The use of the rib grafts in head and neck reconstruction

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Abstract Background: Many grafting materials are available for reconstructing variable defects of the head and neck.
Objective: The aim is to describe the advantages and disadvantages of the rib grafts in head and neck reconstruction.
Patients and methods: The rib grafts were used to reconstruct variable deformities and/or defects in the mandible (12 patients), nose (13 patients), skull and cranial base (six patients), maxilla (five patients), trachea (three patients), and auricle (one patient).
Results: All patients showed good healing at the recipient site with successful reconstruction of the structural deformity and accepted esthetic and functional results indicating survival and take of the grafts except in one patient (2.5%) where graft necrosis occurred because of infection. Wound dehiscence and graft exposure were not reported. At the donor site, mild wound infection occurred in two patients (5%) which was controlled by conservative measures with no reports of dehiscence or pneumothorax.
Conclusion: The rib provides reliable abundant grafting materials sufficient to successfully reconstruct variable defects in the head and neck region.

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1. Introduction

Reconstruction of different kinds of defects or deformities of congenital or acquired etiology is a fundamental and frequent practice in head and neck surgery. The use of different types of autogenous grafting and alloplastic materials has minimized the resultant functional and cosmetic problems associated with such defects and deformities. Alloplasts have the following advantages: unlimited availability, lack of donor site morbidity, ease of contouring, maintenance of shape and volume over time and relative simplicity of insertion. Although they have achieved widespread success, alloplasts have potentially serious complications of infection, aggressive foreign body...
reaction, extrusion and damage to the soft tissue and skin covering. Among sources of non-vascularized autografts, the rib is unique in providing cartilage, bone, and combination of both. The use of different rib components in grafting is an established and basic modality in nasal, auricular, cranial and mandibular reconstruction. The aim of this study is to describe the advantages and disadvantages of the rib grafts in head and neck reconstruction.

2. Patients and methods

The rib grafts were used in reconstructing deformities or defects in the craniomaxillofacial skeleton and trachea in 40 consecutive patients in the departments of ENT and neurosurgery during the period from March 1999 to December 2009. They were 21 female and 19 male, with an age range of 8–61 years. According to the site needed to be reconstructed, they were categorized into patients indicated for mandibular, nasal, cranial, maxillary, tracheal, and auricular reconstruction (Tables 1 and 2).

The preoperative clinical data of concern included the etiology, duration, site, and description of the structural, functional, and esthetic consequences of the deformity or the defect. The radiologic investigations included plain chest X-ray, orthopandentogram (panorama) in patients with mandibular deformities, and CT and occasionally MRI before and after contrast administration in patients with tracheal stenosis and cranial and maxillary tumors.

Flexible fiberoptic laryngoscopy and rigid bronchoscopy were done in patients with tracheal stenosis.

2.1. Graft harvesting, set, and fixation

The right sixth rib was harvested, osseous only or chondro-osseous (costochondral), for mandibular, maxillary and cranial reconstruction. An inframammary skin incision was done down to the muscles that were split and retracted to expose the rib. The periostium was sharply incised along the anterior surface of the rib and carefully dissected in a circumferential manner from both surfaces by curved and Doyin elevators taking care not to injure the underlying pleura. The bone was sharply separated from the chondral junction and cut posteriorly with bone cutting forceps. When a costochondral graft (CCG) was desired for reconstructing the mandibular ramus, the perichondrium on the anterior surface was preserved in continuity with a small strip of periostium. If another graft was desired the fourth one was harvested.

The right ninth costal cartilage was the source of cartilage grafts used in reconstructing nasal dorsal saddling, tracheal stenosis, and auricular deformities. A subcostal skin incision was used and dissection was continued as previously described strictly in a circumferential subperichondrial fashion. The anterior perichondrium was preserved in the cases of tracheal reconstruction.

During harvesting, continuous palpation of the underlying rib is essential to avoid pleural injury. Pneumothorax was excluded by the absence of air leakage after filling the wound with saline solution while the anesthetist was applying positive pressure into the lungs. The wound was then infiltrated with 5–10 ml of 2% xylocaine and closed in layers after application of a suction drain. The rib grafts used to reconstruct the mandible (split rib, onlay whole rib, CCGs) were fixed by 0.5 mm stainless steel wire or 13 mm long titanium self tabbing mini-screws preceded by maxillomandibular fixation that was released 1–3 weeks postoperatively (except in the patient where the rib was used as an onlay graft). For nasal reconstruction, an endonasal approach consisting of a transfixion septal incision and bilateral intercartilagenous incisions was used to create the dorsal and columellar pockets. The dorsal cartilage strut was fixed to the upper lateral cartilage by a 4/0 polyglactin 910 transverse stitch on both sides. The columellar strut was fixed to the anterior nasal spine and the medial crura of the lower lateral cartilage by 4/0 polyglactin 910 stitches. In cranioplasty, the rib bone was split, contoured by bone bending forceps, and fixed by stainless steel wires to the edges of the skull defect and by 2/0 polyglactin 910 stitches to the pericranium. The split ribs were fixed by 0.5 mm stainless steel wires or to previously contoured titanium 2 mm thickness miniplates that were fixed to the remaining nasal, zygomatic and maxillary alveolar bones in mid face reconstruction. In tracheal reconstruction, the trachea was exposed, tracheostome was refashioned, the stenotic area above the tracheostome was slit opened till the lumen was reached, a silicone tracheal T tube was inserted and the rib cartilage was carved to reconstruct the anterior tracheal wall with perichondrium facing mucosal. It was fixed to the trachea using 3/0 prolene stitches. The following additive surgical procedures were done:

- Temporalis muscle flaps were used in patients with temporomandibular joint (TMJ) ankylosis (10 patients) and with maxillary defects (five patients).

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Type of graft</th>
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<tr>
<td>Mandibular defects:</td>
<td></td>
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<tr>
<td>Unilateral temporomandibular joint ankylosis</td>
<td>Unilateral costochondral graft</td>
<td>6</td>
</tr>
<tr>
<td>Bilateral temporomandibular joint ankylosis</td>
<td>Bilateral costochondral graft</td>
<td>4</td>
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<tr>
<td>Flat body</td>
<td>Onlay rib bone</td>
<td>1</td>
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<tr>
<td>Segmental post ablative defect</td>
<td>Split rib bone</td>
<td>1</td>
</tr>
<tr>
<td>Nasal dorsal saddling</td>
<td>Dorsal and columellar cartilage struts</td>
<td>9</td>
</tr>
<tr>
<td>Tracheal stenosis</td>
<td>Costal cartilage</td>
<td>3</td>
</tr>
<tr>
<td>Cauliflower auricular deformity</td>
<td>Costal cartilage</td>
<td>1</td>
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</table>
Nasal osteotomies were done in three patients with saddling and significant septal deviations were corrected in another three patients.

The pericranium was used to reconstruct the anterior cranial base with the split rib bone grafts in three patients.

Patients were followed up during a period that ranged from six months to six years.

3. Results

3.1. Patients with mandibular defects or deformities (Table 1)

All the patients with TMJ ankylosis (10 subjects) were suffering from limitation of mouth opening, chewing difficulties, multiple caries, and dental malocclusions following trauma in the form of a fall on the chin dating back to a period of 4–20 years. When such trauma was in the childhood period, the patients acquire facial deformity in the form of retrognathia with symmetric face in bilateral ankylosis and asymmetry in the form of deviation of the chin to the affected side in unilateral cases. Such patients suffer from snoring and possible sleep apnea.

In these 10 patients the CCGs were used to reconstruct the ramus after condylectomy and coronoidectomy. This was followed by restoration of mouth opening as measured by a maximal interincisal distance of more than 35 mm maintained by mouth training exercises for a period not less than 6 months. Improvement of the esthetic deformity (retrognathia and facial asymmetry) was noted in all patients especially in young patients with unilateral ankylosis in the form of correction of retrognathia and chin deviation except in a single patient (with unilateral TMJ ankylosis) because of infection of the graft. Another patient needed to trim a projecting edge of the applied CCG that was causing a prominent angle.

In another patient the use of the rib bone as an onlay graft was followed by a satisfactory esthetic result in camouflaging the post traumatic flattened right mandibular body deformity (Fig. 1).

The split rib bones were used to successfully reconstruct a segmental mandibular body defect of 5 cm length following excision of an adenocarcinoma of the submandibular gland with good healing and prevention of the post mandibulectomy esthetic deformity.

3.2. Patients with nasal dorsal saddling (Table 1)

The cause of saddling in these patients was a neglected facial trauma (10 patients) and previous submucous resection of the nasal septum (three patients). None had previous attempts of surgical correction of saddling. Preoperatively, all the patients were found to have variable degrees of broadening and saddling of the nasal dorsum, rounded nostrils and tip deformity in the form of low projection and downward rotation (Fig. 2a). Three patients suffered from nasal obstruction due to significantly deviated septum. Postoperatively all the patients reported satisfactory esthetic results (Fig. 2b). None of the grafts was extruded. Wounds healed without reported infections. Minor degree of dorsal graft wrapping was noted in a single patient.

3.3. Patients with cranial and skull base defects

The split rib bone grafts were used to primarily reconstruct defects in the frontal (Figs. 3 and 4a) and temporal bones of a size that ranges from 32 cm² to 180 cm² and in the anterior cranial base with a size of 10–40 cm² (Table 2). The ribs were completely filling the whole defect with rib to rib contact in all the cranial defects except in the patient with the interosseous meningioma where the defect consisted of both frontal bones (Fig. 4a). In all patients wound healing was reported without infection, dehiscence or graft exposure. Good esthetic result was obtained in these patients with prevention of the sinking skin flap syndrome with no reports of pulsating exophthalmos or enophthalmos. A less satisfactory result, albeit accepted by the patient, was noted in the patient with the bifrontal meningioma. CSF leaks were not reported.

3.4. Patients with maxillary defects

Together with the temporalis myofascial flaps, the split rib bone grafts fixed by plates and screws or wires were used in primary (four patients) (Fig. 4b) and secondary (one patient)
reconstruction of post maxillectomy defects. Reconstruction of the whole alveolar arch was done in two patients with pleomorphic adeoma necessitating total palatal resection. The grafts were applied according to the defects needed to be reconstructed that differ from a patient to another (Table 2). Patients were satisfied by the cosmetic result (Fig. 4c) and good chewing and speech abilities. Wound dehiscence, infection, and graft exposure did not occur. One patient (with the recurrent myxoma) suffered from persistent lower eyelid chymosis with epiphora.

3.5. Patients with tracheal stenosis: (Fig. 5)

These patients developed tracheal stenosis after prolonged endotracheal intubation for a period that ranged from 21 to 40 days. The causes of admission to the intensive care unit (ICU) were motor car accident in two patients and suicidal intake of organophosphorus material in the third patient. All of them had an already done tracheostomy. They presented after one month to two years following ICU discharge. Resection

Figure 1  The patient with flattening of the right mandibular body: (a) preoperative view, (b) postoperative view after the use of an onlay rib bone graft.

Figure 2  A patient with nasal dorsal saddling: (a) preoperative view, (b) postoperative view after the use of dorsal and columellar costal cartilage struts.
anastomosis was done in one of them with recurrence of stenosis one year after the operation. Preoperative endoscopic and radiologic evaluation revealed the presence of tracheal narrowing without subglottic affection. Vocal cords were freely mobile. Operatively, the length of stenotic segment was found to be 4–6 cm. Postoperatively, the silicone tracheal T tube was removed after 4–6 months. All the patients did not develop post extubation stridor during a follow up period not less than 16 months. Two of them had postoperative harsh voice.

The single patient with the auricular cauliflower deformity presented five years following perichondritis of the auricle. He did not attend regular follow up and did not complete further adjustment procedures (Fig. 6).

As regarding the donor site, control of the postoperative pain was achieved in most patients with 75 mg diclofenac intramuscular injection once or twice daily for 3–5 days followed by the oral intake of 50 mg diclofenac three times daily till the end of the week. Minor wound infection was reported in two patients (5%) which was controlled without sequels. Wound dehiscence or pneumothorax was not reported.

4. Discussion

The surgeons' preference for different grafting procedures in reconstructing many head and neck defects and deformities of variable etiology depends on many factors such as the age of the patient, nature of the defects; with their consequent structural, functional, and cosmetic effects; available resources, and personal experience and training. Despite significant advances in biomedical engineering, the perfect graft material has to be attained. The rib grafts are among the sources of free non-vascularised bone and cartilage grafting materials that have versatility in craniomaxillofacial reconstruction.

In mandibular defects and deformities, the modality of reconstruction chosen includes the use of simple bone graft with or without a myocutaneous flap, pedicled osteomucocuta-neous flap and the complex vascularised free flap.12,13 Vascularised free flaps are now the state of the art for reconstructing mandibular defects especially of composite nature as they are reliable, resistant to radiation and infection, provide soft tissue and bone components and allow the placement of dental implants.14 Despite the great progress in the transfer of microsurgically anastomosed free flaps, such techniques are limited by their high financial cost, prolonged surgical time, need for two teams with increased technical expertise, significant donor site morbidity and the inability of use in young patients.15 As alternatives to vascularised free flaps, autologous bone grafts in the form of free rib and iliac bone grafts have been widely used for reconstructing large mandibular defects due to their resistance to infection and the large volume of bone they provide with possible dental implantation.16 The CCG have been widely used for replacement of mandibular condyle in various clinical situations and recently, it is still the best option in the growing children and adults.17–19
In this study 14 CCGs were used to reconstruct the mandibular ramus after condylectomy in 10 patients with TMJ ankylosis (four bilateral and six unilateral). In such cases the graft was proved to have the advantages of restoring the shortened posterior face height, correcting the facial disfigurement in the form of symmetric and non-symmetric retrognathia, preventing recurrence of the ankylosis, and providing a potential for growth in children. Graft loss because of infection seems to be the major disadvantage of the use of CCG. The perioperative administration of systemic antibiotics and the temporary storage of the graft in an antibiotic/saline solution are considered to limit the incidence of such infection. This complication was reported in a single out of 10 patients with relapse of retrognathia that is planned to be corrected by mandibular advancement using distraction osteogenesis. Although there are reports of CCG overgrowth, such phenomenon was not reported in this study possibly because of the limited number of patients. Based on a histological study, the asymmetric masticatory movement and the uneven loading of the reconstructed condyle were suggested to interpret overgrowth of CCG.

In the remaining two patients, where the significant bone defect or deformity requires large volume of bone, the preferable grafting material would be either the rib or the ilium as alternatives to the vascularized bone transfer. Although the iliac bone graft is preferred by some authors in reconstructing segmental mandibular defects because of providing bone of favorable thickness in accepting implants and restoring alveolar crest, it was not used in the patient with the postablative defect because of her refusal. In the patient with flattening of the mandibular body, the rib was a more favorable choice because of its shape similarity, suitable thickness and pliability in contouring than the iliac bone. Still the problem of resorption is limiting the use of autologous bone grafting. Recently, the addition of bone inducing factors as Recombinant Bone Morphogenetic Proteins as an osteoinductive material to the conventional osteoconductive graft scaffolds, was tried with successful results in achieving predictable reconstruction and preventing graft resorption. Another point of importance in preventing graft resorption, is stabilization of the grafted bone by maxillomandibular fixation and proper rigid fixation of the graft to the recipient site allowing bone to bone contact.

Several grafting and alloplastic materials are described in correction and augmentation of the nasal saddling deformity that results from reduced structural support secondary to surgery, trauma or infection. Although alloplasts have multiple advantages, many experts believe that they should not be the first choice particularly in rhinoplastic procedures as they have increased risk of extrusion because of three reasons; first, the nose being of prominent location is commonly traumatized with an increased risk of trauma-associated displacement and extrusion, second, the thin skin soft tissue envelope providing little cushioning for the alloplast, and third, mobility of the

Figure 4 (a) Operative view showing the split rib grafts reconstructing the bifrontal defect in the patient with the interosseous meningioma; (b) operative view of the split rib graft reconstructing the zygomaticomaxillary and pterygomaxillary buttresses; (c) postoperative view of a patient after maxillary reconstruction with an accepted esthetic appearance; (d) postoperative 3DCT scan of the patient in (c) showing the survived bone grafts.
lower third of the nose. There are five potential donor sites for autogenous dorsal onlay grafts in rhinoplasty: septal, auricular, and rib cartilages and iliac and calvarial bones. In this study, the costal cartilage was used with a successful outcome in correcting the structural, esthetic and functional components of the saddling deformity with the advantages of providing sufficient cartilage material with a reliable skeletal support, flexibility, easy shaping, carving, fixation, and sculpturing, and a stable consistent result along six years of follow up in some patients with no extrusion, infection, or resorption. In these patients the amount of septal cartilage was insufficient to compensate for the structural defect because of either previous removal or concomitant deformity adding to the advantages of costal cartilage. Among different literature the rib cartilage stands as the primary choice for dorsal augmentation when: the septal or auricular cartilages are insufficient, a large amount of cartilage material is needed for correcting severe saddling, or there is poor preoperative recipient site conditions caused by previous surgeries. In addition to donor site morbidity, graft wrapping is a frequently mentioned drawback for the use of costal cartilage in rhinoplasty. Such disadvantage, that was reported with a minimal degree in a single out of 13 patients in this study, can be minimized by the central placement of stabilizing K-wire in the graft and performing cross sectional carving. Apart from appropriate graft fixation, certain surgical technical considerations are controversial in augmentation rhinoplasty e.g. whether the open or closed approach is selected, or whether to fix the dorsal to the columellar strut or not. These issues are out of the scope of this study.
Several therapeutic procedures are described for managing tracheal stenosis including observation, tracheostomy, balloon dilatation, laser and a variety of open surgical procedures. Laser vaporization proved disappointing results in circumferential scarring of segments more than 1 cm. Various stents to enlarge the stenotic part of the trachea have been used, but the indications for their use are not clear. The choice of the open surgical procedures depends on the length of the stenotic segment. Segmental tracheal resection with an end to end anastomosis became the best method but only for short stenotic segment without involvement of the upper part of the subglottis. For patients with medium length stenosis, the slide tracheoplasty has become a preferred method that doubles the circumference of the trachea. In long segment tracheal stenosis, tracheal reconstruction with a variety of grafting materials has been the surgical treatment of choice. The costal cartilage has been useful in this study as a grafting material in tracheoplasty as preferred by many studies. The abundance of cartilage material sufficient to reconstruct long tracheal segment, stability, strength, absence of resorption and ease of shaping and fixation resemble the advantages of the costal cartilage in tracheoplasty. In general tracheoplasty is considered successful if the patient is decannulated with an adequate comfortable breathing without the need for reintubation over a long period of follow up. The three patients suffering from postintubation tracheal stenosis presented in this study were successfully decannulated and practiced a normal physical activity without respiratory difficulty along a period of follow up not less than 16 months.

Although used in a single patient, the use of rib graft is an established modality in auricular reconstruction. Because of the complexity of the auricular structure, the tedious process of harvesting rib cartilage, the difficulty of achieving an esthetically satisfactory result, the multiplicity of the surgical stages till an end result is obtained with the possible need for revision and skin expansion, some prefer the use of other reconstructive methods as the porous polyethylene implants or osseointegrated prosthesis. From the result shown in the single patient of this study, advantages of the costal cartilage grafts in auricular reconstruction could not be stated with the need of more patients compliant for follow up.

The post operative pain and the threat of pneumothorax present the major rib graft donor site morbidities. The former was reduced by performing muscle “split” rather than “cut” during flap harvest, infiltration of the wound with xylocaine at the end of the procedure, and the use of post operative analgesia. Pneumothorax was prevented by strict preservation of the posterior peristeum.

In this study, the rib showed the potential to supply the reconstructive surgeon with cartilage and/or bone of abundant amount that provide suitable grafting materials in many head and neck defects and/or deformities that are easily shaped, bent, sculptured, and fixed with bone of good osteoconductive property and a fair degree of resorption resistance. The ample blood supply of the head and neck region which is assumed to inhibit bone graft resorption may explain the high rate of rib graft take in this study with a single case of graft loss (2.5%) because of infection. The good osteoconductivity of the split rib graft refers to its high content of progenitor cells which will initiate the bone formation at a short span of time. However, stating particular advantages of the rib grafts in each defect

The surgical repair of large skull defects is still a challenge for the craniofacial surgeon. In addition to the cosmetic considerations, these defects when large leave a significant area of the brain unprotected and are known to be associated with chronic headache, developmental delay in young children, and the syndrome termed sinking-skin-flap syndrome. Alloplasts and autologous grafts are the options for cranioplasty. Among alloplasts titanium has been used extensively in the last 20 years due to its malleability, lightweight, and bioinert and non-magnetic properties. Others include polymethylmethacrylate, hydroxyapatite, and more recently bioceramics. Because of the increased rate of infection, extrusion, and intense foreign body reaction associated with the use of alloplasts, cranioplasty using autologous split rib and calvarium has been universally accepted as the preferred option in adults and pediatric patients. In this study the split rib was preferred than the split calvarium although the latter is easier to harvest during cranioplasty without the need for an extracranial operation. Split calvarium is harder, stiffer, and difficult to shape and bend than the rib graft. Moreover, it is limited by the individually variable skull thickness and cannot provide large amount of bone to reconstruct big cranial defects. Follow up of the patients in this study proved the ability of the rib graft to not only prevent problems of cranial defects but also successfully reconstruct skull base defects avoiding their drastic complications. The use of split rib grafts placed across each other arranged in a fashion mimicking the baseball catcher’s mask is a recently introduced novel surgical solution to solve the problem of huge defects with minimal grafting material.

Different techniques are readily available to reconstruct partial maxillectomy defects with a considerable success. A prosthetic obturator is a simple solution for a small defect after inferior maxillectomy. A clasp retained obturator can later be substituted by a more stable one based on bone anchored implants. In edentulous patients with poor prosthetic stability or in large inferior maxillectomy defects, the temporalis muscle flap is an easy, simple, and reliable method of reconstruction. However, reconstruction of extensive post maxillectomy defects is among the most difficult surgical tasks because of their complex nature involving soft tissue and bone components, the resultant esthetic grotesque deformity and the associated functional disability in eating, and speaking. With the development of vascularized composite tissue transfer using microsurgical techniques, reconstruction of such maxillary defects has been achieved to a high level of functional and esthetic results. Limitations to such techniques were previously mentioned. As an alternative to the vascularised composite flaps the split rib grafts fixed to previously contoured miniplates supported by the temporalis myofascial flap were used in reconstructing partial as well as total maxillary defects in the patients of the present study whether primary or secondary. Following this technique, considerably accepted esthetic and functional results were obtained with a clinical and radiological evidence of a reliable skeletal support without noticeable resorption for at least two years (Fig. 4c and d). The important role of buttress reconstruction in the surgical management of maxillary skeletal defects has been addressed. The split rib grafts were fixed by interosseous wires or miniplates in a manner affording restoration of the pterygomaxillary and/or the zygomaticomaxillary buttresses which is an important approach to obtain the most effective reconstruction of complex maxillectomy defects.
The use of the rib grafts in head and neck reconstruction requires further studies including large number of patients among each category of defects with a longer follow up.

5. Conclusions

- The rib provides reliable abundant grafting materials sufficient to successfully reconstruct variable defects in the head and neck region.
- The best use of the rib cartilage is in dorsal augmentation of the nasal saddling deformity and in tracheoplasty.
- The costochondral graft is the modality of choice in reconstructing the mandibular ramus.
- The split rib bones are reliable grafts in cranioplasty.
- The rib bone can be an alternative to composite vascularised flaps in maxillary and mandibular reconstruction.

References