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TMJ Reconstruction-A Review

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Abstract:
The temporomandibular joint (TMJ), rightly called as craniomandibular articulation is a highly specialized joint in both anatomy and function as unlike other synovial joints in the body, the articular surfaces of TMJ are covered with avascular fibrocartilage instead of hyaline cartilage. Currently there are three acceptable management modalities available for total TMJ reconstruction (TJR) which include **-** *autogenous bone grafts (fibula, metatarsal, clavicle, iliac crest and costochondral) and alloplastic replacement(acrylic, synthetic fibers, ulnar head prosthesis, compressible silicone rubber and total joint systems) and transport distraction osteogenesis techniques. Current reconstructive techniques lie in favor of autogenous replacement in children and alloplasts in adults. Bioengineered TMJ devices are currently being investigated and may be a futuristc viable option for TJR.*

Key word: *Temporomandibular joint, osteogenesis, reconctruction, articular disc*

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I. Introduction

The temporomandibular joint (TMJ), rightly called as craniomandibular articulation is a highly specialized joint in both anatomy and function as unlike other synovial joints in the body, the articular surfaces of TMJ are covered with avascular fibrocartilage instead of hyaline cartilage. It is a unique joint that accommodates for more than 2000 hinge and sliding movements per day in activities like talking, eating, yawning etc. It is one of the most active joints in the human body. TMJ may be afflicted with various disorders ranging from pain and reduction in mouth opening to end stage joint disease all resulting in significant morbidity of the patient and devastating influences on quality of life of the patients. Congenital dysmorphism, trauma, osteoarthritis, rheumatoid arthropathy, ankylosis, condylar resorption, neoplasia, and previous failed reconstruction of the TMJ attribute to the development of TMD and are indications for TMJ reconstruction[1]. TMJ reconstruction is indicated by the severity of the structural damage to its anatomic components that result in decrease in mandibular function and concomitant loss of anatomic form. The goals of temporomandibular joint reconstruction should be: 1) improvement of mandibular form and function; 2) reduction of disability and suffering; 3) containment of excessive treatment and cost and 4) prevention of further morbidity. Difficulty in achieving these treatment goals is illustrated by the multiplicity of autogenous and alloplastic materials proposed or currently used to reconstruct the TMJ.[2]

II. Development and Anatomy

During human development the temporomandibular joint has two distinct stages: the primary and secondary temporomandibular joint. The primary early embryonic temporomandibular joint consist of meckel's cartilage and the first branchial arch ear ossicles. This primary temporomandibular joint is an axial hinge joint and progressively replaced after 16 weeks by the secondary temporomandibular joint, the articulation between mandibular condyle and the mandibular fossa of temporal bone. The secondary temporomandibular joint serves as the diarthrodial joint throughout life. It forms mostly between 7 and 11weeks of gestation.[3]

Fig-1 The temporomandibular joint

At three months of gestation the secondary jaw joint, the tmj begins to form. The temporomandibular joint begins to develop from two separate blastemas (mesenchymal condensations) one for the temporal bone component and one for the condyle. The temporal blastema appears first and initially is separated from the later appearing condylar blastema by some distance. Rapid growth of the condylar blastema in the dorsolateral direction quickly reduces this gap but a band of uncondensed mesenchyme persists. A membranous ossification center appears in the middle of the temporal blastema and this is followed by appearance of a cleft immediately above the condylar condensation which is the forerunner of the inferior joint cavity. Cartilage appears in the condylar blastema following this clefting to form the condylar growth cartilage. A second cleft now appears below the bone forming in the temporal blastema which creates the upper body joint cavity leaving a band of mesenchyme from which the disk of the joint forms.[4]

Components of TMJ are:-

a) Capsule
b) Articular Eminence
c) Glenoid Fossa
d) Condyle
e) Articular Disc
f) Synovial Membrane
g) Extracapsular Ligaments
h) Disk Ligaments.

CAPSULE- The joint capsule is a fibroelastic, highly vascular and highly innervated dense connective tissue. The lower part of the joint is surrounded by tight fibers which attach the condyle of the mandible to the disc. The upper part of the joint is surrounded by loose fibers which attach the disc to temporal bone. Thus the articular disc attach separately to temporal bone and to the mandibular condyle. The capsule is attached above the anterior edge of the preglenoid plane, posteriorly to the lips of squamotympanic fissure between these to the edges of the articular fossa below the periphery of the neck of the mandible. The lateral aspect of the capsule attaches zygomatic tubercle, the lateral rim of the glenoid fossa and the postglenoid tubercle. Medially, the capsule attaches to the medial rim of the glenoid fossa.[5]

ARTICULAR EMINENCE- The articular eminence, a transversally elliptical region sinuously curved in the saggital plane and tilted forward at 25 degree to occlusal plane, forms most of articular surface of articular fossa. Its steepness is variable and becomes flatter in edentulous. The articular surface of mandibular condyle is slightly covered and tilted forward at 25 degree to occlusal plane. Like the articular eminence, its slope is variable. In the coronal plane its shape varies from the gable (particularly marked in those whose diet is hard) to roughly horizontal in edentulous.[5]

GLENOID FOSSA- The glenoid fossa is limited posteriorly by the squamotympanic fissure and petrotympanic fissure. Medially the fossa is limited by the spine of sphenoid and laterally by the root of the zygomatic process of temporal bone. Anteriorly the fossa is bounded by the articular eminence. The roof of the fossa is thin and separates the brain from the joint cavity, therefore during surgical manipulation at the fossa, care should be taken to avoid perforation of the roof of the fossa. The fossa is covered by the thin fibrous layer.

CONDYLE- The articular surface of the mandible is represented by mandibular condyle. The condyle is 15 20mm long and 8-12mm thick. Its articulating surface is strongly convex in an antero-posterior direction and slightly convex mediolaterally. Medially and laterally the condyle terminates at medial and lateral poles. With medial pole in particular extending beyond the neck of the condyle and positioned more posteriorly so that the long axis of the condyle deviates from the coronal plane such that, when extended, it runs medially and backwards to meet a similar axis drawn from the other condyle at the anterior border of the foramen magnum. The condylar covering is classified as fibrocartilage and its components vary with age. At young age, the deepest layer of the fibrocartilage is rich in small undifferentiated cells; this is called as the reserve cell layer. In the aging condyle, only remnants of the cartilage remain and become calcified. At this stage, trauma from overloading may lead to degenerative joint tissue.[5]

ARTICULAR DISC - The term disc is preferred over meniscus because the latter refers to a semilunar structure that may have a central perforation. The transversely oval articular disc is composed predominantly of dense fibrous connective tissue. In the saggital section, disc appears to posses a thin intermediate zone thickened anterior and posterior bands, and its upper surface appears concavo-convex where its fit against the convex articular eminence and concavity of articular fossa. Posteriorly disc is attached to region of loose vascular and nervous tissue which splits into two laminae, the bilaminar region, unlike the rest of the disc, its normal function is to provide attachment rather than intra articular support. Cells in the disc secrete chondroitin sulphate- a glycosaminoglycan found in cartilage- which is most heavily concentrated in center of disc and which probably gives the disc some of resilience and compressive strength of cartilage. The negative charges on the glycosaminoglycans attract water and allow the disc or the condylar cartilage to absorb the stresses applied to it by deforming and leaking water. After relief from the compressive force, the water content is restored and the loaded tissue returns back to its original shape.[4]

SYNOVIAL MEMBRANE- The internal surface of the capsule is lined by a synovial membrane. Finger like projections of the synovial membrane occur in the anterior and posterior limits of the joint to accommodate the movements of the capsule. It consists of two layers, a cellular intima resting on a vascular subintima. The subintima is a loose connective tissue containing blood vessels, scattered fibroblasts and macrophages, mast and fat cells and some elastic fibers. The intimal layer consists of cells embedded in an amorphous fiber free intercellular matrix. The cells of this layer are an intermingling of fibroblast like and macrophage like cells. The synovial fluid is a dialysate of plasma to which is added some protein and sodium hyaluronate. Its total volume is 1ml and the fluid exhibits non-newtonian flow which means its viscosity decreases with increased shear rate.[4]

DISK LIGAMENTS- The disk ligaments consist of the anterior and posterior bilaminar zones, the lateral and medial collateral ligaments. All these are vascular, innervated and fibro elastic in nature. The anterior ligament has a superior stratum that inserts on the ascending slope of the articular eminence and an inferior stratum that inserts inferiorly at the anterior aspect of the condyle. The ligament is normally relaxed and folded on itself while the mandible is in centric relation. The ligament stretches downwards as the condyle rotates during mouth opening. The posterior ligament or bilaminar zone consists of a highly elastic superior stratum that inserts on the petrotympanic fissure and an inferior stratum that inserts on the posterior aspect of the condyle below. The posterior bilaminar zone stretches considerably during jaw opening to allow the disk to continue to cover the condyle at all angles of motion. The medial and lateral collateral ligaments are collagenous and firmly attach the disk to the medial and lateral poles of the condyle. These allow the mediolateral shift of the disk relative to the condyle.

EXTRA CAPSULAR LIGAMENT- Ligaments are defined as non-elastic collagenous structures which restrict that provide stability to the joint are the temporomandibular ligament and the sphenomandibular ligament.

Sphenomandibular Ligament: The sphenomandibular ligament is medial to, and normally seperate from the capsule. It is flat, thin band that decends from the spine of sphenoid and widens as it reaches the lingula of mandibular foramen Lateral pterygoid and the auriculotemporal nerve are lateral relations, the chodra tympani nerve lies medial near its upper end and medial pterygoid is an inferomedial relation. The sphenomandibular ligament is separated from the neck of the mandible below lateral pterygoid by maxillary artery and from the ramus of mandible by the inferior alveolar vessels and nerve and a parotid lobule.

Temporomandibular Ligament: This ligament is attached above to the articular tubercle on the root of zygomatic process of temporal bone. It extends downwards and backwards at the angle of mandible 45degree to the horizontal to attach to the lateral surface and posterior border of neck of condyle and deep to the parotid gland. It appears to be poorly developed in edentulous. A short almost horizontal band of collagen connects the articular tubercle in front to the lateral pole of condyle behind, it may function to prevent posterior displacement of the resting condyle.

Stylomandibular Ligament: The stylomandibular ligament is thickened band of deep cervical fascia that stretches from the apex adjacent anterior aspect of styloid process to angle and posterior border of the mandible. Its position and orientation indicate that it cannot mechanically constrained any normal movements of mandible and does not seem to warrant the status of a ligament of the joint .[4]

III. History Of TMJ Reconstruction

Most widely accepted autogenous condylar reconstruction involves the use of the costochondral graft (CCG) first described by **Sir Harold Gillies**in the 1920[5]. The current technique for temporomandibular joint replacement with the costochondral graft was popularized by **Poswillo**(1987). **Wolford et al**. reported splitting the clavicle head and applying only the superior half of the clavicle for condylar reconstruction. The metatarsophalangeal (MTP) joint as a graft for condylar replacement was reported in 1909 by **Bardenheur**, as a half joint transplant of the fourth metatarsal using the metatarsal head for replacement of the mandibular condyle. **Posnick et al**. first reported a series of cases using the free fibula flap for immediate reconstruction of paediatric mandibular tumours in 1993. In 2000, Wax et al reported placement of the distal portion of the flap directly into the glenoid fossa for condylar reconstruction.[7]

Smith and Robinson(1957) solved the problem of recurrence of bony ankylosis by placing a stainless steel plate between the skull and mandible. The plate was curved to create a virtual rotation-point at the former middle of the condyle (fig.2).

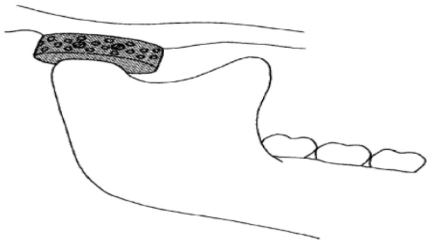

Fig-2 the fossa eminence prosthesis of Robinson.

Christensen (1963) refined the idea of robinson by covering the glenoid fossa and articular eminence with a 0.5mm vitallium surface. The most suitable prosthesis was fixed by screws in the lateral part of the articular tubercle and the zygomatic arch (fig-3).

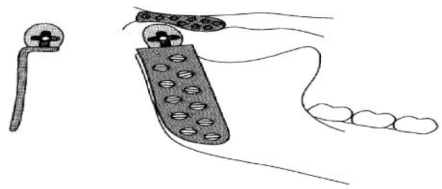

Fig. 3 the prosthesis of Christensen

Kummoona (1978) designed a prosthesis with condylar part consisted of a head on a perforated plate that was inserted between the medial and lateral cortical walls of the mandibular ramus. It was fixed with PMMA cement, transferring the load uniformly from the prosthesis to the mandible. The fossa part was fixed by screws and covered the fossa and eminence, which was flattened, thus allowing fibrous tissue penetration from the capsular wall of the joint (fig. 4).

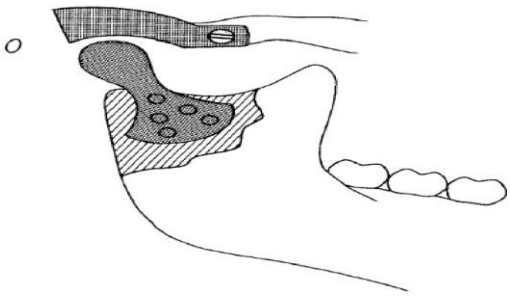

Fig. 4 the prosthesis of Kummoona.

Techmedica (Wolford et al, 1994) solved the fitting problem by using plastic models of the individual patient fabricated on the basis of three-dimensional CT scans. On the model, a titanium shell was constructed to conform to the fossa, articular eminence, and lateral rim of the fossa. Four layers of titanium mesh were fixed on both sides of the shell. The cranial mesh permits ingrowth of bone and soft tissue to maximize stabilization; the caudal mesh was used to fix the polyethylene articulating surface to the shell. The fossa prosthesis was fixed to the zygomatic arch with three or four screws[7] (fig 5).

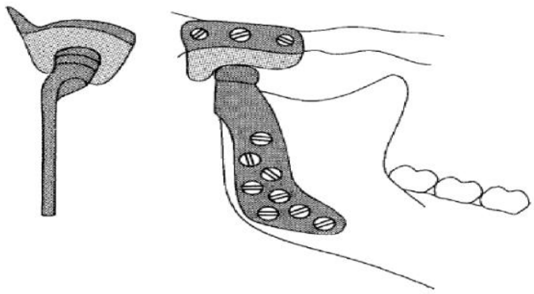

Fig 5. The techmedica prosthesis.

IV. Autogenous Of TMJ Reconstruction

Autogenous temporomandibular joint replacement is defined as reconstruction of the mandibular ramus-condyle unit, glenoid fossa and temporomandibular joint meniscus with the patient's tissue. The use of autogenous tissues has been the traditional standard care for reconstruction of the temporomandibular joint.
Autogenous grafts derived from distant sites:**- Costochondral graft, Sternoclavicular graft, Metatarsal head, Calvarial bone graft, Fibula free flap, Iliac crest.**
Autogenous grafts derived from the vicinity:**-Coronoid process, Posterior border of ramus, Ankylotic mass.**

1.) COSTOCHONDRAL GRAFT- Most widely accepted autogenous condylar reconstruction involves the use of the costochondral graft (CCG) first described by Sir Harold Gillies in the1920s. Initially used for replacement of defective or missing mandibular condyles. Clinically the graft provides the mandible with an active growth center in children while in adults it prevents jaw deviation or production of an open bite in bilateral cases. This graft is biologically compatible, easily workable especially when contouring the cartilaginous part to fit into the glenoid fossa, and takes less time to heal. The standard surgical technique of costochondral grafting includes Preauricular and Risdon incisions.[8]

2.) **STERNOCLAVICULAR GRAFT-** Sarnet and Laskin noted that in humans the sternoclavicular joint and TMJ are similar anatomically and physiologically. An animal study by Ellis and Carlson showed the close histomorphological similarities between the sternoclavicular joint and the temporomandibular joint in monkeys at all stages of postnatal development.[8] These factors have encouraged the use of sternoclavicular grafts in reconstruction of temporomandibular joint. The sternoclavicular articulation has a growth center, and an interarticular fibrocartilage articular disc that simulates the meniscus of the temporomandibular joint.[9]

3) METATARSAL HEAD- The metatarsophalangeal provides a good supply of articular cartilage combined with upto 7cm of vascularized bone. In addition to replacement of condyles, it can also be used for simultaneous reconstruction after wide tumor resection. Using the metatarsal head for articulation in the glenoid fossa with the tarsal plate interposed between the articular surface and head of the graft can simulate condylar head and the interpositional cartilage disc.

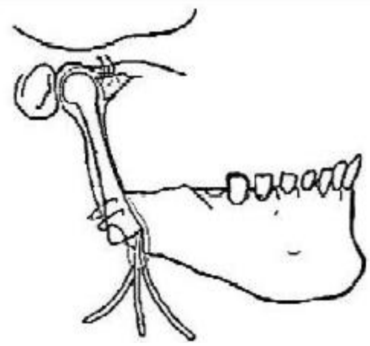

Fig 6. Reconstruction of condyle with MTP graft.

4.) **CALVARIAL BONE GRAFT-** Calvarial bone is commonly used for reconstruction of the facial skeleton in the form of onlay or interpositional grafts. Marciani et al reported the ability of autogenous pericranium muscle and cranial bone to restore form and function of the temporomandibular joint in a nonhuman primate model.

5.) FIBULA FREE FLAP- Posnick et al. first reported a series of cases using the free fibula flap for immediate reconstruction of paediatric mandibular tumours in 1993. The fibula is a tubular and densely cortical. It can be easily adapted to passively fit in the glenoid fossa, and its narrow shape allows an easy fit (fig. 7).

Fig 7. Fibula reconstruction with skin paddle

V. ALLOPLASTIC TMJ RECONSTRUCTION

Reconstruction of the temporomandibular joint with alloplastic materials can be a difficult challenge for oral and maxillofacial surgeons. Before the early to mid 1980s, alloplastic temporomandibular joint prosthesis were primarily used in managing cases involving trauma, ankylosis, severe joint disease or joint reconstruction after severe ablative surgery. Thereafter they were also used as treatment for internal derangements and in the management of patients who had previously undergone multiple failed nonsurgical and surgical therapies. Currently there are three FDA-approved total temporomandibular joint replacement systems available: 1) Christensen TMJ prosthesis system, 2) TMJ concepts prosthesis and 3) Biomet microfixation TMJ replacement system. Only the TMJ concepts prosthesis and the biomet microfixation TMJ replacement system were approved after premarket clinical trials.

1) CHRISTENSEN TEMPOROMANDIBULAR JOINT PROSTHESIS SYSTEM-In the early 1960s, Christensen initially reported the use of a cast vitallium glenoid fossa against a natural condyle for the treatment of mandibular ankylosis (fig. 12). The original cast cobalt chromium fossa was available in 20 different sizes based on anatomic variations in human adult skulls.[10]

Fig 8. Christensen glenoid fossa prosthesis articulation against meniscus.

2) TEMPOROMANDIBULAR JOINT CONCEPTS PROSTHESIS-The custom-made total joint prosthesis (fig.13) were originally developed in 1989 by Techmedica Inc., Camarillo, CA, USA, and are currently manufactured by temporomandibular joint Concepts, Inc. Ventura, CA, USA. These prostheses were CAD/CAM devices (computer assisted design/computer assisted manufacture), designed to fit the specific anatomical requirements for each patient. The temporomandibular joint Concepts/Techmedica temporomandibular joint prosthesis design principles and materials are those that have been proven highly successful in orthopedics.

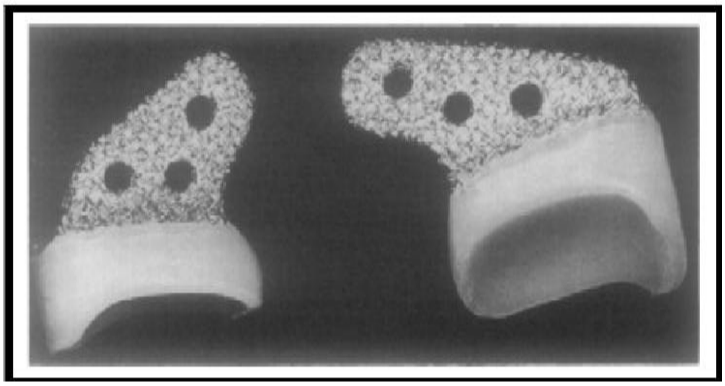

Fig 9. The techmedica custom CAD/CAM fossa component

3) BIOMET MICROFIXATION TEMPOROMANDIBULAR JOINT PROSTHESIS-The biomet total temporomandibular prosthesis (fig 65) is designed as a stock product. In contrast to an individually designed prosthesis, such as temporomandibular joint concepts, it comes in fixed sizes and shapes, it has a fossa component made out of ultra high molecular weight poly ethylene. The mandibular component is made of cobalt chromium with a titanium layer sprayed on the surface that faces the bone. The fossa and the mandibular component are available in three different sizes.[11]

VI. TISSUE RESPONSE TO IMPLANT MATERIALS

1) TISSUE RESPONSE TO SILICONE- Silicones are a family of silicon dioxide polymers that differ in addition of organic side chains, polymer length, use of fillers and degree of cross linking. The siloxane polymer backbone combines silicon and oxygen (SiO) in a flexible molecular linkage. Curing is undertaken with catalysts to form cross linking of the polymer chains, resulting in solid silicon rubber or elastomers. The local tissue reactions to various silicones have been studied and are remarkably similar. Ranging them mild exudative phase in the first three days, consisting of PMNs, plasma cells and marcophages then changing to a predominance of lymphocytes, fibroblasts and plasma cells.[12]

2) TISSUE RESPONSE TO PROPLAST/TEFLON- Proplast is the porous form of Teflon (polytetrafluoroethylene, PTFE) and has been fused with other vitreous carbon (proplast I) or aluminium oxide (proplast II) and then laminated with Teflon. Zardeneta and coworkers have demonstrated a protein interaction with the surface of the particulate Teflon. This coating of protein onto these particles happens rapidly, and the protein can be structurally distorted. Macrophages respond to this distortion of proteins and release cytokines and enzymes and free radicals which may be recognized as foreign thus provoking an immune response.

3) TISSUE RESPONSE TO OTHER ALLOPLASTS- The other alloplasts used in temporomandibular joint are components of total joint systems studied by orthopaedic community. Pandey et al evaluated the tissue response to particulates of titanium, stainless steel, chrome cobalt, high density polyethylene (HDP) and PMMA. The subcutaneous lesions produced by the particles were partially or completely surrounded by fibrous tissue that was thicker around implanted PMMA and HDP particles than around metal particles.[12]

VII. DISTRACTION OSTEOGENESIS

In recent years, distraction osteogenesis has become an effective method in the treatment of congenital craniofacial deformities and acquired skeletal defects. In transport distraction osteogenesis, a small segment of the bone called the transport disc is slowly moved away from the host bone and transported into the defect. Osteogenesis occurs at the trailing edge of the transport disc while a cap of fibrocartilage forms at the disc’s leading edge. This phenomenon can be used to advantage in reconstruction of the temporomandibular joint.

VIII. TISSUE ENGINEERING

Tissue engineering was first proposed in the 1980s by a chemist, R. Langer, and a surgeon, J. P. Vacanti. It first employs the knowledge of life sciences (e.g., cell biology, molecular biology, biochemistry) for the growth and development of new tissues. Tissue engineering is a multidisciplinary field which involves the ‘application of the principles and methods of engineering and life sciences towards the fundamental understanding of structure-function relationships in normal and pathological mammalian tissues and the development of biological substitutes that restore, maintain or improves tissue function (Shalak and Fox, 1988).

Advantages**-** Avoidance of morbidity associated with second surgical site.

Limitations**-** The specific structural requirements of tissue engineered TMJ cartilage to withstand the in vivo forces as well as the fixation and connection of remaining ligaments.

IX. Summary And Conclusion

The temporomandibular joints are bilateral, diarthrodial, ginglymoid, synovial and freely movable joints. Reconstruction of the temporomandibular joint because of degenerative disease, autoimmune disease, trauma and congenital abnormalities ranks amongst the most complex and challenging task for maxillofacial reconstructive surgeons. Temporomandibular joint reconstruction has been performed using metatarsophalangeal graft, costochondral graft, sternoclavicular graft, iliac crest and calvarial bone graft. Use of autogenous tissues decreases the likelihood of foreign body reaction. Cost and time of preparation are additional secondary advantage over alloplasts. The chief disadvantages associated with autogenous grafts are donor site morbidity and the variability of biologic behavior of the graft like resorption, ankylosis or excessive growth.

In recent years, distraction osteogenesis has become an effective method in the treatment of congenital deformities and skeletal defects. Reconstruction of the temporomandibular joint by combining transport distraction osteogenesis with a vertical ramus or sagittal split osteotomy meets most of the functional requirements.

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