

**Greenstick Fracture Technique for Adaptation and  
Fixation of Costochondral Graft in Temporo  
Mandibular Joint Ankylosis**

*Dissertation submitted to*

**THE TAMILNADU Dr.M.G.R MEDICAL  
UNIVERSITY**

*In partial fulfillment for the Degree of*  
**MASTER OF DENTAL SURGERY**



**BRANCH – I**

**ORAL & MAXILLOFACIAL SURGERY**

**FEBRUARY 2005**

## **CERTIFICATE**

This is to certify that **Dr. M. RAJMOHAN**, Post Graduate student 2002-2005 in the Department of Oral and Maxillofacial Surgery, Tamil Nadu Government Dental College and Hospital, Chennai-3 has done his dissertation titled “**GREENSTICK FRACTURE TECHNIQUE FOR ADAPTATION AND FIXATION OF COSTOCHONDRAL GRAFT IN TEMPORO MANDIBULAR JOINT ANKYLOSIS**” was carried under my direct guidance and supervision in partial fulfillment of regulation laid down by the **Tamil Nadu Dr. M.G.R. Medical University, Chennai** for M.D.S Branch-I (Oral and Maxillofacial Surgery) degree examination.

**Dr. C. KUMARAVELU, M.D.S.,**  
Professor & Head  
Department of Oral & Maxillofacial Surgery  
Tamil Nadu Government Dental  
College & Hospital, Chennai-3.

**Dr. T.R. SUDARSAN, M.D.S.,**  
Principal,  
Tamil Nadu Government Dental  
College & Hospital, Chennai-3.

# **CONTENTS**

- 1. INTRODUCTION**
- 2. AIM OF THE STUDY**
- 3. SURGICAL ANATOMY**
- 4. REVIEW OF LITERATURE**
- 5. MATERIALS & METHODS**
- 6. CASE REPORTS**
- 7. OBSERVATION & RESULTS**
- 8. DISCUSSION**
- 9. SUMMARY & CONCLUSION**
- 10. BIBLIOGRAPHY**

## INTRODUCTION

**ANKYLOSIS** is a Greek word meaning “stiff joint” A slightly more complete definition of the term is an abnormal immobility and consolidation of the joint as given by **DORLAND**.

The temporomandibular joint is a unique joint with features, which distinguish it from most other joints.

- ❖ Both temporomandibular joints function as single unit. Thus, the term craniomandibular articulation is often used to emphasize the bilateral nature of this system.
- ❖ The craniomandibular articulation has a rigid end point of closure, the dentition.
- ❖ The articulating surfaces of the temporomandibular joint consists of fibro cartilage, where as most synovial joints are lined by hyaline cartilage.
- ❖ The articular disc separates the temporomandibular joint into two separate spaces with different functions: the inferior compartment function as a hinge (ginglymus) and the superior compartment as a gliding (arthrodial, translatory), thus the term ginglymo-arthrodial (hinge-sliding) joint.

Temporo Mandibular joint ankylosis is a distressing affliction that denies the victim the benefit of taking a normal diet, careers that

require normal speech and causes severe facial disfigurement that aggravates his psychological stress. It is a seriously disabling condition that a maxillofacial surgeon often comes across. The condition occurs unilaterally and less commonly bilaterally.

It is a condition of diverse etiology and symptomatology that frequently poses complex diagnostic and therapeutic problems. Patients with temporomandibular joint ankylosis suffer functionally from an inability to open their mouth a sufficient amount for chewing or routine oral hygiene. This restriction inhibits functional motion that stimulates mandibular growth. The earlier in patient's life the ankylosis occurs, the greater is the facial deformity.

Temporo Mandibular joint ankylosis was classified into two types, Intra articular or true ankylosis, and Extra articular or false ankylosis by **KAZANJIAN**<sup>65</sup> (1938). The various causes of intra articular ankylosis are congenital, trauma, infections, metastatic malignancies, post irradiation, rheumatoid arthritis, and ankylosing spondylitis. In the literature majority of cases have been categorized as (a) Post traumatic and (b) Post infective **GARCIA**<sup>78</sup> (1971) states that the commonest causative factor was infection. However, following the advent of antibiotics, the incidence of post infective ankylosis has reduced. At present traumatic ankylosis is higher (31-98%). Intra articular ankylosis is divided into Osseous ankylosis, Fibro osseous ankylosis, and Fibrous ankylosis and further divided into Complete and Incomplete.

An ankylosed joint undergoes chronic progressive destruction along with deterioration of meniscus, flattening of the mandibular fossa, thickening of the condyle and ossification or calcification of attached fibrous tissue. Thus, the mandible is rendered continuous with the base of the skull. Definite diagnosis of the type and extent of ankylosis is made after a complete history and a thorough clinical examination along with an extensive radiographic survey.

The major objective of surgical treatment in patients with temporomandibular joint ankylosis is the meticulous and radical removal of the ankylotic bone and, reconstruction and restoration of the physiologic functions of the lower jaw. Reconstruction of an adult temporomandibular joint because of congenital, developmental, or acquired deformities continues to challenge the oral and maxillofacial surgeon. A successfully reconstructed temporomandibular joint should reproduce normal joint structure, provide functional articulation, and permit adaptive growth and remodeling. Difficulty in achieving this treatment goal is illustrated by the multiplicity of autologous and allogenic materials proposed or currently used to reconstruct temporomandibular joint.

Historically a gradual evolution of surgical procedure and techniques has occurred in the past 150 years. Various techniques and materials that have been utilized in the past include.

1. Condylectomy and Gap arthroplasty.
2. Interposition arthroplasty with temporalis muscle and fascia, acrylic, zirconium, silastic, teflon and tantalum.
3. Autogenous reconstruction of ramus condyle unit with second metatarsal joint, Fibular graft, iliac bone, costochondral graft and sternoclavicular graft.
4. Use of total Temporo Mandibular joint prosthesis.

Among the myriad of surgical procedures and materials used in treating temporo mandibular joint ankylosis, biological reconstruction of the mandibular condyle using Autogenous costochondral graft has become widely accepted and popular surgical procedure. **GILLIES**<sup>102</sup> in 1920 first used Costochondral graft for treating a case of Temporo Mandibular Joint ankylosis. **SARNAT** and **ROBINSON**<sup>97</sup> advocated the use of actively growing costo chondral graft in 1956. In animal experiments, condylar replacement with a costochondral graft yielded excellent results. Several biological and anatomical similarities to the mandibular condyle and less donor site complication made autogeneous costochondral grafting to be considered the most acceptable technique for temporo mandibular joint reconstruction.

Nowadays costochondral graft has found application in cases of congenital dysplasia, developmental defects, neoplastic disease, osteo arthritis, Post-traumatic dysfunction, and temporo mandibular joint ankylosis. Initially the grafts were fixed to the ramus with wires with the disadvantage of wire cutting through the graft and fracturing of graft, because of thin rib cortex. Later rigid fixation with titanium

screws or mini plates was the rule and today is probably the method of choice. However, some times in young patients, the weakness of rib graft cortex results in intrusion of screw head into the graft and so loosening and fracturing of the ribs takes place.

Another problem encountered with rib graft is that the graft and the ascending ramus of mandible have opposite curvatures and during surgery a space can occur between the mandible and the graft. This fact can lead to unexpected complications, such as delayed or incomplete ossification in the recipient site, thereby leading to a lack of stability and increasing the risk of pseudo arthrosis. In 1989, **MOSBY** and **HIATT** described a new technique to securely fix the graft and therefore the dimension of gap between the rib graft and the mandible minimised while pressing the graft against the mandibular surface. In our study, we had developed a variation of this method, which enables a precise adaptation of the rib graft to the mandible by green stick fracturing of the graft.

In our study, four cases of unilateral true ankylosis of the temporo mandibular joint in patients who had reported to the **Department of Oral and Maxillofacial Surgery at TamilNadu Government Dental College & Hospital, Chennai** have been treated by this technique of green stick fracturing of the rib grafts for fixation and adaptation of the Costo chondral rib graft. The results of the cases are discussed and relevant literatures reviewed.

## REVIEW OF LITERATURE

In spite of many developments in maxillofacial surgery, ankylosis of the temporo mandibular joint ankylosis remains a problem, which is difficult to solve in a satisfactory and definite way. Many different surgical techniques have evolved in the past 150 years. We shall review the literatures in this section accordingly to the various treatment modalities available.

### GAP ARTHROPLASTY

Patients suffering from ankylosis were considered incurable until **Esmarch**<sup>31</sup> proposed the treatment in 1851. He removed a wedge of bone approximately  $3/4^{\text{th}}$  of an inch long from the body of the mandible anterior to the point of ankylosis and created a false joint. Even though the technique failed, his report at the Congress at Gottingen 1855 stimulated interest in the treatment of temporo mandibular joint ankylosis that continues even today. Surgical treatment of temporo mandibular joint ankylosis has undergone a gradual, although decided evolution of surgical procedures and techniques in the past 150 years.

In 1856, **Humphrey**<sup>48</sup> performed the first Condylectomy to relieve fibrous ankylosis.

**Rizzoli**<sup>102</sup> in 1858, attempted surgical correction of the bony ankylosis of the temporo mandibular joint through intra-oral approach.

**Grube**<sup>43</sup> in 1863 performed an osteotomy in the ascending ramus below the level of the coronoid process and condylar mass to relieve temporo mandibular joint ankylosis.

**Abbe**<sup>1</sup> in 1880, recommended gap arthroplasty rather than interpositional arthroplasty.

**Bellinger D.H**<sup>4</sup>, in 1940, classified temporo mandibular joint ankylosis as intra articular (true ankylosis) and extra articular (false ankylosis). Joint involvement could be unilateral or bilateral, in either type. The etiology was mainly attributed to infection or trauma. The author also discussed the pathogenesis of ankylosis by quoting the experimental studies of **Allison** and **Brooks**, and concluded that; bony ankylosis is a slowly developing process, which consisted of the following stages.

1. Union by granulation tissue
2. Union by fibrous tissue
3. Metaplasia of fibrous tissue into fibro cartilage and a direct transformation of this tissue into bone.

The shortest period in which complete bony ankylosis was observed, experimentally, was 180 days.

The author advocated resection at the neck of the condyle when the fusion is confined to the joint. He also advised resection at the ramus when the fusion involved condyle, coronoid and sigmoid notch.

**Blair and Ivy**<sup>7</sup> in 1951, performed bilateral condylectomy as a single stage procedure in a five year old and they observed normal opening and closing of the mouth post operatively.

**Cerenea**<sup>12</sup> in 1955 stated that performing condylectomy in a child produces deformity of the face by affecting growth of the mandible. He also stated that recurrences are more if Condylectomy is performed in younger individuals.

**Thoma**<sup>108</sup> in 1955 suggested that none of these materials need to be interposed between the ends of the bone, as long as a large cavity or space is created.

**Kazanjian**<sup>40</sup> in 1955 presented a case of bilateral ankylosis associated with an extreme degree of retrusion of the mandible. Four separate operations were performed. The first two consisting of arthroplasty on each temporo mandibular joint about months apart. The last two were performed six years later for correction of deformity of the lower portion of the face. Emphasis was placed on the construction of suitable appliance for the postoperative care.

**Hubesch** and **Staple**<sup>50</sup> in 1957, corrected bilateral temporo mandibular joint ankylosis as two-stage operation at an interval of 6 weeks. They approached the osteotomy site through Risdon's submandibular incision. Bilateral osteotomy was done in the ramus above the lingual from the sigmoid notch to the posterior border of the ramus.

**Ward**<sup>112</sup> in 1961, stated that ankylosis of the temporo mandibular joint should be treated as soon as possible.

**Topazian**<sup>110</sup> in 1961 had done condylectomy or osteoarthrotomy in cases of intra articular ankylosis. He stated that the operation should be performed early to allow stimulation of growth of the mandible.

**Stones**<sup>105</sup> in 1966 stated that exercise should be tried first to relieve fibrous ankylosis. When exercise fails to relieve fibrous ankylosis the author advice arthroplasty.

**Stein Hauser**<sup>107</sup> in 1973 recommended performing arthroplasty between the ages 7 and 10 years. The main benefit derived from relatively early operative intervention was the avoidance of damage to the permanent dentition, which occurred when proper oral hygiene was not possible. He also emphasized on postoperative exercises under parental supervision, which are as important as the proper operative technique.

**Mofty**<sup>86</sup> in 1974 employed a technique of removing bone about 1.5 cm in width in the region of the neck of the condyle with no attempt to remove the condyle in 16 patients. He recommended sectioning in the ramus when ankylosis had obliterated the sigmoid notch and coronoid process.

**Henry**<sup>48</sup> in 1979 stated two basic principles in performing arthroplasty.

1. Creation of 1-1.5 cm gap
2. Early vigorous exercise and sustained postoperative jaw exercises.

**Vanderwall**<sup>110</sup> in 1980, performed condylectomy in patients with fibrous ankylosis. In those cases, where the condylar process could not be removed, an osteotomy was performed below the condylar process. Patients with temporo mandibular joint ankylosis and fusion of the coronoid process with zygomatic arch were treated by a horizontal osteotomy in the ascending ramus.

**Rajagopal**<sup>97</sup> in 1983 treated 11 cases of unilateral and 4 cases of bilateral ankylosis. Patients in his series were corrected by gap arthroplasty using:

1. Pre-auricular hockey stick incision.
2. Removal of a wide segment of bone including the coronoid.
3. Early post-operative mobilization.

## INTERPOSITION ARTHROPLASTY

**Verneuil**<sup>111</sup> in 1860, introduced interposition arthroplasty. He removed a section of bone from the mandibular neck area, developed a temporal muscle-fascia flap, and interposed between the bone segments. This technique did not meet with immediate favour.

However, because of recurrences seen with gap arthroplasties, **Helferich** in 1904 reintroduced **Verneuil** technique of interposition arthroplasty with temporal muscle fascia flap. He also made -the first experimental attempts in rabbits and determined the possibility of transplanting cartilage.

**Blair & Murphy**<sup>7</sup> in 1914, stressed on the following principles to be followed for all temporo mandibular joint ankylosis and its surgical management.

- i. A pre-auricular hockey stick incision
- ii. Removal of wide segment of bone
- iii. Interposition of temporal muscle fascia to prevent contact of residual raw bone surface
- iv. Early post-operative motion.

**Risdon**<sup>96</sup> in 1934 stated that high condylectomy procedures were difficult through pre-auricular incisions, and advocated the approach through a submandibular incision at the angle of the mandible that bears his name. **Risdon** has also discussed placing of gold foil in the glenoid fossa to prevent reankylosis.

**Kazanjian V.H**<sup>65</sup>, in 1938, described an operative technique in which a simple pre-aural vertical incision, the resection of sufficient bone and the use of fascia lata transplants had all been necessary. The stress was on post operative care and long-term follow-up of the cases. He has also mentioned the danger of condylectomy, because of the close relationship of the condyle to the middle cranial fossa.

**Ding man**<sup>21</sup> in 1944, reported a case of bilateral ankylosis of the temporo mandibular joint for which he performed arthroplasty for the left joint without interposing any substance, through pre-auricular approach. After one month he performed arthroplasty for right joint with the interposition of a pedicled flap consisting of the superficial subcutaneous tissue, the superficial temporal fascia and the deep temporal fascia along with the interposed fat and fibrous tissue.

**Egger**<sup>30</sup> in 1946, in cases of temporomandibular joint ankylosis introduced tantalum foil as a substitute for temporal fascia.

**Wardwill**<sup>110</sup> in 1947 used bovine cartilage as interposing medium.

**Goodsell**<sup>41</sup> in 1947 reported a case with tantalum as an interpositional substance in temporo mandibular joint arthroplasty. He treated a case of fibrous ankylosis in two stages.

**Sir Cecil Wakeley**<sup>18</sup> in 1948, advised that in case of bony ankylosis, considerable portion of bone should be removed so as to leave quarter of an inch between the two surfaces and a piece of fascia lata, celluloid or muscle graft should be inserted between the bony surfaces so as to ensure a false joint and prevent any bony union.

**Braithwaite & Hooper**<sup>9</sup> in 1952 approached the ankylosed region through pre-auricular incision and they removed adequate amount of bone between the base of the skull and the ramus especially on the medial aspect. In one case they inserted temporalis

muscle and fascia between the bone ends and ox-cartilage in another case.

**Hooper F.E**<sup>9</sup> in 1952, used ox-cartilage as an interpositional medium after doing temporo mandibular joint arthroplasty. In 1947 **Wardwill** first described the use of ox-cartilage as a substitute for autogeneous cartilage in plastic and reconstructive procedures.

**Skaloud**<sup>98</sup> in 1953, used vitallium plate to prevent re-ankylosis.

**Gottlieb**<sup>42</sup> in 1956, used acrylic as a replacement for condyle after condylectomy.

**Smith & Robinson**<sup>105</sup> in 1957 wrote of a surgical procedure for the creation of false temporo mandibular joint in case of ankylosis by means of non-electrolytic metal.

**Smith A.E**<sup>106</sup>, in 1957, described a new surgical procedure for the creation of false temporo mandibular joint in case of ankylosis by means of non-electrolytic metal. He stated that by this new surgical procedure a normal Intermaxillary relation, a normal profile and a usable masticatory organ could be re-established.

**Georgiade, Altony & Pickrell<sup>66</sup>**, in 1957, explained that satisfactory correction of temporo mandibular joint ankylosis could be obtained following a high condylar arthroplasty with continuing of the newly created bone surface. The insertion of autogeneous dermal grafts in the created joint space provided a meniscus like tissue with the resultant new physiologic mandibular joint. This new operative procedure described both on an experimental and clinical basis with excellent cosmetic and functional results.

**Walker<sup>111</sup>** in 1958 used both temporal fascia and silastic as interposing medium to prevent re-union at the osteotomy site of gap arthroplasty.

**Goodsell<sup>40</sup>** in 1958 reported a case of temporo mandibular joint ankylosis. Arthroplasty had been performed in 1945 utilizing the so-called **Risdon's** method with the added feature of the tantalum foil between the sectioned ends of the bone. The clinical result at the time of the original report was excellent and time had proved that, in this instance, at least the method was sound.

**Martensen**<sup>77</sup> in 1960, used vitallium plate between the bone ends to prevent reunion.

**Topazian & Hexington**<sup>110</sup> in 1966, made a comparison of gap and interpositional arthroplasty in the treatment of temporo mandibular joint ankylosis. Review of twenty patients treated for ankylosis by either gap arthroplasty or by interposition arthroplasty indicated that recurrence of ankylosis was less likely when autogenous tissue was interposed to fill the defect between the bone ends. Eight of the fifteen patients treated by gap arthroplasty had recurrence of ankylosis, but none of the five patients treated by interposition arthroplasty had recurrence.

**Freedman & Gordon**<sup>32</sup> in 1968, advocated creation of pseudoarthrosis by interposition of autogenous material to prevent reankylosis.

**Robinson**<sup>99</sup> in 1968, corrected temporo mandibular joint ankylosis using silastic as an interpositional medium. In this technique, the silastic is fixed to the glenoid fossa. Therefore, the movement of the implant is less and it is surrounded by fibrous capsule without any disturbance.

**Bromberg et al**<sup>10</sup> in 1969 shared their experience in treating six cases of massive temporo mandibular joint ankylosis. It would appear from their experience that the extensive resection to give adequate mobility and replacement interposition were the key stones of the surgical management.

**Hansen**<sup>49</sup> in 1969 described the procedure in which he used silastic to reconstitute temporo mandibular joint meniscus.

**William C.Rast**<sup>109</sup> **et al** in 1969, corrected bilateral ankylosis in one stage. They performed bilateral oblique osteotomy in the ramus just above the mandibular foramen from the sigmoid notch to the posterior border of the mandible. A block of silastic was placed at the osteotomy site to prevent reankylosis. The silastic was fixed to anterior fragment by means of 24-gauge stainless steel wire. They further stated interposition of silastic restored the vertical height of the ramus.

**Silagi & Schow**<sup>102</sup> in 1970 reviewed the literature on arthroplasty and reported a case of bilateral ankylosis and its

treatment. They created a gap in the ramus just above the mandibular foramen from the sigmoid notch to the posterior border of the mandible. The silastic plate was inserted into the gap and fixed to the mandibular stump.

**Hartwell**<sup>46</sup> in 1974, treated temporo mandibular joint ankylosis by replacing the condyle with silicone rubber after condylectomy.

**Miller, G.A. et al**<sup>83</sup>, in 1975 discussed the factors pre-disposing to ankylosis and the probable pathogenesis. The past and present modes of treatment were discussed. The early surgical intervention of ankylosis could prevent many problems that arose following ankylosis. Interposition arthroplasty was the accepted means of treatment for ankylosis in the case report that was presented. The ultimate post-operative result was dependent on surgical timing, surgical technique and post-operative physiotherapy.

**Kameros & Himmelfarb**<sup>65</sup> in 1975 described the utilization of preformed 'L' shaped acrylic resin implants lined with methyl methacrylate for insertion between the cut edges of the ramus after a 1 cm gap had been created.

**Narang & Dixon**<sup>88</sup> in 1976 have reported success with fascia lata taken from the thigh and inserted as an interpositional medium.

**Skooge & Johanson**<sup>104</sup> in 1976 demonstrated the formation of articular cartilage from free perichondral grafts. There was a possibility that a new joint could be constructed, which would work more physiologically, than the "crude" non-union or pseudo arthrosis.

**Popescu & Vasiliu**<sup>95</sup> in 1977, states that among all the interposition materials, full thickness skin possess the most suitable qualities. They further state that the biologic integration of full thickness skin ensures a complete and permanent separation between the mandibular extremity and the temporal surface. They also stated that in large series of cases the condyle head was the site of resection.

**Howe**<sup>47</sup> in 1979, performed interpositional gap arthroplasty for ankylosis of the temporo mandibular joint using silastic as an interposing medium.

Various approaches to the temporo mandibular joint ankylosis and surgical treatment for bony ankylosis were discussed by **Irby** in 1980. Irby operated on 35 patients with temporo mandibular joint ankylosis. In this report, he has discussed about,

1. The age at which surgery should be done.
2. Site of surgical resection.
3. Necessity for an interposing medium.
4. Placement of autogenous bone graft over the alloplastic materials.
5. Reconstruction of the head and neck of the condyle.

**Irby**<sup>52</sup> had also stated that ankylosis should be corrected as soon as possible. He also stated that separating the ankylosed condylar head from the glenoid fossa and base of the skull attained the most satisfactory function and the lowest incidence of reankylosis and inserting interposing medium. He recommended attachment of curved silastic block to the non-mobile part to minimize the possibility of, dislocation. According to him mobile part to minimize the possibility of, dislocation. According to him when metals are used as interposing medium, they allow only hinge action of the mandible.

**Irby**<sup>52</sup> in 1980, concluded after careful analysis of alloplastic and biologic media that the success of surgery depends not so much on the nature of the material, but on the adequacy of surgery, location of resection, and post-operative exercises. In children corrected by interpositional arthroplasty showed growth and development of the mandible, but they do not overcome the asymmetry that developed before surgery.

**Irby**<sup>52</sup> has also written about the factors that prevent reankylosis:

1. Creation of a gap of sufficient width (1:5 cm)
2. Careful application and stabilization of suitable interpositional medium that completely covers the surface of the sectioned bones.
3. Jaw exercises.

**George Habel & Robert Hensher**<sup>36</sup> in 1986 described the uses of temporalis muscle flap in various reconstructive surgeries. He has used pedicled temporalis muscle flap as an interpositional substance between the bone ends after removal of the ankylosis.

**Shawney**<sup>44</sup> in 1986 treated 70 cases of temporo mandibular joint ankylosis using acrylic cylinder as interposing medium. In his article he classified the pathology of temporo mandibular joint ankylosis into

- Type I      There were dense fibrous adhesions all round the joint, which makes the joint immobile.
  
- Type II     The bony fusion limited to a small area either on the anterior portion of the joint or the posterior aspect of the joint.
  
- Type III    A bridge of bone fuses the zygomatic arch and the ramus on the lateral aspect. The upper articular surface and the disc on the deeper aspect were intact.
  
- Type IV    Complete replacement of architecture of the joints because of bony fusion between the ramus and zygomatic arch.

**Raveih. J. et al**<sup>98</sup> in 1989, discussed and described the surgical treatment of twenty patients with ankylosis of temporo mandibular joint as well as various methods used for functional restoration. The patients were classified into four groups according to the anatomic

borders and the extent of the involvement of articular fosse and the skull base.

- Class 1 Ankylotic bone tissue limited to condylar process and articular fossa
- Class 2 The bone mass extends out of the fossa involving the medial aspect of the skull base up to the carotid jugular vessels.
- Class 3 Extension and penetration into the middle cranial fossa.
- Class 4 Combination of class 2&3.

The author also emphasized on the radical removal of the ankylotic bone, as well as the advantages of interposing of the lyophilized cartilage.

**Feinberg**<sup>32</sup> in 1989 used the pedicled temporalis muscle pericranial flap as an interpositional medium in the replacement of the temporo mandibular joint disc and TMJ ankylosis surgery.

**Schobel G., et al**<sup>101</sup> in 1992, undertook a postoperative clinical study of thirteen patients, with ankylosis of the temporo mandibular joint. The study consisted of an evaluation of the surgical concept of

resection and with lyophilized dura. Early mobilization and aggressive physiotherapy were growth as a result of functional matrix, early surgical intervention to correct ankylosis should be performed regardless of the age of the patient to prevent recurrence and later developing disto-occlusion.

**Chossegres et al**<sup>12</sup> in 1997 presented a retrospective study comparing the different materials (skin, temporal muscle, homologous cartilage) used for interpositional arthroplasty over a period of 22 years. A total of 25 patients (32 joints) with atleast 3 years of follow-up were included. Good results were achieved in 92% of cases using total full thickness skin graft and 83% of cases using temporal muscle flap. Homologous cartilage gave poor results.

**Chossegres et al**<sup>13</sup> in 1999 prescribed a retrospective review of 31 patients treated with full thickness skin graft interposition following gap arthroplasty in temporo mandibular joint ankylosis. The purpose of the study was to document the feasibility of full thickness skin grafting and its effectiveness in preventing recurrences of temporo mandibular joint ankylosis. Results were successful in 90% of the 20 patients with follow-up longer than one year.

**K. Su-Gwan**<sup>106</sup> in 2001 evaluated the efficacy of interpositional arthroplasty with temporalis muscle and fascia flap in the treatment of unilateral temporo mandibular joint ankylosis in adults. The findings of this study support the use of temporalis muscle and fascia flap. However, early postoperative exercise, physiotherapy, and strict follow-up play an important role in preventing postoperative adhesion.

**E.Erdem, & A. Alkan**<sup>30</sup> in 2001 presented a report on the follow-up of 47 cases, with osseous or fibro-osseous temporo mandibular joint ankylosis, where on acrylic marble was used as the interpositional material to prevent recurrence after aggressive resection of the ankylotic mass. The authors achieved good results and believe that it is a simple alternative to other interposition arthroplasty techniques. Moreover, it has the advantage of reducing operating time and not requiring any personal skill.

## **RECONSTRUCTION OF RAMUS / CONDYLE. UNIT**

**Berdenheur**<sup>102</sup> in 1909 was quoted as having replaced the mandibular condyle with the fourth Meta tarsal joint.

**Gilles**<sup>102</sup> in 1920 reported the first transplantation of costochondral graft in temporo mandibular joint ankylosis.

**Longacre & Gilby**<sup>76</sup> in 1951, made use of autogenous costochondral cartilagenous graft in the first bilateral case of ankylosis and were impressed not only with the correction of marked apertognathia, but the excellent degree of function that the patient had attained and retained ever since. The authors believed that this was due to the fact that interposition of cartilage served the purpose of allowing the residual condylar neck to act as the fulcrum and so retain the function of the mandible as a lever of third class. In the unilateral cases, the authors observed that the tendency to drift was not present. The degree of correction of deviation of chin and restoration of facial asymmetry that followed arthroplasty rendered later cosmetic operations less imperative. In 1952, they presented a two and a half year review of cases, where autogenous cartilage was employed in one group and another group employing temporal fascia and fascia lata. Certain differences became self-evident. With fascia, there was a tendency of the patient to develop open bite and increasing retrusion. This indicated that fascia had tended to gradually absorb while the cartilage implant had borne up well under

the trauma of continuous use. The accurately fitted cartilage implant had not shown any tendency to shift from its position.

**Hinds**<sup>46</sup> in 1955, corrected temporo mandibular joint ankylosis in 3 cases using costochondral cartilage.

**Entin**<sup>28</sup> in 1958 explained the changing pattern of normal growth of various components of the human mandible and compared with that of the congenitally deformed condyle. The surgical management of such cases with autogenous bone transplant and bank bone was discussed. The author also insisted on the maintenance of occlusion and the eruption of permanent dentition in establishing the stability of the affected side of the mandible.

**Christensen**<sup>13</sup> in 1963 reported 3 cases, where the correction of temporo mandibular joint was done by insertion of a Cast Vitallium glenoid fossa.

**ingman R.O., & Grabb W.C**<sup>23</sup>, .in 1964, reported the construction of both mandibular condyles with autogenous fifth metatarsal transplants. The fifth metatarsal head with its

cartilagenous articular surface provides a satisfactory transplant for reconstruction of the temporo mandibular joint. They observed that the patients treated, had good range of motion with normal occlusion and excellent function. Clinical and radiographic examination indicated that half joint transplants did not undergo the destructive changes of the bone and articular cartilage that occurred in the whole joint transplant.

**Peskin S., & Laskin D.M**<sup>94</sup> in 1965, evaluated the amount of growth potential which remained after partial removal of the condyle and determined whether autogenously transplanted condylar growth centers could restore the growth of the mandible after condyloidectomy. Thirty-one young dogs were used to study the effects of condyloidectomy and hemicondyloidectomy, as well as replacement of the resected portion of the condyloid process with autogenous graft. Because of both gross and histological observations, it was concluded that removal of the entire condyle markedly retarded the growth of dog mandible and caused some changes in shape. Resection of a part of the other condyloid process on the other hand initially reduced the amount of mandibular growth but ultimately the condyle regenerated and relatively normal growth

was attained. When an autogenous graft of part of the contra-lateral side was used to replace the entire condyloid process or a resected half, the graft was able to contribute to the mandibular growth and a relatively normal mandible was achieved.

**Ware & Taylor**<sup>113</sup> in 1966 reported in their article about growth center transplantation study on Rhesus monkey and in 1970 they have tried this principle in their young patients with temporo mandibular joint ankylosis. They observed increased growth on the transplanted side.

**Bell W.H**<sup>4</sup>, in 1968, stated that, the types of bone growth and the adequate preparation of the graft bed are important for the success of bone grafting procedures used in oral surgery, where, the aim is to place a readily vascularizable osteogenic organic structure in intimate contact with a vascular osteogenic cancellous host bed. Of all the types of bone substitutes available to the oral surgeon, autogenous cancellous bone accomplishes this goal best. Adherence to sound orthopedic principle is a prime requisite to the success of a graft.

**Hunsuck**<sup>51</sup> in 1968 experimented autogenous grafting for replacing temporo mandibular joints and mandibular condyles in eight young rhesus monkeys. In one group of four animals, the condyle was replaced with graft from the sternal end of the clavicle. In the second group of four monkeys, the condyle and the temporo the sternal end of the clavicle with its capsule and disc replaced mandibular joint. Growth centers were reconstituted in the healed grafts and fibrous connective tissue covering of the articulating surface was retained. Similar procedure perhaps would be applicable in treating humans with ankylosed or missing temporo mandibular joint and mandibular condyle.

**Poswillo**<sup>96</sup> in 1970 demonstrated in animal studies on Macaca iris monkeys that costochondral graft had capabilities for remodeling and adaptation.

**Marshall & Waldren**<sup>83</sup> in 1971, used silastic testicular implant in the reconstruction of the temporo mandibular joint ankylosis.

**Snyder et al**<sup>105</sup> in 1971 reported using a sternoclavicular whole joint raft as a substitute for the temporo mandibular joint in a 70-year-

old man who underwent resection of the temporo mandibular joint following cylindroma.

**Rowe N.C**<sup>100</sup> in 1972, stated that condyle which is the primary growth centre when destroyed, produced deformity of face which can be corrected by costochondral graft.

**Kennet**<sup>67</sup> in 1973, recommended costochondral graft over metatarsal graft, because it not only restored the height but also initiated secondary growth.

**Clifford, L. et al**<sup>17</sup>, in 1974, discussed- the diagnosis and treatment of temporo mandibular joint problems. The present therapeutic modalities were reviewed and a case was presented where the temporo mandibular joint was replaced with apparent success using vitallium prosthesis applying Charnley's technique.

**Kent**<sup>67</sup> and associates in 1974 designed prosthesis of cast stainless steel with a backing of proplast inlay on its medial surface. In growth of fibroblasts into the lining material enhances stability and relieves stress on the retaining screws.

In 1974, **Fieldhouse**<sup>32</sup>, in his article described a case of bilateral temporomandibular joint ankylosis with associated micrognathia in a 31-year-old female. This patient had undergone three previous operations for this condition. Fieldhouse treated this case by the insertion of costochondral graft with a silastic inlay unilaterally, osteotomy and augmentation genioplasty.

**Freedus M.S**<sup>36</sup> in 1975 discussed the recent literature regarding growth and development of the craniofacial region and the development of facial deformity associated with temporomandibular joint ankylosis. The author stated that the concept of a growth centre in the condyle is probably misleading; instead, the soft tissues of the orofacial region seem to provide the primary growth forces. They stated that the condylar cartilage acts as an adaptive centre rather than true growth centre. They placed costochondral grafts to stimulate the growth of mandible to restore the vertical height of the ramus.

**Bowerman**<sup>8</sup> in 1976, corrected temporomandibular joint ankylosis by placing costochondral grafts in the osteotomy site.

**Macintosh & Henny**<sup>74</sup> in 1976 used costochondral graft in 26 cases. He observed linear growth in an anteroposterior dimension.

**Silver et al**<sup>103</sup> in 1977, reported successful replacement of the condylar head in 3 patients using vitallium prosthesis.

**Tasanen & Leikoma**<sup>102</sup> in 1977 reported in their article that costochondral graft might necessitate the growth of the mandible.

**Lewin & Wright**<sup>73</sup> in 1978, reported successful adaptation of silastic head prosthesis as a condylar replacement. They used this prosthesis after resection of the condylar head for rheumatoid and degenerative arthritis and as an interpositional material after resection of the ankylosed joint.

**Kumoona**<sup>69</sup> in 1978 used chrome-cobalt prosthesis to replace condyle. He further states that the patient must be taken to the theatre on the third postoperative day and the mouth should be opened forcefully under general anesthesia.

**Tajima**<sup>104</sup> in 1978 described -a technique where two pieces of perichondrium from the 7th and 8th costal cartilage measuring 35x15 mm, were harvested. The two pieces were sewn together. One end

was placed over the condylar stump; the other end was used to line the silastic, which was fixed to the glenoid fossa.

**Munroe**<sup>77</sup> in 1980, used rib graft with costochondral junction to treat ankylosis.

**Matukas V.J. & Szymela, N.F.**<sup>82</sup> in 1980 described a procedure, which involved using a composite cartilage - bone iliac crest graft and fixing to the zygomatic process of the temporal bone with the cartilagenous portion facing the stump of the mandibular ramus. This procedure was easier to facing the stump of the mandibular ramus. This procedure was easier to accomplish than a costochondral graft. The advantages are that it does not require Maxillo-mandibular fixation and offers the possibility of appositional growth.

**Siemssen**<sup>100</sup> in 1982 described a new method of temporomandibular arthroplasty by means of a muscle - pedicled sternoclavicular joint. They used an articular graft pedicled on the clavicular head and the sternohyoid muscle and presented its clinical application in four patients (three with temporomandibular joint ankylosis and one with hemi facial microsomia).

**Jones, N.F. & B.C. Sommerland**<sup>62</sup> in 1983, described a method of reconstruction of the zygoma, temporomandibular joint and hemi mandible utilizing a segment of outer table of sternum, sternoclavicular joint vascularized by an ipsilateral pectoralis major muscle flap. The post operative, functions of the temporomandibular joint were compared and discussed in detail.

**John Kent & Dale J. Misiek**<sup>60</sup> in 1983, discussed in detail about the use of proplast-coated condyle in adult patients suffering from ankylosis. This had produced very satisfactory results in the rehabilitation of the temporomandibular joint. About 87.5% of cases were successful following the use of proplast coated metallic condyle. The procedure and the outcome were discussed in detail.

**William Sympton**<sup>112</sup> in 1983, used costochondral graft to treat ankylosis in 5 patients. He observed in all the patients the mandibular growth was excellent.

**Adekeye**<sup>2</sup> in 1983, in his survey of 76 patients with ankylosis of mandibular joint in Nigerians, were treated by condylectomy in cases of intra-articular ankylosis, through pre-auricular approach with costochondral grafts in one.

**Kreutziger**<sup>63</sup> in 1984 described the surgical anatomy of the temporomandibular joint and the surgical approaches to the temporomandibular joint, such as pre-auricular, post auricular and end aural. Surgical technique of each incision has been described in detail.

**Egyedi**<sup>26</sup> in 1985 advised the use of the costochondral graft on the ankylosed side and subcondylar osteotomy on the unaffected side to improve the esthetics and to maintain the function.

**Giglio**<sup>37</sup> in 1985 describes the replacement of ankylosed temporomandibular joint with an autogenous costochondral graft and he advises to place the cartilagenous end into the glenoid fossa to prevent ankylosis.

**Ellis III, Carlson D.S**<sup>27</sup>, in 1986 described the histological similarities between sternoclavicular joint, costochondral joint and temporomandibular joints during growth in *Macaca mulatta*. The results indicated that the temporomandibular joint and sternoclavicular joint are very similar morphologically throughout the growth period. The clavicular head contained layers of cartilage cells typical of mandibular condyle. The costochondral junction, however,

did not resemble the condyle but appeared to be more similar to the growth' plate in a long bone epiphysis during growth. The results of this investigation indicate that the sternoclavicular joint may be more suitable for mandibular condylar replacement than the costochondral joint.

**Lindquist et al**<sup>14</sup> in 1986 studied 66 patients clinically and have done 66-costochondral arthroplasty upon them during the period of 1969-1984. In nearly half of the cases, ankylosis was the main indication for operation followed by dysplasia, tumors and osteomyelitis. In the majority of the patients (67%), the postoperative function of the mandible was considered good.

**Rajakummoona**<sup>69</sup> in 1986 replaced ankylosed temporomandibular joint by a chondro osseous graft from the iliac crest in 6 children. He found good functional results, better esthetic appearance and no recurrence of ankylosis.

**Reid**<sup>98</sup> in 1986 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.

**Daniels et al**<sup>19</sup> in 1987, conducted a study to evaluate histologically short term adaptations within the temporomandibular joint after replacement of the mandibular condyle with the autogenous sternal head of the clavicles and compared these adaptations with autogenous costochondral joint and mandibular condyle transplants in 12 juvenile *Macaca mulatta*. The results indicate that the sternoclavicular joint may be more suitable for mandibular condylar replacement than the costochondral joint, especially since individuals on whom such grafting procedures are contemplated are usually young persons who have compromised joints with a disrupted periosteum and decreased osteogenic potential.

**John Bowerman**<sup>58</sup> in 1987 presented the details about the use of non-vascularised osteo-chondral grafts and the role of vascularised grafts in the treatment of congenital malformations of the temporomandibular joint. The results were satisfactory. The advantages and disadvantages were also discussed.

**Christian Lindquist et al**<sup>13</sup> in 1988 evaluated the clinical and radiological behavior of autogenous costochondral grafts used for temporomandibular joint reconstruction in 16 patients with a mean

follow up of 10 years. The grafts were classified into four groups according to the degree of radiologic classification or remodeling (adaptation). Total adaptation was observed in six cases, and in two cases, no changes were found. The function of the new joint was excellent irrespective of the radiologic status and seemed to improve with time.

**Kaban et al**<sup>64</sup> in 1990 suggested a protocol for management of temporomandibular joint ankylosis. The protocol consisted of

1. Aggressive resection of the callus.
2. Ipsilateral coronoidectomy.
3. Contra lateral coronoidectomy when necessary.
4. Lining of the temporomandibular joint with temporalis fascia or cartilage.
5. Reconstruction of the ramus with a cartilage graft.
6. Rigid fixation of the graft.
7. Early mobilization and aggressive physiotherapy.
8. Correction of mandibular deformities.

**Korrula P et al**<sup>68</sup>, in 1991 described a modified technique of pedicled sternoclavicular joint transfer and evaluated its advantages.

**Guyron. B & Carlos, Lasa**<sup>45</sup> in 1991 reported the long term follow up of eight adolescent patients who underwent reconstruction of the temporomandibular joint and ramus for correction of hemifacial microsomia or trauma related temporomandibular joint ankylosis during varying periods of growth. Four patients had excessive growth of the graft, one had sub optimal growth and three had no growth. They concluded that the growth of costochondral graft was extremely unpredictable.

**Timo Peltomaki**<sup>91</sup> in 1992 undertook a study to examine the growth and adaptation of costochondral grafts in the temporomandibular joint. The results provided evidence that costochondral transplants do not adapt to the functional conditions of the temporomandibular joint and that the amount of cartilage in the graft has some bearing on its growth capacity.

**Henning et al**<sup>47</sup> in 1992 investigated the long-term effects of transplanted clavicles to the temporomandibular joint in juvenile monkeys. The results showed that the sternal end of the clavicle may be a viable option in mandibular condyle transplant surgery.

**John Kent et al**<sup>61</sup>, in 1993 presented a retrospective study on 262 VK I (N=138) & VK II (N=124) partial and total temporomandibular joint placed between 1982 and 1990. The study showed that wear of the Teflon fluorinated ethylene propylene polymer surface was the primary reason for VK I failure, there was no material failure of the VK II prosthesis. A highly significant improvement in success was found if no surgery has been performed before either VK 1 or VK II total joint placement. Total temporomandibular joint surgery must be reserved for patients in whom, alternative, surgical methods have failed or no longer indicated.

**Larry M. Wolford et al**<sup>71</sup> in 1994, evaluated the long term outcomes of fifty-two sternoclavicular grafts for the temporomandibular joint reconstruction in thirty-eight patients. The results of the study support the use of the sternoclavicular graft for the temporomandibular joint reconstruction in selected group of patients.

**Larry M. Wolford**<sup>70</sup> in 1994 presented the results of the 56 patients with 100 reconstructed temporomandibular joint using the techmedia custom-made total joint system. The results were

categorized as good, fair and poor based on the clinical assessment. The morbidities and the postoperative problem were discussed in detail.

**Perrot D.H. et al<sup>93</sup>**, in 1994, presented a retrospective study of 26 patients who received costochondral grafts for reconstruction of ramus / condyle unit. Facial appearance, jaw motion, occlusion, contour and linear growth changes were documented preoperatively, immediate postoperative, and long term. The result of this study indicate that a costochondral graft may be used successfully to construct / reconstruct the ramus / condyle unit and that linear overgrowth of the graft does not appear to be a clinical problem with the method described.

**Charles H. Henry & Larry M. Wolford<sup>70</sup>** in 1995 presented the reports of the outcome of free temporalis fascia and muscle graft (TFG) reconstruction of the temporomandibular joint with and without simultaneous orthognathic surgery (SOS). TPG with or without SOS produced similar treatment outcomes. Combining treatment outcomes for both groups, the number of previous joint surgeries

significantly affected success. The presence of osteoarthritic changes did not significantly affect treatment outcome.

**Jan-Paul Van Loon et al**<sup>54</sup> in 1995 described the useful elements of applied temporomandibular joint prosthesis and discussed the factors necessary to be addressed in an appropriate temporomandibular joint prosthesis design. He presented the review of literature on temporomandibular joint prosthesis from 1946 to 1994 and also the implications for future prosthesis design.

**Aum Rustia**<sup>3</sup> in 1996 conducted study to evaluate by computed tomography and clinically the structure and function of costochondral grafts (CCG) used to replace mandibular condyles in 11 patients. The study showed that the most of the patients seemed to have benefited from replacement of the deformed mandibular condyle with a CCG as estimated by improved range of mandibular movements and decreased symptoms. There were some problems related to unpredictable growth and location of the graft, as well as restricted movement of the replaced condyle.

**Thomas B. Dodson et al**<sup>109</sup> in 1997 conducted a study to evaluate the efficacy of cranial bone graft to reconstruct the

mandibular condyle in a non human model. The study showed that full thickness cranial bone grafts provided functional joint that resisted resorption. Cranial bone may therefore provide a suitable alternative to other Autologous or Alloplastic graft materials for reconstruction of the human mandibular condyle in non-growing patients.

**Gunaseelan**<sup>44</sup> in 1997 presented a new method of condylar reconstruction after arthroplasty in extensive ankylosis of the temporomandibular joint in adults. An autogenous graft, consisting of the excised ankylotic mass, was contoured, reimplanted and used for condylar reconstruction.

**Hossein Behnia et al**<sup>49</sup> in 1997 studied the long-term outcomes and clinical result of costochondral transplant used for the treatment of condylar ankylosis of the mandible in children with and without application of postoperative activation appliances. The results showed that the costochondral growth centre transplants to be effective in restoring mandibular growth of the affected side, however, symmetry, arch coordination, correction of occlusal canting, mandibular deviation, facial growth and prevention of reankylosis were obtained with better control only in those cases that underwent

long term orthodontic activator therapy postoperatively and were followed closely.

**Florencio monje et al**<sup>34</sup> in 1998 modified the fixation technique earlier used in costochondral graft to adapt the graft perfectly to the contour of the ramus of the mandible to achieve and intimate contact between the graft and ramus of mandible. This overcame various problems related to the earlier fixation technique i.e. delayed healing pseudo arthrosis lack of stability of the graft.

**Ellen wen ching et al**<sup>29</sup> 1999 evaluated the post operative growth of mandible after reconstruction of condylar process using costochondral graft in children and concluded that using costochondral graft to reconstruct temporomandibular joint ankylosis in children provides a functional condyle with growth potential. However, there is possibility of excessive growth of graft resulting in deviation of chin and mandibular prognathism years later. Although the costochondral graft showed an unpredictable growth pattern, it is still a good biologic reconstruction material when used in caution.

**Maturra et al**<sup>80</sup> in 2001 the study investigated the costochondral graft in temporomandibular joint of sheeps. In the

study on Marino sheep condyle alone was resected and replaced with a costochondral graft from 13<sup>th</sup> rib. The exam in the joints after 3 months radiological, histologically, macroscopically and concluded that new condylar head with a normal configuration and function with chondrocytes arranged in a similar fashion of normal joints was achieved by the costochondral grafts. The study showed that when costochondral grafts were used to replace condyle in an otherwise normal sheep TM joint, they fused to ramus and reconstructed a nearly normal functional joint.

**T.Peltomaki et al**<sup>92</sup> 2002 on their study of the effect of unilateral costochondral graft on the growth of the marmoset mandible and concluded that depending on the cartilage in unilateral costochondral graft, a tissue separating force is generated in growing monkeys, capable of propelling the mandible to unoperated site.

## **SUMMARY & CONCLUSION**

**“Children of the lesser god have ankylosis”- Lindquist**

This statement aptly describes the emotional, psychological and functional disability of the patients. The Maxillofacial surgeon

has, over the years had a unique role to play in the management of these children. This stands to reason for the plethora of techniques available to treat ankylosis.

Over time there has been a general consensus that treating ankylosis alone would not suffice the patient had to be provided with a mandibular joint that remained fully functional and contributed substantially to the growth of the jaw. Costochondral graft fitted the bill.

The Costochondral graft has been extensively researched upon and tried. It has its own advantages; it has the capacity to adopt itself to the temporomandibular joint histologically, morphologically and macroscopically. This study was undertaken to develop a new fixation technique in adapting the costochondral graft to the ramus of the mandible. The radio graphical and the functional results obtained in our study were satisfactory. However, a definite conclusion regarding the superiority of the fixation technique could not be arrived. Since the size of our sample is less and duration of follow up of our patients is short, it was felt that a long-term follow up was essential to study the adaption and fixation of the graft.

This technique of fixation of graft by green stick fracturing and adapting exactly to the contour of the ramus of the mandible has been used in four patients, and no complications related to the fixation technique have occurred. In all cases, an optimal ossification between the rib graft and the mandible was seen radiologically (plain radiographs and ortho pantomograms) with no undesired movements of the graft.

Therefore, this simple variation of the standard fixation technique seems to be suitable for fixation of the costochondral graft to the mandible in the reconstruction of the TMJ. The advantages are that it provides a large surface of contact between the rib and the mandible, and thus may improve the ossification process. It also avoids burring and decorticating both the inner cortex of the rib and the external surface of the ascending mandible to achieve an accurate contour of the graft. In addition, the rib graft can always be harvested from the right side; thereby decreasing the risk of pericardial damage during the procedure and postoperative discomfort is less likely to be confused with cardiogenic pain.

We therefore content that the modified fixation technique by the green stick fracturing of the costochondral graft still accords the surgeon a valuable choice for reconstruction of the temporomandibular joint in growing patients without any complications like delaying in healing, pseudoarthrosis and loosening and fracturing of the graft.

## **BIBLIOGRAPHY**

1. **Abbe**, Quoted by Silagi Schow. Temporomandibular joint Arthroplasty. Review of literature and report of a case. J. Oral surgery 28:920, 1970.
2. **Adekeye, E.O.**, Ankylosis of the mandible-Analysis of 76 cases. J Oral Maxillofacial surgery 41:422-449,1983.
3. **Alkayat, Brahmley**, Modified Pre-auricular approach to the Temporomandibular Joint and malar arch; British journal of Oral Surgery 17:91-103,1979-1980.
4. **Bellinger**, Temporomandibular Joint ankylosis and its. Surgical correction, JADA 27; 1940.

5. **Berry w Beck et al** complication of two technique of dermal harvest in temporomandibular joint reconstruction J O M S: 1999:57:930-934.
6. **Blaine D. Austin, Stephen M. Shupe.** The role of Physical Therapy in recovery after Temporomandibular Joint surgery. J. Oral Maxillofacial Surg 51:495-498,1993.
7. **Blair & Ivy,** Diseases of the Temporomandibular Joint-Limited Motion of the Jaw. Essentials of oral Surgery, IV edition, C.V. Mosby & co; 1951.
8. **Bowerman,** Reconstruction of the Temporomandibular Joint by Costochondral ribs graft. Abstracts 3rd Congress, Maxillofacial Surgery, 1976.
9. **Braithwaite & Hopper,** Ankylosis of the Temporomandibular Joint. British Journal of Plastic Surgery 5:105-121, July 1952.
10. **Bromber,** Surgical Treatment of bony ankylosis of the Temporomandibular Joint. Plast-Recons. Surgery, 43:Jan 1969.
11. **Chossegres et al,** Comparison of different materials for interposition arthroplasty in the treatment of Temporomandibular

Joint ankylosis surgery: long-term follow up in 25 cases. British J. of Oral Maxillofacial Surg 35:157-160,1997.

12. **Chossegres. C et al**, Full thickness skin graft interposition after Temporomandibular Joint ankylosis surgery - A study of 31 cases. Intl J Oral Maxillofacial Surg. 28:330-334, 1999.
13. **Christian Lindquist et al**, Adaptation of Autogenous Costochondral Grafts used for Temporomandibular Joint reconstruction: A long-term clinical and radiologic follow-up. J. Oral Maxillofacial Surg 46:465 470,1988.
14. **Christian Lindquist**, Autogenous costochondral grafts in Temporomandibular Joint Arthroplasty. J. Maxillofacial Surg 14:143 149,1986.
15. **M M Chidzonga**, Temporomandibular ankylosis review of 32 cases J O M S: 1999:37:123-124
16. **Constantinus Politis, Eric Fossion**, The use of Costochondral Grafts in Arthroplasty of Temporomandibular Joint. J of Cranio-Max-fac Surg 15:345-354, 1987.

17. **Converse et al,** Surgical release of Bilateral Temporomandibular Joint Ankylosis. *Plast Reconst. Surgery* 64:404,1977.
18. **Cool,** Teflon implantation in Temporomandibular Joint Arthroplasty *Oral Surgery* 33:706,1972.
19. **Daniels, Edward Ellis III, David S. Carlson,** Histological Analysis of costochondral and sternoclavicular Graft in the Temporomandibular Joint of the Juvenile monkey *J. Oral Maxillofacial Surg* 45(8): 675 683,1987.
20. **Dechamplain,** Autopolymerising Silastic for interpositional Arthroplasty *J. Oral Maxillofacial Surg.* 46: 522-525, 1988.
21. **Dingman R.O,** Bilateral Ankylosis of the Temporomandibular Joint with retrusion Deformity. Report of case J. of *Oral Surgery* 2:71-76, Jan 1944.
22. **Dingman R.O,** Fifteen years Experience with Temporomandibular Joint disorders. Evaluation of 140 cases. *Plast. Reconst. Surg* 44:no.2, 119-124, Aug 1969.

23. **Dingman R.O, and Grabb.W.C**, Reconstruction of both Mandibular' condyles with metatarsal bone grafts. Plast.Reconst.Surg 34:441,1964.
24. **Dorrance et al**, Arthroplasty of the Temporomandibular Joint 79:485,1924.
25. **Dorrlt W.Mitzal et al**, Surgical Management of temporomandibular Joint Ankylosis type III by retaining the displaced condyle and disc. J Oral Maxillofacial Surg 56: 1133-1138, 1998.
26. **Egyedi**, Treatment of Unilateral Ankylosis of the Temporomandibular Joint. J Maxillofacial Surg 13(5), 1985.
27. **Ellis E III Carlson D.S**, Histological Comparison of the Costochondral, Sternoclavicular and Temporomandibular Joint, during growth in Macaca mulatta. Jour of Oral Maxfac Surg 44:312, 1986.
28. **Entin MA.**, Reconstruction in Congenital deformity of Temporomandibular Joint component. Plast. Reconst. Surg 21:461,1958.

29. **Ellen wen ching KO** et al Temporomandibular Joint reconstruction in children using costochondral graft. J O M S 1999: 789-798.
30. **Erdem E, Alkan A**, The use of Acrylic marbles for interposition Arthroplasty in the treatment of Temporomandibular Joint ankylosis follow-up of 47 cases. Int J Oral Maxillofacial Surg 30:32-36, 2001.
31. **Esmarch**, Quoted by Silagi Schow. Temporomandibular Joint Arthroplasty J. of Oral Surg 28(12): 920. Dec 1970.
32. **Fieldhouse J**, Bilateral Temporomandibular Joint Ankylosis with associated Micrognathia-Report of a case. British J. of Oral Surg 11:213-216,1974.
33. **Figuerca A.A., Gans B.J., Pruzansky S**, Long term follow up of Mandibular Costochondral grafts. J. Of Oral Surg 58:257-268,1984.
34. **Florencio monje et al** Green stick fracturing of costochondral graft for adaptation and fixation in temporomandibular joint ankylosis patients J oral maxillofacial Surg 56:103-105.1998.

35. **Freedus M.S., Ziter W.D., Doyle P.K,** Principles of treatment for Temporomandibular Joint Ankylosis Jour of Oral Surg 33:757-765,1975.
36. **Georgiade N., Altany F., Pickrell.K,'** An Experimental and Clinical evaluation of Autogenous dermal grafts used in the treatment of Temporomandibular Joint ankylosis Plast. Reconst. Surg 19:4,1957.
37. **Giglio J.A., Daniel M.Laskin,** Current Advances in oral surgery. Quitesense International 59-70 1985
38. **Gilles,** Quoted by Irby in current advances of Oral Surg. Vol. IV Ed. William B. Irby.
39. **Goode et al** Bone and cartilage grafts: current concepts. Otol. Clin. North America 5 (1972) 447-455.
40. **Goodsell J.O,** Tantalum in Temporomandibular Arthroplasty after 12th Postoperative year Report of case. J. Of Oral Surg 16:517-518, Nov 1958.
41. **Goodsell J.O,** Tantalum in Temporomandibular Arthroplasty; Report of case J. of Oral Surg 5:41-45 Jan 1947.

42. **Gottlieb**, Temporomandibular Joint Arthroplasty. Oral Surg Oral Med Oral Path 9:362,Dec 1956
43. **Grube**, Quoted by A.G. Miller Temporomandibular Joint Ankylosis. Review of literature and report of two cases of bilateral involvement. J. Of Oral Surg 33:792, 1975.
44. **Gunaseelan H**, Condylar reconstruction in extensive ankylosis of temporomandibular joint in adults using resected segment as auto graft. Int. J. Oral Maxillofacial Surg 1997: 26:406-407.
45. **Guyuron B., Lesa C.I.**, Unpredictable growth pattern of Costochondral graft. Plast. Reconst. Surg 90(5): 880-886, 1992.
46. **Hartwell**, Mandibular condylectomy with silicone rubber replacement. Plast. Reconst. Surg 53:440,1974.
47. **Hennig T.B., Ellis III E., Carlson D.S.**, Growth of the mandible following replacement of the mandibular condyle with the sternal end of the clavicle. An experimental investigation in Macaca mulatta. J. Oral Maxillofacial Surg 50:1196, 1992.
48. **Henny**, Quoted by Kruger, Text book of Oral and Maxillo-Facial Surg V Ed.P 428

49. **Hossein Behnia et al**, Use of activator appliances in Pediatric patients treated with costochondral grafts for Temporomandibular Joint Ankylosis: Analysis of 13 cases J of 'Oral Maxillofacial Surg 55: 1408 1414, 1997.
50. **Hubesch and Staple**, Surgical correction of Bilateral Ankylosis of Temporomandibular Joint. J. Of Oral Surg 15(3), 238, July 1957.
51. **Husuck E.E.**, Autogenous grafts for replacing Temporomandibular Joint and Mandibular condyles in rhesus monkeys. J. of Oral Surg 27:167, 1969.
52. **Irby**, Current advances in oral Surgery. Ed. William B. Irby Pg.320
53. **James D R & Gordon Irvine** autogenous rib grafts in Maxillofacial surgery J M F S 1983: 11:201-203
54. **Jan Paul Van Loon, Lambert G.M.** Evaluation of Temporomandibular Joint Prostheses: Review of the literature from 1946 to 1994 and Implications for future prosthesis designs J.Oral Maxillofacial Surg 53:984-986,1995

55. **Jeffrey C. Poshick, Jeffrey A. Goldstein** Surgical management of Temporomandibular Joint Ankylosis in the Pediatric population. *Plast Reconst. Surg*, April 1993.
56. **Jeffrey J Moses et al.** Arthroscopic Laser debridement of Temporomandibular Joint fibrous and Bony Ankylosis: Case report. *J Oral Maxillofacial Surg* 56:1104-1106, 1998.
57. **Jeffrey O. Link, David C. Hoffman,** Hyperplasia of a costochondral Graft in an adult. *J Oral Maxillofacial Surg* 51:1392-1394, 1993.
58. **John Bowerman,** Reconstruction of the Temporomandibular Joint for acquired deformity and congenital malformation. *British J. of oral Maxillofacial Surg.* 25:149-160,1997.
59. **John E. Deburg Norman and Paul Bramley,** A text book and color Atlas of the Temporomandibular Joint.
60. **John Kent, Dale. J. Misek, Richard K,** Temporomandibular Joint Condylar Prosthesis. *J Oral Maxillofacial Surg* 4:245-254, 1983.

61. **John Kent, Michael S. Block**, Update on the Vitek partial and Total Temporomandibular Joint systems. J Oral Maxillofacial Surg 51:408-415, 1993.
62. **Jones M.F., Sommerland B.C.**, Reconstruction of the Zygoma, Temporomandibular Joint and mandible using a compound pectoralis major Osteo-muscular flap. British Jour of Plast. Surg 36:491, 1983.
63. **Joram Raveh**, Temporomandibular Joint Ankylosis. Surgical treatment and long-term result. J Oral Maxillofacial Surg 47: 900-906, 1989.
64. **Kaban et al**, A protocol for management of Temporomandibular Joint Ankylosis. J Oral Maxillofacial Surg 48(11): 1145-1151,1990.
65. **Kameros, Himmelfarb**, Treatment of Temporomandibular Joint Ankylosis with Methyl Methacrylate Interpositional Arthroplasty. J Oral Surg 33,282-287, 1975.
66. **Kennet**, Temporomandibular Joint Ankylosis. The rationale for graft in a young patient. J. Of Oral Surg 31:744, 1973.

67. **Kent et al**, Condylar Reconstruction treatment planning. J. of oral Surg 37:489,497, 1974.
68. **Korula, RamachandranM.E. Dhanaraj.P**, Temporomandibular joint Arthroplasty by pedicled transfer of the Sterno Clavicular joint- A simplified technique. Brit J. of Plast. Surg 44(6): 110-111, 1991.
69. **Kumoon R**, Chondro-Osseous iliac graft for one stage reconstruction of the ankylosis of Temporomandibular joint in children. J. Maxillofacial Surg 14(4) : 215-220, 1986.
70. **Larry M. Wolford**, Temporomandibular Joint devices; Treatment factors and outcomes. Oral Surg, Oral Med, Oral Path Vol 83, Number 1.
71. **Larry M. Wolford, David A. Cottrell and Charles Henny** Sterno Clavicular grafts for Temporomandibular joint reconstruction J Oral Maxillofacial Surg 52:119-128,1994.
72. **Lewin & Wright**, Silastic Ulna head prosthesis for use in Surgery of the temporomandibular joint ankylosis. J. Of Oral Surg 26:906, 1978.

73. **Lewin & Wright**, Use of Autogenous cartilage graft in arthroplasty of the temporomandibular joint ankylosis. *Plast. Reconst. Surg* 7:27, 1951.
74. **Longacre J.J and Gilby R.F**, Further observation on the use of autogenous cartilage graft in the Arthroplasty of Temporomandibular joint. *Plast. Reconst. Surgery* 10:238, 1952.
75. **Longacre J.J and Gilby R.F**, The use of Autogenous cartilage graft in arthroplasty for true ankylosis of the temporomandibular joint. *Plast. Reconst. Surgery* 7:271, 1951.
76. **Macintosh Henny**, A spectrum of application of autogenous Costochondral Graft *J Maxillofacial Surgery* 15:257, 1977.
77. **Macintosh R.B**, Current spectrum of Costo-chondral and dermal grafting in Bell WH (ED) *Modern practice to Orthognathic and Reconstructive Surgery* Vo1.2 WB Saunders, 873-949, 1992.
78. **Macintosh R.B**, The use of Autogenous tissues for temporomandibular joint reconstruction *J O M S* 58:63-69:2000.

79. **Martinez & Garcia**, Surgical correction of recurrent bony ankylosis of the Temporomandibular Joint. British Jour of Oral Surgery 9:120, 1971.
80. **Matsuura et al** Costochondral Graft Reconstruction in temporomandibular joint ankylosis after condylectomy B J O M S; 39; 189-195; 2001.
81. **Matsuura et al**, Effect of partial immobilization on reconstruction of ankylosis of temporomandibular joint with costochondral graft B J O M S; 39;196-203;2001
82. **Matukas V.J and Schmidt J.F**, Surgical treatment of bony ankylosis in a child using a composite cartilage bone iliac crest graft. J. Of Oral Surg 38:903, 1980.
83. **Miller G.A., Page L. Griffith C.R.**, Temporomandibular Joint ankylosis review of literature and report of two cases of bilateral involvement. Jour of oral Surg 33(10): 792, 1975.
84. **Miyamoto, et al**, The effect of an intra-articular bone fragment in the genesis of temporomandibular joint ankylosis Int. J. Oral Maxillofacial Surg. 2000; 29: 290-295.

85. **Miyamoto, et al,** The effect of partial immobilization of temporomandibular joint ankylosis reconstructed with costochondral graft. A sheep study I J O M S 2001;39;196;203.

86. **Mofty et al**, surgical treatment of temporomandibular joint ankylosis J O S; 32; 202-206; 1974.
87. **Mosby EI, Hiatt RW**, A technique of fixation of Costochondral grafts for reconstruction of the Temporomandibular Joint. J Oral Maxillofacial Surg 47:209-211, 1989.
88. **Narang and Dixon**, Temporomandibular Joint Arthroplasty with Fascia lata. Jour of Oral Surg 39:45-50, 1975.
89. **Obeib G, Guttenberg SA**, Costochondral Grafting in Condylar replacement and mandibular reconstruction J. Oral Maxillofacial Surg 48:177-182, 1988
90. **Paul C. Salins**, Soft and hard tissue correction of facial deformity associated with bilateral Temporomandibular Joint ankylosis, Int J Oral Maxillofacial Surg. 27:422-424,1998.
91. **Peltomaki T**, Growth of a costochondral graft in the temporomandibular Joint J Oral Maxillofacial Surg 50(8):851-857, 1992.
92. **Peltomaki T**, Effect of unilateral costochondral graft in the temporomandibular Joint on the growth of marmoset mandible J Oral Maxillofacial Surg 60:1307-1314; 2002.
93. **Perrot D.H, Umede H, Kaban L.B**, Costochondral graft construction /reconstruction of the ramus / condyle unit. Long-term follow-up. Int J. Oral Maxillofacial Surg 23:321-328, 1993.
94. **Peskin.S, Laskin P.M**, Contribution of Autogenous Condylar grafts to mandibular growth Jour of oral Surgery 20:518, 1965.
95. **Popescu & Vasiliu** treatment of temporomandibular joint ankylosis with particular reference to the interposition of full thickness auto transplant; J M F S;5;3-14;1977.

96. **Poswillo D.E**, Biological reconstruction of the Mandibular Condyle. British j oral Maxillofacial Surg 25:100, 1987.
97. **Rajagopal A**, Temporomandibular Joint Ankylosis. A report of 15 cases J Maxillofacial Surgery 11:37-47, 1983.
98. **Reid et al**, The Clavicular head of Pectoralis major musculo cutaneous free flap. British J. of Plast. Surg 39:57, 1986.
99. **Robinson M., Arnet G**, Cobalt radiation to prevent reankylosis after repeated surgical failures-Report of a case. J. Of Oral Surgery 35(10): 850-4,1997.
100. **Siemssen S.O**, Temporomandibular joint arthroplasty by transfer of the sternoclavicular joint on a muscle pedicle. British Jour of Plast Surgery 35:225-238, 1982.
101. **Siemssen S.D. Kirby B**, Immediate reconstruction of resected segment of the lower jaw using a compound flap of clavicle and sternomastoid muscle. Plast Reconst. Surg 61:724, 1976.
102. **Silagi J.C., Schow C.E**, Temporomandibular Joint Arthroplasty. Review of literature and report of a case. J. Of oral Surgery 28:920, 1970.
103. **Silver et al**, Arthroplasty of the temp9romandibular joint with use of vitallium condyle prosthesis. J. Of Oral Surgery 35:909-914, 1977.
104. **Skooge T, Johnson S.H**, The formation of articular cartilage from free perichondral grafts. Plast. Reconst. Surg 57: 1, 1976.
105. **Snyder C.C., Levine G.A., Dingman D.C**, Trial of Sternoclavicular whole joint as a graft as a substitute for the Temporomandibular Joint. Plast Reconst. Surgery 48:447, 1971.

106. **Su-Gwan. K**, Treatment of temporomandibular joint ankylosis with temporalis muscle and fascia flap. In1. J. Oral Maxillofacial. Surg 2001; 30: 189-193.
107. **Steinheuser E.W**, Treatment of Ankylosis in children. Int. Jour of Oral Surgery 2:129, 1973.
108. **Thoma K.H**, Textbook of Oral Surgery. Ed. 4 St-Louis, Cx Mosby 10 1969.
109. **Thomas B. Dodson, Robert A. Bays**, Cranial bone grafts to reconstruct the mandibular condyle in Macaca mulatta. J Oral Maxillofacial. Surgery 55:260-267, 1997.
110. **Topazian H.G.**, Comparison of gap and interpositional Arthroplasty in the treatment of ankylosis. J. of Oral Surgery 25:405, 1966.
- 111 **Verneuil**, quoted by Silagi [- Schow. Review of literature and report of case. Journal of oral surgery L.O, 920, 1970.
- 112 **Ward T G** surgery of temporomandibular joint Annals of R C S of England Vol 28; 1961; 139.
- 113 **Ware & Taylor** cartilagenous growth centre transplantation to replace mandibular condyle in monkeys.
- 114 **Ware & Brown G** Growthcentre transplantation to replace mandibular condyle. J O M S Feb. 1981.