

Dr. Tanmoy Ghorui*, Dr. Arnab Saha*, Dr. Amit Ray**, Dr. Samiran Ghosh***

Abstract

Temporomandibular joint ankylosis is one of the most common pathologies affecting the facial skeleton in the developing countries. Patients encounter difficulties in mastication, digestion, speech, function, cosmesis, maintenance of oral hygiene, acute compromise of airway which further invariably results in physical & psychological disability.¹⁻² This paper looks into different treatment protocols for comprehensive treatment of TMJ ankylosis associated with / without dentofacial deformities which includes different reconstruction options after release, needs for osteodistraction or not & also controversies regarding the release of ankylosis with osteodistraction including our experiences. 30 patients suffering from TMJ ankylosis visited the Department of Oral & Maxillofacial Surgery, Gurunanak Institute Of Dental Sciences & Research, Kolkata, India from 2009 to till date are included in this study.

Key Words Temporomandibular joint ankylosis, obstructive sleep apnea syndrome, gap arthroplasty, temporalis muscle fascia, osteodistraction, Reconstruction, sternoclavicular graft, costochondral graft.

INTRODUCTION

Temporomandibular joint ankylosis (TMJ) is a rare disorder due to the fusion of mandibular condyle at the cranial base.³ TMJ ankylosis is classified by location (intra-articular or extra-articular), type of tissue involved (bone, fibrous, fibro-osseous) and extent of fusion (complete or incomplete).⁴ The main etiological findings are trauma, inflammation, sepsis and / systemic diseases.⁵ When it occurs in a child, it can have devastating effects on the future growth and development of the jaws and teeth. Furthermore, in many cases it has a profoundly negative influence on the psychosocial development of the patient, because of the obvious facial deformity, which worsens with growth. It also causes other disabling conditions like problems in mastication, digestion, speech, function, cosmesis & maintenance of oral hygiene. There is disturbances of facial growth & acute compromise of airway which invariably results in Physical & psychological disability (Vasconcelos; Porto; Bessa-Nogueira et al., 2009 and Vieira; Rabelo, 2009).³

Ankylosis, or Anchylosis (from Greek ἀγκυλος, bent, crooked) means stiffness of a joint, as a result of injury or disease and results in hypomobility or no mobility which further results in inability to open the mouth beyond 5 mm of interincisal opening due to pathological fusion of head of the condyle with articulating surface of the glenoid fossa. Generally it affects all ages but more common between ages 0-10 yrs. Incidence are equal between male & female. It is more common in Asia.

ABOUT THE AUTHORS

* 3rd year PGT, dept. of OMFS, GNIDSR

** Prof. & HOD, dept. of OMFS, GNIDSR

*** Professor, dept. of OMFS, GNIDSR

Articular trauma is the basic cause of ankylosis with higher incidence in children resulting with scarring & excessive bone formation that leads to hypomobility. Ankylosis due to infection commonly occurs secondary to contiguous spread from otitis media or mastoiditis but it also may result from hematogenous spread of infectious conditions such as tuberculosis, gonorrhoea, scarlet fever. Systemic cause include ankylosing spondylitis, rheumatoid arthritis & psoriasis.⁶

Comprehensive treatment for TMJ ankylosis is still a controversy regarding sequence for release of ankylosis & correction of dentofacial deformities. Some surgeons recommend a staged approach for the treatment of the patient with concomitant TMJ ankylosis & secondary deformities and others prefer to release the ankylosis & correct the deformities simultaneously. Additionally most of the reports have not mentioned the use of genioplasty, which may, indeed, be very important for such micrognathia cases.

AIMS & OBJECTIVES

This study serves to compare different treatment protocols for comprehensive treatment for TMJ ankylosis associated with / without dentofacial deformities which includes different reconstruction options after release, needs for osteodistractor or not

& also controversies regarding the release of ankylosis with osteodistractor.

MATERIAL & METHODS

30 patients came to us with facial asymmetry & limited mouth opening, diagnosed clinically & radiologically as having TMJ ankylosis, formed the study group. They were selected from department of Oral & Maxillofacial Surgery, Gurunanak Institute Of Dental Sciences & Research, Kolkata, India from 2009 to till date. Study protocol, use of data for research & risk-benefit ratio were explained to the patients to take an informed & understood consent.

Our patients divided into three groups –

- 1. Adult with dentofacial deformities**
- 2. Adolescent children with / without dentofacial deformities**
- 3. Children without dentofacial deformities**

1. For adults patients with deformities (Fig.1 - Fig.3)-

Most of all adults came to us with facial deformity, limited mouth opening along with Obstructive sleep apnea syndrome (OSAS) due to collapsed posterior airway space. Treatment procedures included release of ankylosis first with



Fig.1 - preoperative view with unilateral ankylosis



Fig.2 - bone formation in distracted fragments



Fig.3 -postoperative mouth opening



Fig.4 - preoperative view with unilateral ankylosis



Fig. 5 -TMJas inter positional materials



Fig.6 - extraoral distraction procedure



Fig.7-postoperative mouth opening



Fig.8- preoperative mouth opening with unilateral ankylosis



Fig.9- predistraktion profile with facial deformity



Fig.10- intraoral distraction procedure



Fig.11- postoperative mouth opening



Fig.12- preoperative mouth opening with unilateral ankylosis



Fig.13- CCG harvested from 6th rib & placed at recipient site



Fig.14- postoperative view



Fig.15- postoperative OPG



Fig.16- preoperative mouth opening with unilateral ankylosis



Fig.17- SCG harvested & placed at recipient site



Fig.18- postoperative mouth opening



Fig.19- post operative chest radiograph showing complete development of SCJ

gap arthroplasty for all the patients as per modified Kaban's protocol along with placement of temporalis muscle fascia (TMF) interposition. Then the adults were treated with osteodistraction by extraoral / intraoral means with / without genioplasty for correction of dentofacial deformities.

1. For adolescent patients -

a) with deformities (Fig.4 – Fig.7) -

They were treated with release of ankylosis and placement of TMF first followed by distraction osteogenesis with / without genioplasty to correct the dentofacial deformities.

b) without deformities (Fig.8 – Fig.11) –

They were treated with release of ankylosis and TMF placement. But we found after the completion of mandibular growth, there were facial deformities. So, distractions were performed with /without genioplasty thereafter.

3. Children without dentofacial deformities (Fig.12 – Fig.15 costochondral graft; Fig.16 – Fig.19 Sternoclavicular graft) -

For children after release and TMF placement immediate reconstruction were done with autogenous bone grafts. In our institution we used sternoclavicular joint (SCJ) graft & costochondral

bone graft (CCG) as a reconstruction material for condyle.

All of our patients were managed surgically under general anaesthesia. Achievement of an airway to give anaesthetics was difficult in case of TMJ ankylosis. So, all of our series underwent fiber optic intubation procedure.

RESULTS AND OBSERVATION

All the patient were recalled periodically for evaluation & recording of degree of mouth opening, esthetic satisfaction & improvement of airway embarrassment. Radiographs were carried out at intervals to observe both donor & recipient sites as well as airway. Overall results were satisfactory regarding mouth opening, airway improvement & esthetic concerns. In our study we found that there is no recurrence till date.

1. For adults patients with deformities -

After the release of ankylosis mouth opening was improved along with improvement of speech impairment and mastication. To correct the dentofacial deformity distraction was performed followed by with / without genioplasty which helps in mandibular advancement procedure for the treatment of retroglossal airway obstruction. Only in one of our adult patients we encountered the choking sensation, bradycardia & sudden drop of oxygen saturation to a certain extent during the extubation procedure following gap arthroplasty. So we performed tracheostomy procedure in that case.

2. For adolescent patients –

a) with deformities –

Again after the release of ankylosis mouth opening was improved along with improvement of speech impairment and mastication such as in the adults. Then to correct the dentofacial deformity distraction was performed followed by with / without genioplasty.

b) without deformities –

After release we kept them under periodic follow ups upto completion of mandibular growth to see if there was any facial deformity present or not & depending upon the Moss theory¹² there should not be. But we found that after complete growth of mandible there was dentofacial deformity. So distractions were performed thereafter followed by with/without genioplasty.

3. Children without dentofacial deformities –

After the release of ankylosis immediate

reconstruction with autogenous graft i.e. SCG or CCG was done. Mouth opening was improved along with improvement of speech impairment and mastication.

DISCUSSION

The treatment of TMJ ankylosis is surgical, either by gap arthroplasty, interpositional arthroplasty and joint reconstruction with autogenous or alloplastic materials.^{7,8} A variety of treatment techniques have been described in the literature.⁹ But the role of temporomandibular joint (TMJ) surgery is not well defined. Part of the reason is that hard evidence is lacking since, unlike orthopaedic surgery, there is no universal classification that allows the collection of standard data that can be used to compare the various techniques published in the literature.¹⁰ Treatment of TMJ ankylosis is done to restore full mouth opening & normal oral function remains a challenge in children & adults. The type of operation & treatment policy vary from one country to another. Surgical treatment depends on the extent & type of ankylosis, the age of the patient, onset & time of surgery and whether the ankylosis is unilateral or bilateral. No single method has produced uniformly successful results. As per Gustavo Lopes Toledo et al.³ before mandibular body osteotomy, cases were considered non treatable (Esmarch, 1851 in Vasconcelos; Porto; Bessanogueira et al., 2009). Humphrey (1854) performed the first condylectomy for these situations (Vasconcelos; Porto; Bessanogueira et al., 2009). Gap arthroplasty was developed by Abbe (1880) and revised by Risdon (1934). Until the use of interpositioning materials, treatment results occasioned a high index of recurrences (Danda; Ramkumar; Chinnaswami, 2009). The complications most often reported are limited range of movement & recurrence of ankylosis (usually within 6 months after surgery).¹¹

The use of a temporal muscle flap generated good results aimed to create an aponeurotic muscle, known as “neodisc”. For this, the disc was repositioned according to the normal physiology of the TMJ complex.³ This technique is indicated for patients with external ankylosis, where the ramus height is sufficient to receive the graft, and the disc is still present on the medial articular side (Chossegros; Guyot; Cheynet et al., 1997).

In our study, for release of ankylosis we followed modified Kaban's protocol(2009) and after the release we performed osteodistraction with / without genioplasty or immediate reconstruction with autogenous graft depending upon our patient group divisions. And our result is quite satisfactory regarding increased mouth opening, function & esthetics. Most important observation is that there are no recurrence in all the groups till now. For adolescent without dentofacial deformity, after

release of ankylosis we found there was facial deformity when the mandibular growth was completed. This result was not in accordance with the Moss theory, who stated that condylar cartilages are not the primary growth sites, in any way responsible for mandibular growth as a whole, but rather act as site of secondary & compensatory growth of the condylar process alone & growth of the other portions of the mandible is governed by their own growth processes & is independent of condylar growth.¹²

In patients with TMJ ankylosis in adults with jaw deformity it is paramount importance to look for clinical sign of OSAS.¹³ For such patients 3 school of thoughts are there regarding release of ankylosis & osteodistraction¹⁴ -

- 1) Simultaneous procedure i.e. release of ankylosis with osteodistraction**
- 2) Osteodistraction followed by release of ankylosis**
- 3) Release of ankylosis followed by osteodistraction**

Simultaneous procedure obviates need for a second operation but it can result in an improper outcome due to unpredictable vector management & the active post-operative physiotherapy may cause physical interference to the distraction process.

Distraction is best performed after a detailed preoperative evaluation. It is not possible if distraction is performed first. On the other hand if osteodistraction is done first there are less scope of decompensation for occlusal disharmony, difficulties in both surgeon & orthodontist evaluation & difficulties in the development of a comprehensive treatment plan. Also, dental hygiene must be optimal which is not possible if distraction is done first.

The third option is release of ankylosis first followed by osteodistraction. Many of the surgeons prefer this method as it helps to regain normal mandibular function, allows adequate food intake due to increased mouth opening which is better as most of the patient are malnourished for limited mouth opening. This procedure also provide better orthodontic evaluation for second surgery, better observation for chances of recurrence that might influence the later treatment plan & address the chief complaint first.

In our institution we followed the 3rd protocol i.e. release first followed by osteodistraction. Besides its huge advantages the critics have pointed out that the main disadvantages of this 3rd protocol are the choking sensation, bradycardia & sudden drop of oxygen saturation to a certain extent in the immediate postoperative period. In our study we found only one patient having this said difficulties

during the extubation procedure. So we performed tracheostomy procedure. But tracheostomy is not a major concern in a case of TMJ ankylosis surgery now a days regarding its surgical steps or complications. On the other hand blind intubation is basically impossible due to limited or no mouth opening. Another alternative is fiber optic intubation on which we regularly rely in our institution for release of TMJ ankylosis, but it may not be available in all the units throughout the countries. So, if modernized technical facilities like fiberoptic intubation is unavailable, for release of ankylosis under general anesthesia tracheostomy is still the only option.

One of the main advantages of osteodistraction is the controlled distraction of the bone, there is not only elongation of mandibular bony tissue, but also proportional & harmonic modification of the surrounding soft tissues. Mandibular distraction can improve facial profile & provide relief to the airway obstruction¹⁴. Other advantages include less possibilities of relapse, increased stability due to longer time of soft tissue adaptation, avoidance of donor site, obviates the need of bone grafts.¹⁵ However, DO fails to completely address the deficient chin that almost exist in these ankylosis patients & affects the improvement of facial appearance & OSAS. To achieve the best outcomes, advancement Genioplasty is used.¹⁴ A definitive explanation for an improvement in the airway status after mandibular advancement is still ambiguous. However, greater acceptance has been given to the fact that there is repositioning of the genioglossus along with the advancing segment which pulls the tongue forwards from the posterior pharyngeal wall leading to better airway patency.¹⁶ Recent studies reveal that the genial musculature in these patients show an abnormal neuromuscular activity which improves with mandibular advancement leading to a significant improvement in the airway patency.¹⁶

A successfully reconstructed TMJ should reproduce normal joint structure, provide functional articulation and permit adaptive growth or remodeling.¹⁷ Difficulty in achieving these treatment goals is illustrated by the multiplicity of autogenous & alloplastic materials proposed or currently used to reconstruct the TMJ.¹¹ Alloplastic materials have been developed claiming closer reproduction of normal TMJ anatomy. It immediately helps to return normal mandibular function. But there are potential disadvantages such as wear & or failure of material with wear, particles generating a giant cell foreign body reaction with potential loosening of the implant resulting in occlusal change, displacement or fracture, dystrophic bone formation and lack of growth which precludes the use of such joints in children.^{11,18} Autogenous grafts for condylar reconstruction have some drawbacks but are the most widely used grafts.

Autogenous graft derived from distant site :

Sternoclavicular graft (SCG)

It is potential choice for reconstruction of the mandibular condyle. This graft has the advantage of being usable in the growing patient because there is transfer of a growth center. The sternoclavicular articulation has a growth center, and an interarticular fibrocartilage articular disc that simulates the meniscus of the TMJ.¹⁹ The main advantage of the superior portion of the sternal head of the clavicle is that it has microarchitecture similar to that of the mandibular condyle, and a similar growth pattern.²⁰ Daniels et al. stated that in TMJ area it undergoes remodeling & resembles the native condyle unlike the CCG which does not. Moreover significantly less morbidity postoperatively is the added advantage. Ellis & Carlson showed the close histomorphological similarities between SCG & TMJ in the monkey at all stages of postnatal development.

The disadvantages include damage great vessels during harvesting, scarring, donor site morbidity due to instability of clavicle under stress with resulting shoulder instability postoperatively.²¹ Improper harvest can cause clavicle fracture which in turn may impinge the brachial plexus.²²

Sternoclavicular graft was first reported by Synder et al. in 1971 in which whole joint graft consisting of a portion of manubrium, the intact capsule & a portion of clavicle on a 70 years old man with cylindroma. In 1994, Wolford et al. reported splitting the clavicular head & applying only the superior half of the clavicle for condylar reconstruction. When whole joint is used, the two adjacent synovial compartments & the strong fibrous capsule resemble those in TMJ. Its absence is also of no great anatomical, functional or esthetic consequence.¹¹ SCG graft significantly reduces the patient morbidity postoperatively as there is complete regeneration of donor site has also been reported.²³ In our study we also found that there was complete development of SCG graft region (Fig.-19). After harvesting, Wolford et al. suggested the use of a figure of eight bandage for up to three months to support the shoulders to immobilize the arm on the side of the graft as well as for clavicle fracture. They also noted that it reduces postsurgical fracture incidence of clavicle. Patient must be also careful not to lift any heavy weight, use of arms for lifting themselves out of bed until 3-4 months postoperatively.¹¹ We agree with the authors who stated that superior half of the clavicle gives improved fit, excellent uptake & vascularization due to direct exposure of medullary portion to the adjacent soft tissues. After taking the superior half we found there is complete growth of SCG on radiograph. In our study we faced fracture of clavicle postoperatively in one case during harvesting & that was managed by bone plating.

Costochondral graft (CCG)-

CCG is the most widely used graft for condylar reconstruction now a days. Sir Harold Gillies in 1920 first described the use of CCG. Poswillo popularized it for TMJ replacement. The main advantages are biological compatibility, better fit of contoured cartilaginous part into glenoid fossa, reduced healing time & incorporation into a new environment allowing restoration of bone & cartilage components.^{11,18} It has also capability to remodel into adaptive mandibular condyle & there is always a potential at the donor site to grow & regenerate.²⁴ An additional advantage in children due to its growth potential.^{24, 25} The main disadvantage is excessive and unpredictable growth.^{26,27} Other disadvantages include necrosis and resorption, relapse presenting with typical "bird face" deformity, poor quality of cortical & medullary bone, possible separation of the cartilage from bone, donor site complications like pleural tear, pneumothorax, pleural effusion, atelectasis, empyema, pneumonia & occasional fracture¹¹ and chances of reankylosis in 5-39% cases.²⁸ Patients who have undergone previous release of ankylosis & who have developed recurrent ankylosis are not good candidate for CCG grafting. On the other hand to harvest CCG graft better technical expertise needed to maintain periosteum & perichondrium junction & to prevent donor site morbidity.¹¹ In one case we faced the rupture of the parietal pleura which was managed accordingly.

Based on radiographic measurements Mulliken et al. reported that the highest rate of growth occurs about two years after the placement of the CCG graft and follows a slow & irregular pattern, not a linear pattern, although there are individual variations.¹¹

In our study we found that remodeling CCG graft is also quite good & we can not differentiate the better acceptance between CCG & SCG.

Some other distant autogenous grafts like iliac crest, metatarsal, fibular bone grafts are also reported in different literatures. Literatures also mentioned some other closed vicinity autogenous grafts like coronoid, posterior border of ramus, ankylosis mass.^{11,18}

Regarding alloplastic reconstruction silicone, acrylic, polymethylene, ceramic and various metals have been described. Autogenous materials are preferred as there the possible migration, fragmentation and foreign body reaction can occur with alloplasts. In a study of 38 patients treated with condylectomy and placement of silicon blocks or sheets as interposition material, Ortak et al. reported a 7.8% incidence of infection.¹⁸

CONCLUSION

In our study we found that Modified Kaban's protocol (2009) is highly effective for release of TMJ ankylosis. Regarding the comprehensive treatment protocol we prefer the release of ankylosis at first. For adult patients with dentofacial deformity & OSAS, after release osteodistraction with / without genioplasty was performed which showed no such postoperative morbidity except one case where tracheostomy was performed. For adolescent patient we can conclude that after release same procedures should be performed like adults, presence or absence of dentofacial deformity is not a concern. For children after release immediate reconstruction with autogenous graft is the best option.

Finally we can conclude that comprehensive treatment for TMJ ankylosis is a challenging problem. Until now no single standard treatment protocol has been reported. The failure rate remains still high as it not only depends upon reankylosis but also some other factors like limited inter incisal opening, chin deviation or facial deformities. Careful patient selection before commencement of treatment is advocated. For better outcome aggressive excision of the fibrous and bony pathological tissue followed by reconstruction or distraction is needed depending upon the individual case presentations.

FUNDING –

None

COMPETING INTERESTS –

None declared

ETHICAL APPROVAL –

Not required

REFERENCE

1. Moorthy AP, Finch LD (1983) Interpositional arthroplasty for ankylosis of the temporomandibular joint. *Oral Surg Oral Med Oral Pathol* 55: 545-552.
2. Kaban LB, Perrott DH, Fisher K (1990) A protocol for management of temporomandibular joint ankylosis. *J Oral Maxillofac Surg* 48: 1145-1151.
3. Gustavo Lopes TOLEDO et al. Temporomandibular joint ankylosis surgical treatment with arthroplasty in gap literatura review and clinical case presentation. Bauru-São Paulo State, in partial fulfillment of the requirements for a Specialist degree, 2010.
4. Perrott DH, Kaban LB: Temporomandibular joint ankylosis in children. *Oral Maxillofacial Clin North Am* 6:187, 1994
5. Walford LM. Facial asymmetry: diagnosis and treatment considerations. In: Fonseca RJ, Scully JR, Costello BJ, editors. *Oral and Maxillofacial Surgery*. 2nd ed. New York: Elsevier publishers; 2009. p. 272-315.
6. Cheema SA. Temporal fascia as interpositioning material in cases of temporomandibular joint ankylosis. *J Coll Physicians Surg Pak* 2005; 15(2): 89-91.
7. Topazian RG: Etiology of ankylosis of the TMJ: Analysis of 44 cases. *J Oral Surg Anesth Hosp Dent Serv* 22:227, 1964
8. Lindquist C, Pihakari A, Tasanen A, et al: Autogenous costochondral grafts in temporomandibular joint arthroplasty. *J Maxillofac Surg* 14: 143, 1986
9. Sawhney CP: Bony ankylosis of the TMJ: Follow up of 70 patients treated with arthroplasty and acrylic spacer interposition. *Plast Reconstr Surg* 77:29, 1986
10. G. Dimitroulis. A new surgical classification for temporomandibular joint disorders. *Int. J. Oral Maxillofac. Surg.* 2013; 42: 218–222.
11. A. Khadka, J. Hu. Autogenous grafts for condylar reconstruction in treatment of TMJ ankylosis: current concepts and considerations for the future. *Int. J. Oral Maxillofac. Surg.* 2012; 41: 94-102.
12. Melvin L. Moss et al. The role of the functional matrix in mandibular growth. April, 1968
13. N.N. Andrade, R. Kalra, S. P. Shetye: New protocol to prevent TMJ reankylosis & potentially life threatening in triad patients. *Int. J. Oral Maxillofac. Surg.* 2012; 41: 1495-1500.
14. Jibua Li et al. Staged Treatment of Temporomandibular joint Ankylosis With Micrognathia Using Mandibular Osteodistraction and Advancement Genioplasty. *American Association of Oral & Maxillofacial Surgeon* 2012; 70:2884-2892.
15. Mikhail L. Samchukov et al. Craniofacial Distraction Osteogenesis 2001.
16. Ramanathan Manikandhan et al. Impact of Mandibular Distraction Osteogenesis on the Oropharyngeal Airway in Adult Patients with Obstructive Sleep Apnea Secondary to Retroglossal Airway Obstruction. *J. Maxillofac. Oral Surg.* (Apr–June 2014) 13(2):92–98.
17. Daniels S, Ellis 3rd E, Carlson DS. Histologic analysis of costochondral and sternoclavicular grafts in the TMJ of juvenile monkey. *J. Oral Maxillofac Surg.* 1987; 45: 675- 83.
18. Fonseca et al. *Oral & Maxillofacial Surgery*, 2nd Edition; Trauma, Surgical pathology, Temporomandibular Disorder – functional disorders of the temporomandibular joint .Chapter 47: 903-904.

19. Snyder CC, Levine GA, Dingmen DL. Trial of a sternoclavicular whole joint graft as a substitute for the temporomandibular joint. *Plast Reconstr Surg* 1971; 48: 447–452.
20. Ellis III E, Carlson DS. Histologic comparison of the costochondral, sternoclavicular & temporomandibular joint during growth in *Macaca mulatta*. *J Oral Maxillofac Surg* 1986; 44: 312-21.
21. Demir Z, Velidedeoglu H, Sahin U, Kurtay A, Coskunfirat OK. Preserved costal cartilage homograft application for the treatment of temporomandibular joint ankylosis. *Plast. Reconstr Surg*. 2001; 108: 44- 51.
22. Wolford LM, Cottrell DA, Henry C. Sternoclavicular grafts for temporomandibular joint reconstruction. *J Oral Maxillofac surg.* 1994; 52: 119-28.
23. Singh V, Verma A, Kumar I, Bhagol A. Reconstruction using fibula grafts. A review of 96 cases. *Br J Oral Maxillofac Surg* 2002; 40: 322 – 9.
24. Ko Ew, Huang CS, Chen YR. Temporomandibular joint reconstruction in children using costochondral grafts. *J Oral Maxillofac Surg* 1999; 57: 789-98.
25. Kaban LB, Perrott DH, Fisher K. A protocol for management of temporomandibular joint ankylosis. *J Oral Maxillofac Surg* 1990; 48 1145-51.
26. El- Sayed Km. Temporomandibular joint reconstruction with costochondral graft using modified approach. *Int J Oral Maxillofac Surg* 2008; 37: 897-902.
27. Baek RM, Song YT. Overgrowth of costochondral graft in reconstruction of the temporomandibular joint. *Scand J Plast Reconstr Surg Hand Surg* 2006; 40: 179-85
28. Rahaman MN, Mao JJ. Stem cell based composite tissue constructs for regenerative medicine. *Biotechnol bioeng* 2005; 91: 261-84.