehensive Review of Classifications and Treatment Approaches

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Abstract: ***Ankylosis of the temporomandibular joint (TMJ) is a debilitating condition characterized by the fusion of the craniomandibular structures, often resulting from displaced condylar fractures that affect the meniscus. Ankylosis can be fibrous, fibro - osseous, or bony, and may occur unilaterally or bilaterally. The severity of the deformity depends on factors such as the onset, duration, and type of ankylosis. While various surgical methods have been proposed for treatment, no single approach is universally recommended due to inconsistent outcomes and a high rate of failure. This paper reviews various classifications, clinical manifestations, surgical approaches and treatment modalities of Temporomandibular Joint ankylosis. Articles related to classifications and surgical techniques were reviewed and analyzed for this study. Many surgical techniques to manage temporomandibular joint (TMJ) ankylosis have been described in the literature. The aim is to present a comprehensive understanding of the condition and its management approaches for enhanced clinical decision - making.***

Keywords: Temporomandibular Joint Ankylosis, Gap Arthroplasty, Interpositional Arthroplasty, Joint Reconstruction, Surgical Management, Neocondylogenesis

1. Introduction

The temporomandibular joint (TMJ) is a synovial diarthrodial joint formed between the mandible's condyle and the glenoid fossa of the temporal bone, separated by an articular disc [1]. The TMJ is a specialized joint that can be categorized both anatomically and functionally. Anatomically, it is classified as a diarthrodial joint, characterized by discontinuous articulation between two bones, allowing movement controlled by associated muscles and restricted by surrounding ligaments. [2]

Temporomandibular disorder is a broad term referring to any abnormality related to the jaw joint. Among these conditions, ankylosis is one of the most severe, significantly affecting quality of life. The term "ankylosis" comes from Greek, meaning a stiff joint. It can be categorized as a fibrous, fibro - osseous, or osseous fusion of the joint components. Trauma is the primary cause, with other factors including rheumatoid arthritis, degenerative arthritis, infectious spondylitis, and psoriasis. [3, 4]

Ankylosis of the temporomandibular joint (TMJ) can be either unilateral or bilateral, with the degree of facial deformity influenced by the type of ankylosis, as well as its onset and duration. During the growth phase, the deformity is more severe and can impact nutrition, speech, growth, oral hygiene, tooth eruption, malocclusion, and in severe cases, micrognathia, which may cause obstructive sleep apnea. After the growth phase, ankylosis primarily results in functional loss, with minimal aesthetic deformity. In this review, we will discuss the etiopathogenesis, classifications, surgical approaches, and various treatment modalities of TMJ ankylosis.

Etiopathogensis of TMJ Ankylosis

Ankylosis of the TMJ can be caused by several factors, with trauma being the most common, along with local or systemic infections and systemic diseases. Trauma may lead to an intra - articular hematoma, resulting in fibrosis, excessive bone growth, and eventually joint hypomobility. The TMJ can also become infected from nearby areas like otitis media and mastoiditis, or through hematogenous spread from conditions such as tuberculosis, gonorrhea, and scarlet fever. Systemic diseases associated with TMJ ankylosis include ankylosing spondylitis, rheumatoid arthritis, and psoriasis. [4]

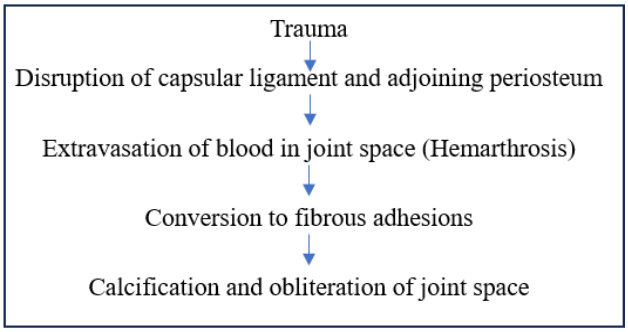

Figure 1: Etiopathogenesis of TMJ ankylosis

Classification of TMJ Ankylosis

Over the years, various classification systems have been suggested for TMJ ankylosis. Most classification systems focus on the radiographic extent of the ankylotic mass and do not consider clinical and functional factors. Table 1 summarizes the various classifications.

Table 1: Various classifications of TMJ ankylosis

Classification	Description of each subtype
1. Kazanjian [5] (1938)	True ankylosis: joint is affected False ankylosis: fusion is extra articular
2. Topazian [6] (1964)	Stage I: ankylotic bone limited to the condylar process Stage II: ankylotic bone extending to the sigmoid notch Stage III: ankylotic bone extending to the coronoid process
3. Sawhney's [7] (1986)	Type 1: Minimal bony fusion but extensive fibrous adhesions around the joint Type 2: Bony fusion at the outer edge of the articular surface but no fusion on medial area of the joint Type 3: Bridge of bone between the mandible and temporal bone Type 4: Joint is replaced by a mass of bone
4. Turlington and Durr [8] (1993)	According to heterotopic bone formation within the ankylotic mass Grade 0: No bone islands visible Grade 1: Islands of bone visible within the soft tissue around the joint Grade 2: Periarticular bone formation Grade 3: Apparent bony ankylosis Grades 1, 2, and 3 are further classified as symptomatic (S) and asymptomatic (A)
5. El Hakim and Metwalli [9] (2002)	Based on axial and coronal CT Class I: unilateral and bilateral fibrous ankylosis. The condyle and glenoid fossa retain their original shape, and the maxillary artery is in normal anatomical relation to the ankylosed mass. Class II: unilateral or bilateral bony fusion between the condyle and the temporal bone. The maxillary artery lies in normal anatomical relation to the ankylosed mass. Class III: the distance between the maxillary artery and the medial pole of the mandibular condyle is less on the ankylosed than on the normal side or the maxillary artery runs within the ankylotic bony mass. Class IV: extensive bone formation and fusion to the skull base with a close relationship to vital structures such as the pterygoid plates, the carotid and jugular foramina and foramen spinosum.
6. Dongmei He and colleagues [10] (2011)	Type A1: fibrous ankylosis without bony fusion of the joint. Type A2: bony fusion on the lateral aspect of the joint, while the residual condyle fragment is bigger than 0.5 of the condylar head in the medial side. Type A3: similar to A2 but the residual condylar fragment is smaller than 0.5 of the condylar head. Type A4: ankylosis with complete bony fusion of the joint.
7. Yan and colleagues [11] (2014)	Based on its development Fibrous - chondral phase demonstrating fibrous tissue and chondrocytes occupied the joint gap. Chondral - calcified cartilage phase manifesting abundant chondrocytes, cartilage matrix, and neo - formative endochondral ossification in the joint space. Bone - cartilage phase showing compacted bone bridge in the lateral joint gap and cartilage in the medial joint gap.
8. Braimah et al. [12] (2018)	Modification of Sawhney's classification Class V: joint architecture completely replaced by bone with fusion of the condyle, sigmoid notch and coronoid process to the zygomatic arch, glenoid fossa and maxilla)
9. Long Xia et al. [13] (2019)	Type I: non - bony ankylosis with near normal joint space. Type II: lateral bony ankylosis with a radiolucent line within a normal joint space. Type III: complete bony ankylosis with only a radiolucent line. Type IV: extensive bony ankylosis with absence of radiolucent line.
10. Bi et al. [14] (2020)	CDA classification system C: whether the condylar head structure could be preserved C0: lateral bony ankylosis of both joints with the medially displaced condyle heads preserved C1: ankylosis of the entire joint presenting with bony fusion and no recognizable condyle or fossa on one or both sides. D: whether the patient has any secondary dentofacial deformity D0: no significant dentofacial deformities D1: dentofacial deformities that affect occlusion and the appearance of the facial profile. A: the skeletal age of the patient Ac: young patient with active dentofacial growth (skeleton immature) Aa: adult patient with a fully developed dentofacial structure (skeleton mature)

Clinical Manifestations

The clinical features of TMJ ankylosis vary according to:

1) Severity of onset
2) Time of onset
3) Duration

In early age group patients, there is severe facial deformity and loss of function, whereas in late age group patients, i. e. after 15 yrs of age, there is function loss majorly with nil facial deformity.

Surgical Anatomy to be Kept in Mind During Surgery

1) Nerve Anatomy

a) Facial nerve: The facial nerve's main trunk exits the skull via the stylomastoid foramen. About 1.3 cm of the nerve

is visible before it splits into the temporofacial and cervicofacial branches. According to Al - Kayat and Bramley (1979) [15], the distance from the lowest point of the bony external auditory canal (EAC) to this bifurcation ranges from 1.5 to 2.8 cm, with an average of 2.3 cm. The distance from the post glenoid tubercle to the bifurcation ranges from 2.4 to 3.5 cm, with an average of 3.0 cm. However, the location where the upper trunk crosses the zygomatic arch is the most variable, ranging from 8 to 35 mm anterior to the most forward part of the bony external auditory canal (EAC), with a mean of 2.0 cm. Incising the superficial layer of the temporalis fascia and the periosteum over the arch within 8 mm can help avoid damaging the upper trunk branches. However, Miloro et al. [16] found that the average distance anterior to the bony external auditory canal was 2.12 cm (ranging from 1.68 to 2.49 cm). Their study, based on MRI, differs from the cadaveric dissection - based research conducted by Al - Kayat and Bramley.

b) Auriculotemporal nerve: This nerve originates from a small loop comprised of two roots that encircle the middle meningeal artery, near the medial side of the posterior neck of the condyle and then moves upward, traveling over the zygomatic root of the temporal bone. Preauricular access to the TMJ area almost always results in injury to the nerve. However, the risk of damage can be reduced by making the incision and performing dissection closely along the cartilaginous portion of the external auditory meatus. [17]

2) Vascular Anatomy

In a cadaver study of structures medial to the temporomandibular joint, Pogrel [18] found that the middle meningeal artery is located, on average, 31 mm (ranging from 21 to 43 mm) medial to the zygomatic arch, and 2.4 mm (ranging from 2 to 8 mm) anterior to the height of the glenoid fossa. In the preauricular approach, the internal maxillary artery is located approximately 3 mm medial to the mid - sigmoid notch. The middle meningeal branch of the internal maxillary artery is the artery most commonly injured during temporomandibular procedures.

2. Surgical Approaches

1) **Preauricular Approach:** It is the most widely preferred and commonly used surgical method for the TMJ worldwide. Its advantages include (1) simplicity of technique, (2) excellent exposure, (3) adaptability for minor modifications, and (4) minimal risk of complications [19]. This approach was first described by Risdon in 1934, but it gained widespread popularity through the contributions of Rowe and Killey in 1968, and later, Rowe's further work in 1972 [20].
   a) Standard preauricular incision: by Dingman in 1946. Traditionally, the incision begins along the helix, just in front of the tragus, extending to the attachment of the earlobe. After passing through the skin and superficial fascia, about 2 cm above the zygomatic arch, an oblique incision is made through the superficial layer of the temporal fascia. Just above the arch, the periosteum of the zygomatic arch is incised and reflected forward as a single flap, along with the outer layer of temporal fascia, superficial fascia containing nerves, and skin. This exposes the ankylotic mass [21].
   b) Blair modification of preauricular incision (1917): The original description of the preauricular incision was shaped like an inverted hockey stick. It features a standard vertical component that gradually curves anteriorly and upwards to a point 1 cm above the helix of the ear, before descending downward and ending 2.5 cm in front of the helix attachment. The disadvantages include an unsightly scar and possible damage to the frontal branch of the facial nerve [22].
   c) Thoma modification of preauricular incision (1945): The vertical limb is positioned along the preauricular fold but is angled at 45° near the hairline, where the superficial temporal vessels bifurcate [23].
   d) Straight line preauricular incision: by Rowe and Killey (1968). This is a straight - line incision that runs from the root of the helix at the top to the attachment of the lobule on the face at the bottom.
   e) Preauricular with Temporal Extension: by Al Kayat and Bramley (1979). This cosmetically acceptable reverse question mark incision provides excellent access to the TMJ while avoiding damage to key anatomical structures. It begins at the scalp in the temporal region and extends down to the inferior tragus. The superficial layer of the temporalis fascia is identified and incised at the root of the arch, angled 45° anterosuperiorly to prevent injury to the branches of the facial nerve [15].
2) **Endaural Approach:** The endaural approach was first introduced by Lempert [24] for middle ear surgery and later adapted for use in TMJ surgery. A popular modification of this approach is Rongetti's [25] limited - length, intra - aural incision, which extends along the depth of the external auditory meatus. The advantages include improved aesthetics and excellent access to the TMJ. However, the disadvantages may involve perichondritis, infection, paresthesia of the pinna, and ear deformity.
3) **Post - Auricular Approach:** The post - auricular approach was first described by Bockenheimer in 1920, with Axhausen providing further development in the early 1930s. This technique involves making an incision behind the ear, followed by dissection in an anterior direction and division of the external auditory canal. The entire external ear is then reflected forward to expose the capsule of the temporomandibular joint (TMJ). However, this approach is rarely used today and has gradually fallen out of favor in TMJ surgery [26].
4) **Rhytidectomy**: Also referred to as the facelift approach, this technique offers extensive exposure of the mandibular condyle, ramus, and angle of the mandible. It is similar to the trans - masseteric antero - parotid approach but provides a larger field of view. The skin incision is a lengthy one, beginning at the preauricular crease, extending downward and around the base of the pinna, passing over the posterior surface of the auricle, and ending with an extension on the skin of the mastoid region [27].

3. Management of TMJ Ankylosis

Treatment Protocol

Kaban [28] and his colleagues developed an approach for treating TMJ ankylosis in 1990, aimed at minimizing the risk of re - ankylosis and ensuring satisfactory joint movement. Their study became a landmark in the management of TMJ ankylosis. In 2009, Kaban [29] revised the protocol, considering the impact of time and growth on the outcomes of TMJ ankylosis in children, and introduced an updated protocol. Image 2 and 3 describes the Kaban's protocol and Kaban's modified protocol respectively.

1. Aggressive resection of the ankylotic segment
2. Ipsilateral coronoidectomy
3. Contralateral coronoidectomy when necessary
4. Lining the joint with temporalis fascia or cartilage
5. Reconstruction of the ramus with a costochondral graft
6. Rigid fixation of the graft
7. Early mobilization and aggressive physiotherapy

Image 2: Kaban's Protocol (1990)

1. Aggressive excision of fibrous and/or bony mass
2. Coronoidectomy on affected side
3. Coronoidectomy on opposite side if steps 1 and 2 do not result in MIO of 35 mm or to point of dislocation of opposite side
4. Lining of joint with temporalis fascia or the native disk, if it can be salvaged
5. Reconstruction of RCU with either DO or CCG and rigid fixation
6. Early mobilization of jaw; if DO used to reconstruct RCU, mobilize day of surgery; if CCG used, early mobilization with minimal intermaxillary fixation (not > 10 days)
7. Aggressive physiotherapy

Image 3: Kaban's Modified Protocol (2009)

Treatment Options

Various surgical methods have been developed to restore normal joint function and prevent reankylosis. The main techniques include: (a) gap arthroplasty, where bone is removed between the articular cavity and mandibular ramus without using any interpositional material; (b) interpositional arthroplasty, which involves placing interpositional material between the newly shaped glenoid fossa and condyle; (c) joint reconstruction, where the TMJ is rebuilt using an autogenous bone graft or a total joint prosthesis; and (d) restoring the ramal condylar unit through distraction—neocondylogenesis. [30]

Gap arthroplasty (GA): This technique was first proposed by Abbe for TMJ Ankylosis in 1880. [31] It offers the benefit of effectively freeing the mandible while preventing excessive bone overgrowth in the condylar region. Additionally, it is a straightforward technique with a short operating time. As a result, it has become a widely recommended approach for ankylosis release. The amount of bone removal is critical, with a minimum gap of 1 cm recommended to prevent reankylosis. However, creating a gap of this size may lead to an anterior open bite in bilateral cases or a posterior open bite on the opposite side in unilateral cases. [32] Various disadvantages of gap arthroplasty include: Pseudo - articulation, short ramus height, failure to remove all bony disease, development of open bite (bilateral release cases), Suboptimal range of motion, Recurrent ankylosis (60%). [33]

Interpositional arthroplasty (IPA): In interpositional gap (IPG) arthroplasty, autogenous or alloplastic materials are placed at the site of the ostectomy to prevent recurrent ankylosis. Various autogenous materials that can be used as interpositional materials include the temporalis muscle flap (TMF), fascia lata, auricular cartilage, dermis, and full - thickness flap. Among these, the temporalis muscle is the most commonly used due to its ease of use, reliable blood supply, proximity to the temporal joint, good functional outcomes, low risk of facial paralysis, successful clinical results, and minimal complications. [34] Image 4 describes various materials used for interposition.

Autogenous	Heterogenous	Alloplastic
Costochondral	Chromatized submucosa of pig bladder	Metallic- tantalum foil/ plate
Metatarsal	Lyophilized bovine cartilage	316L stainless steel
Sternoclavicular		Titanium
Auricular cartilage		Gold
Temporal fascia		Nonmetallic
Fascia lata		Silastic
Dermis		Teflon
		Acrylic
		Nylon
		Proplast
		Ceramic implants

Image 4: Various interpositional materials

In a systematic review and meta - analysis by Desai et al. [35], amongst all interpositional materials, the highest increase in mouth opening was seen with dermis fat graft. Comparison of temporalis myofascial with gap arthroplasty (GA) showed significant increase in Maximum mouth opening. Recurrence was significantly reduced when IPA was used, compared with GA and for Temporalis Myofascial Flap (TMF) when compared with GA. IPA was superior to GA with respect to maximum mouth opening (MMO). Dermis fat graft offers the highest MMO. Hence, IPA were superior when compared to GA in terms of mouth opening and less recurrence.

Joint reconstruction: TMJ reconstruction can be done using autogenous grafts or alloplastic materials. Nowadays, research is ongoing for use of tissue engineering in joint reconstruction. Advantages of autogenous grafts include potential for growth, biocompatibility, and availability, hence preferred for the growing patients. Disadvantages are donor-site morbidity and variability of biologic responses (e. g., resorption, ankylosis, and excessive growth).

Table 2: Various methods of Joint reconstruction

Autogenous Grafts		Alloplastic Joint Reconstruction
From Various Body Parts	From Vicinity	Stock alloplastic reconstruction
Rib (Costochondral graft)	Coronoid process	Custom implants (Patient Specific Implants)
Iliac crest	Posterior border of ramus	
Sternoclavicular joint	Ankylotic mass	
Metatarsal joint		

1) Costochondral graft: It is the most widely accepted autogenous condylar reconstruction graft, first described by Sir Harold Gillies in the 1920s. The current technique was popularized by POSWILLO. It is biologically compatible like any autogenous graft. It has thin, flexible stock of bone with a cartilaginous cap. It is easily workable especially when contouring the cartilaginous part to fit into the glenoid fossa and takes less time to heal. It has capacity for remoulding into an adaptive mandibular condyle. There is always a potential at the donor site to grow and regenerate. [36, 37, 38]
2) Sternoclavicular joint: In 1971, Snyder et al. reported the first sternoclavicular (SCJ) whole joint graft, which included a section of the manubrium, the intact capsule, and part of the clavicle [39]. In 1986, REID et al. reported a free - flap technique that included the clavicular head of the pectoralis major muscle and overlying skin, to provide a vascularized clavicular bone graft. They suggested splitting the clavicle longitudinally and repositioning it with the attached flap as the entire head of the clavicle was too large to fit into the glenoid fossa [40]. Later in 1994, WOLFORD et al. reported splitting the clavicle head and applying only the superior half of the clavicle for condylar reconstruction [41]. The SCJ and TMJ are similar anatomically and physiologically. The head of the clavicle contains layers of cartilage that are similar to the mandibular condyle. The SCJ articulation has a growth centre and an interarticular fibrocartilage articular disc that simulates the meniscus of the TMJ. DANIELS et al. showed that when implanted in the TMJ area, SCJ graft undergoes remodelling and resembles the native condyle unlike CCG which does not. [38]
3) The metatarsophalangeal (MTP) joint: In 1909 by Bardenheur, as a half - joint transplant of the fourth metatarsal using the metatarsal head for replacement of the mandibular condyle. In 1971, metatarsal as a nonvascularized free bone graft for bilateral reconstruction of the TMJ was reported by DINGMAN, who failed to observe any longitudinal growth in the graft [42, 43]. In 1985, TING et al. described the use of a free vascularized second metatarsal for reconstruction of the TMJ in four cases of ankylosis. [44, 38]

4) Coronoid process: In 1989, HONG et al. reported the use of coronoid process for condylar reconstruction. If the coronoid process is not involved in cases of ankylosis, it can be suitable donor material. It can be harvested relatively safely and easily with avoidance of a secondary surgical site and associated donor complications [45, 46]. Compared with CCG, the coronoid process shows less bony resorption due to its membranous origin; and especially if the autogenous coronoid process is pedicled on temporal muscle grafts, it shows lesser bony resorption, lesser decrease of height of the mandible ramus and mouth - opening deviation, and better long - term clinical results. [47]
5) Ankylotic mass: Gunaseelan reported three cases of ankylosis in which the ankylotic mass was reused to replace the missing condyle. The ankylotic mass is often large (typically 20 mm x 25 mm), and when resected in bulk, at least one piece is usually large enough to be shaped and used to maintain the ramus' vertical height. The ankylotic mass is made of dense bone with a smooth cortical surface and sufficient length, allowing for microplate rigid fixation. Reusing the ankylotic mass significantly reduces patient morbidity, as the same bony mass is recycled [48].
6) Alloplastic reconstruction: In 1998, Mercuri LG et al. defined the indications and contraindications of alloplastic reconstruction [49]. FDA - approved materials used for alloplastic reconstruction are: a) Cobalt - chromium alloys (Co Cr - Mo) b) Commercially pure titanium (cpTi), alloyed titanium (Ti6AI4V) c) Ultrahigh molecular weight polyethylene (UHMWPE), At present, there are three U. S. Food and Drug administration (FDA) –sanctioned TMJ prosthetic systems available for implantation: a) Pre - 1976 Amendment Christensen stock as well as the Christensen/Garrett custom devices b) 1999 FDA - approved TMJ Concepts patient - fitted custom - made device (previously Techmedica) c) 2006 FDA - approved Biomet Microfixation total joint stock device.

Neocondylogenesis: In 1997, STUCKI - MCCORMICK pioneered the use of transport distraction osteogenesis (DO) for temporomandibular joint (TMJ) reconstruction. This technique involved creating a transport disc of bone from the ramus of the mandible using an L - shaped osteotomy, while preserving the medial periosteum and muscle attachments to maintain blood supply. After a latency period of 7 days, the transport disc was advanced at a rate of 1.0 mm per day (0.5 mm twice daily) until it made contact with the glenoid fossa and the desired ramus height was achieved. The distraction device was then kept in place for 5 weeks until radiographic evidence showed mineralization at the trailing edge of the transport disc, bridging the defect without the need for bone grafting. The leading edge of the transport disc typically remodels and becomes rounded, forming a neocondyle. Additionally, STUCKI - MCCORMICK observed in post - distraction MRI scans that an intervening fibrous tissue layer appeared to function as a pseudo disc. The advantages of this procedure are: a) functional joint is created without the need for interpositional material. b) The procedure reduces hospital stay, operation time, surgical risks, and the chance of relapse. c) Patients are able to open and close their mouths and chew during the bone generation and expansion process, allowing functional remodeling to take place, which contributes to the positive effects of distraction on the mandibular condyle [50, 51].

In 2008, Schwartz et al. evaluated the use of transport distraction osteogenesis in reconstruction of the ramus–condyle unit (RCU) of the temporomandibular joint (TMJ). Thirteen TMJ reconstructions were carried out in 12 patients. They concluded that successful distraction was carried out in all cases, with development of solid regenerate bone and an effective new articulation. There were no complications. A good functional level was achieved in all cases [52].

4. Conclusion

TMJ ankylosis is a debilitating condition causing significant aesthetic, functional, and psychological challenges. The primary cause of TMJ ankylosis is trauma, primarily resulting from traffic accidents, followed by infection. Long - standing ankylosis that develops in childhood can lead to facial asymmetry and occlusal imbalance. Early TMJ ankylosis in children can hinder normal mandibular growth. Continued research into innovative surgical methods and tissue engineering holds promise for improving patient outcomes and long - term functionality. Future studies should focus on refining surgical protocols and optimizing rehabilitation strategies for enhanced success rates.

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