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RECONSTRUCTION OF THE MANDIBLE IN PATIENTS WITH MALIGNANT TUMORS OF OROFARYNGEAL AREA

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Summary. This article provides literature overview devoted to the problem of reconstruction of mandible in patients with malignant tumors of oropharyngeal area. Microsurgery achievements, development of new synthetic implants and tissue engineering technologies have significantly increased possibility of replacement of segmental mandibular defects and improved functional and aesthetic results of plastic surgery. Modern methods of mandibular reconstruction have been reviewed and their strengths and weaknesses discussed.

Keywords: mandible, defects, reconstruction.

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Locally common cancer of the oral cavity and oropharynx, extending to the mandible, primary malignant neoplasm and osteoradionecrosis of the mandible are the main indications for its segmental resection. Since the mandible forms the contour of the lower face, correct occlusal relationship, supports airways, actively participates in the functions of mastication, swallowing and speech, loss of the mandibular continuity leads to significant functional and cosmetic disorders [1,2]. Thereby the aim of surgery is not only a radical removal of a tumor, but also to restore the continuity and anatomical shape of the mandible. Regardless of their cause, most mandibular defects are combined with mucosa defects (cheeks, lips, gums, floor of the mouth, tongue, oropharynx) and soft tissues (muscles, skin) that also require plastic surgery [1, 3, 4].

Classification of segmental defects of the mandible. Several classifications were developed to evaluate mandibular defects. D. David et al in 1988 identified six types of segmental mandibular defects according to their localization (Fig. 1). D. Jewer et al in 1989 developed a classification that takes into account the complexity of the mandible reconstruction (Fig. 2). This classification highlighted: «C» - central defects of the mandible from canine to canine; «L» - lateral defects extending from the midline to the mandibular condyle, not including the latest, "H" – hemi-mandibular defects, including L-defects and the mandibular condyle. Thus, there are the following defect variations of the mandible - C, L, H, LC, HC, LHC, HCL, HH [5]. In

1993, J. Boyd et al modified this classification taking into account related defects of the tongue «t», mucosa «m» and skin «s» [6].

Mandibular reconstruction techniques. Nowadays for plastic reconstruction of segmental mandibular defects used:

- nonvascularized bone grafts;
- myocutaneous-osseous flaps on the vascular pedicle;
- vascularized bone grafts;
- reconstructive plate (RP) in combination with myocutaneous flap;
- synthetic implants;
- tissue engineering technologies.

Nonvascularized bone grafts. Nonvascularized bone grafts are used for reconstruction of small plastic (□ 6 cm) L-defects of the mandible. Nonvascularized bone graft transplantation is not used for patients who underwent neoadjuvant radiotherapy and have associated mucosal or soft tissue defects. [2, 7]. Crest ilium, fragments of the fibula, ribs and sternum are used for mandibular reconstruction. Among the complications in most cases observed resorption of the graft transplanted without bone regenerate formation and purulence of the graft, which leads to necrosis and rejection. M. Rana et al [8] identified the degree of resorption of various bone grafts during a one-year observation period (Table 1). The frequency of complications according to different authors ranges from 7 to 31%. Many studies indicate a high risk of osteoradionekrosis of transplanted bone after adjuvant radiation therapy [7, 8, 9, 10, 11, 12].

Pedicled myocutaneous-osseous flaps. In 1980, S. Ariyan and C. Cuono reported using myocutaneous flap of pectoralis major muscle with a fragment of the fifth rib for oromandibular reconstructions [13]. The same year, W. Panje presented his experience of using myocutaneous-osseous trapezius flap in 27 patients, and 87% of the transplant cases were successful [14]. Besides the study describes some methods of segmental mandibular defects reconstruction using sternocleidomastoid muscle flap with clavicle and latissimus dorsi with a rib. However, the above mentioned grafts have not been widely used, because they have the following disadvantages: complexity of harvesting, limited arc rotation of the graft, insufficient blood supply to the transplanted bone, limited mobility of a myocutaneous part of the graft relative to the bone; insufficient bone thickness for dental implantation [1, 3].

Vascularized bone grafts. The use of vascularized bone grafts has considerably improved treatment outcomes for patients with significant mandibular and soft tissue defects, particularly after ongoing radiation therapy. Today the most commonly used transplants are:

- fibula;
- iliac crest;
- scapula;
- radial forearm.

These flaps are used as osseous, osteocutaneous and myocutaneous-osseous autografts. Factors that determine the choice of vascularized bone autografts and their characteristics are presented in Table 2 [15, 16].

Fibula flap. Fibula flap (FF) is considered to be the best choice in reconstruction of mandibular segmental defects [1, 2, 15, 16]. Bicortical bone can be a cut of 26-28 cm in length, which makes it possible to reconstruct most mandibular defects, including C-defects. Peroneal artery with its comitant veins is the vascular pedicle of FF. Dual blood supply to the fibula can safely carry the required number of osteotomies for the most accurate reconstruction of mandibular shape [17, 18, 19]. F. Wei et al analyzed blood circulation of lateral surface of the tibia and showed that fasciocutaneous branches that go through the posterior interfascialis membrane provide adequate blood supply to the cutaneous paddle of the flap. It allowed to use FF as an osteocutaneous graft [20]. Reliable cutaneous paddle of FF can be raised in the lower third of the tibia [21]. Additionally, the flexor hallucis longus [22] and soleus muscle [23] can be added to FF for reconstruction of soft tissue defects. It is worth mentioning the possibility of simultaneous work of two teams of surgeons as it is not necessary to change the position of the patient during FF harvesting [16, 24]. The important point for further rehabilitation of patients is that the transplanted fibula is suitable for dental implantation [25]. The results of mandibular reconstruction using FF are presented in Table 3.

The role of preoperative angiography is still to be determined. K. Blackwell strongly recommends to perform angiography for patients with peripheral vascular diseases, as well as previous injuries and operations on lower limbs [26]. The need for routine angiography before FF harvesting is still debated [27, 28].

Complications in the donor site after FF harvesting are the following: pain, ankle joint instability, gait instability [29].

Iliac flap. Iliac flap (IF) is a myocutaneous-osseous autograft which includes iliac crest and internal oblique muscle of abdomen. Monocortical bone can be taken up to 12 cm long. Vascular pedicle of IF is deep circumflex iliac vessels. The main advantage of IF is sufficient height and size of the bone suitable for dental implantation. Iliac crest has a natural curvature that allows to reconstruct L-defects of the mandible without osteotomy [30, 31].

Disadvantages of IF are following: myocutaneous graft component is sufficiently massive, non-mobile and often has insufficient blood supply; reconstruction of C-defects of the mandible using this flap is not possible, because of osteotomies leading to blood supply disorders of the bone; insufficient length of vascular pedicle (up to 6 cm) [15, 32].

Complications in the donor site after IF harvesting: pain, postoperative hernia formation, gait disorder and femoral neoropathy [33].

Scapular flap. Scapular flap (SF) may be harvested in the form of myocutaneous-osseous autograft with one or more fasciocutaneous paddles. When reconstructing significant concomitant soft tissue defects latissimus dorsi is included in the composition of SF [34, 35]. Monocortical bone may be harvested up to 14 cm long. Vascular pedicle of SF is deep circumflex scapular vessels. The advantages of SF is the possibility to use fasciocutaneous paddles which are mobile enough, relatively long vascular pedicle, minimal vessel atherosclerosis, minor disorders in the donor site [1, 34, 36, 37].

Disadvantages of SF are the following: the impossibility of simultaneous work of two teams of surgeons that significantly extends the time of surgery, insufficient segmental blood supply to the lateral scapular border allows for only one osteotomy between curcumflex scapular artery and angle branch of the thoracodorsal artery [38]; the thickness of the scapular bone, usually, insufficient for dental implantation [39].

Radial forearm flap. Radial forearm flap (RFF) can be raised in the form of myocutaneous-osseous autograft. Monocortical bone can be harvested up to 12 cm long. The main advantage of RFF is thin, flexible and having reliable blood supply fasciocutaneous paddle that is ideal for reconstruction of soft tissues of the oral cavity and oropharynx [1, 40]. Utilising of RFF for reconstruction of segmental defects of the mandible has the following disadvantages: performing of osteotomies and dental implantation is impossible; high risk of radius fracture in donor site; the need to immobilize the forearm [41, 42]. Considering the advantages and disadvantages of RFF C. Avery recommends using it for small L-defects of the mandible, combined with significant soft tissue defects [43].

Reconstructive plate in combination with myocutaneous flaps. Independently reconstructive plate (RP) can be used to reconstruct segmental defects of the mandible if no significant concomitant soft tissue defects are present. B. Miles et al note that major complications when utilising the RP is their exposure through the mucous membranes of oral cavity or through the skin out, plate fracture and bridging screws come loose [44]. T. Ettl et al reported experience of treatment of 334 patients with cancer of the oral cavity, who underwent segmental resection of the mandible with reconstruction of RP defects. In 136 patients were observed infectious complications and plate exposure, 7 patients had plate fracture. Thus, complications were observed in 42% of cases. Among the factors that contributed to the development of complications the authors note smoking, preoperative radiotherapy and reconstruction of C-defects of the mandible [45]. D. Coletti et al analyzing the case study of utilising RP in 110 patients reported 36% of complications [46]. P. Maurer et al reported 37% of complications [47]. Early RP exposure is associated with the development of infectious complications and soft tissue necrosis, later exposure is the result of friction between the plate and soft tissues [48]. According to various studies RP fracture ranges from 3 to 16% [48, 49, 50]. This is the evidence that RP does not replace the bone so fracture may occur due to metal fatigue as a result of the lack of bone regeneration [50]. Looseness of bridging screws is associated with the pressure of RP on cortical plate of the mandible, which leads to its resorption and looseness of the screws [51].

To reconstruct segmental defects of the mandible which are combined with mucosal or soft tissue defects reconstructive plates are used in combination with myocutaneous flap. Most commonly used myocutaneous flap of pectoralis major muscle [48, 52], free myocutaneous flap of latissimus dorsi or rectus abdominus muscle are less common [53]. Myocutaneous flap does not only cover the defect of soft tissues, but also prevents reconstructive plate exposure because well-vascularized graft improves tissue nutrition in the recipient zone, thereby increasing the probability of uncomplicated postoperative period [54]. In addition, S. Yokoo et al believe that covering the plate by muscle tissue also prevents its exposure [55]. Frequency and characteristics of complications, according to various studies in reconstruction of oromandibular defects of the mandible are shown in Table 4 [48, 52, 53, 56].

RP in combination with myocutaneous flap is utilised for patients who have contraindications to microsurgical transplantation of bone autografts and for patients at high risk of tumor recurrence [52-54]. Some surgeons give preference to primary reconstruction of segmental defects of the mandible by RP, and further, in the absence of tumor recurrence, conduct delayed bone graft transfer using different methods [50].

Synthetic implants. Nowadays transplantation of vascularized bone autografts is the gold standard of reconstructive-restorative treatment of patients with segmental defects of the mandible [1, 2]. However, besides the advantages, the use of free bone grafting has significant disadvantages:

• complexity and cost of the technique;

• duration of surgery;

• inability to fully restore anatomical shape of the mandible and to perform the arthroplasty;

• complexity of autograft shape modeling;

• functional disorders in the donor site.

Therefore the resurch on development of new synthetic materials for mandibular reconstruction is continuing nowadays [1]. Should be noted carbon/carbon implants “Углекон-М” and “CarBulat” [57, 58]. Implants contain almost pure carbon - carbon fiber, which is connected by pyrocarbon. The material is biocompatible and provides a combination of high mechanical strength with a low modulus of elasticity. The use of carbon/carbon implants for reconstruction of segmental defects of the mandible has the following advantages:

• relative simplicity and low cost of the technique;

• possibility to fully restore anatomical shape of the mandible and quality stomatological rehabilitation;

• no need for additional surgeries to harvest the bone autografts [57, 59, 60].

G. Szabo et al analyzed the long-term results of mandibular reconstruction using carbon/carbon implants «CarBulat» in 16 patients. In 5 of 16 patients was observed intraoral implant exposure. Plate fracture, bridging screws looseness and inflammation around the carbon/carbon implants were not observed. The authors report good functional and cosmetic outcome of the reconstruction [58]. The research has also shown that the structure and morphology of the implant in the human body has not changed in 8 years after the implantation [61].

Tissue engineering technologies. In 1971, M. Urist introduced the term "osteoinduction." He identified osteoinduction as the ability to induce ectopic osteogenesis, ie bone formation in soft tissue. He proved that the bone morphogenetic proteins (BMPs) have this effect. The development of genetic engineering allowed to synthesize recombinant molecules of different types of BMPs groups, particularly - rhBMP-2, rhOP-1, utilisation of which allowed to obtain the standard process of osteogenesis in experimental and clinical settings [62, 63, 64].

P. Warnke et al for mandibular reconstruction used titanium mesh, which was filled with blocks of inorganic bone and infiltrated with rhOP-1 and bone marrow cells. This structure was implanted under the latissimus dorsi. After 7 weeks prefabricated graft together with latissimus dorsi was transferred to the defect site of the mandible, revascularized and fixed by titanium screws. Postoperative osteoradioscintigraphy showed viability of the bone graft [65].

A. Herford et presented the practice of reconstruction of large defects of the mandible using rhBMP-2 on collagen carrier and titanium mesh in 14 patients. In all cases achieved complete bone formation and high levels of functional rehabilitation. Radiologic indications of a newly formed bone appeared in 5-6 months after the reconstruction [65]. The authors believe that this technique is an alternative to different variations of bone autografting [66, 67].

In most known studies for mandibular reconstruction rhBMP-2 were used. C. Clokie and G. Sandor for reconstruction of segmental defects of the mandible utilised rhBMP-7 [68]. A collagen sponge was used as a carrier of the BMPs, which slowly releases them over a period of osteogenesis. Unfortunately, collagen sponge can be easily deformed under the pressure of the soft tissues, therefore titanium mesh should be used to protect the place in which bone is formed. Development of new carriers with better structural stability will solve the mentioned problem. Adding fillers - demineralized bone matrix and autogenous bone is recommended for improving the osteoconductive effect [69, 70]. The study overview that examined the use of the BMPs to reconstruct segmental defects of the mandible is shown in Table 5 [64, 65, 67, 68, 70]. There are treatment results of 37 patients with segmental defects of the mandible published to date. In 32 (86.5%) patients reconstruction was successful, in 5 (13.5%) – attaining of adequate bone formation failed. Based on the small number of observations it is not possible to conclude that BMPs can replace bone autografts. Future clinical studies will determine the true effectiveness of this technique [70].

CONCLUSIONS

Vascularized bone graft transplantation was introduced in the last decade and has significantly improved the results of reconstructive treatment of segmental defects of the mandible. Application of nonvascularized bone, pedicled myocutaneous-osseous flaps and reconstructive plates in combination with myocutaneous flaps is optional in some clinical situations. Development of new synthetic implants and implementation of tissue engineering technologies will increase the range of techniques for reconstruction of mandibular defects in the nearest future.

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