

# REVIEWS

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## Osteoplasty of the Alveolar Cleft Defect

### Plastyka kostna wyrostka zębodołowego w wadzie rozszczepowej

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#### Abstract

Cleft of lip, alveolar process and palate is the most common congenital defect affecting the face. It occurs at the time of early embryogenesis as a result of disturbed differentiation of the primordial cell layer and is associated with genetic and environmental factors. The most severe type of the defect is complete cleft of the lip, alveolar process and palate, unilateral or bilateral, which is accompanied by impaired breathing, sucking, swallowing, chewing, hearing and speaking. The treatment consists in the surgical reconnection (reconstruction) of the cleft anatomical structures and their formation to gain proper appearance, occlusal conditions and speech. The part of the surgical treatment is reconstruction of alveolar bone by means of autogenic spongy bone grafting (osteoplasty). The surgery performed at the stage of mixed dentition following an orthodontic treatment is a recognized standard management modality. Its effects provide stabilization of the dental arches fixed in the orthodontic treatment, possibility of growth of permanent teeth adjoining the cleft as well as separation of the nasal and oral cavities. The grafted bone becomes a platform for the collapsed base of the ala nasi and facilitates restoration of teeth loss. In the graft healing process the volume of the regenerated bone tissue is lower than the graft volume. Methods to augment the healed bone volume are being searched for, as this factor decides substantially on successful outcome of the surgery (**Adv Clin Exp Med 2012, 21, 2, 255–262**).

**Key words:** cleft of the lip, alveolar process and/or palate, alveolar osteoplasty, bone grafting.

#### Streszczenie

Rozszczep wargi i podniebienia jest najczęściej występującą anomalią rozwojową twarzoczaszki. Do jej powstania dochodzi w okresie wczesnej embriogenezy w wyniku zaburzeń różnicowania listków zarodkowych, a przyczyną wystąpienia są czynniki genetyczne i środowiskowe. Najbardziej nasiloną postacią wady jest całkowity rozszczep wargi, wyrostka zębodołowego i podniebienia, jedno- lub obustronny, któremu towarzyszą zaburzenia czynności oddychania, ssania, połykania, żucia, słuchu i mowy. Leczenie polega na chirurgicznym zespoleniu (rekonstrukcji) dotkniętych wadą struktur anatomicznych oraz ich formowaniu w celu uzyskania prawidłowego wyglądu, warunków zgrzyzowych i mowy. Jednym z elementów leczenia chirurgicznego jest rekonstrukcja wyrostka zębodołowego szczęki z użyciem autogennego przeszczepu kości gąbczastej (osteoplastyka). Operacja wykonywana w okresie uzębienia mieszanego (osteoplastyka wtórna) po przeprowadzonym leczeniu ortodontycznym jest uznana za standardową metodę postępowania. Jej rezultatem jest stabilizacja łuków zębowych ustalonych przez ortodontę, możliwość wzrostu zębów stałych sąsiadujących ze szczeliną rozszczepu oraz oddzielenie jamy nosowej od ustnej. Przeszczepiona kość jest platformą dla zapadniętej podstawy skrzydła nosa oraz ułatwia uzupełnienie ubytków zębowych. W procesie wgajania przeszczepionej kości gąbczastej objętość zregenerowanej tkanki kostnej jest mniejsza od objętości przeszczepu. Poszukuje się sposobów, aby objętość wgojonej kości była jak największa, ponieważ ten właśnie czynnik w zasadniczym stopniu decyduje o powodzeniu przeprowadzonej operacji (**Adv Clin Exp Med 2012, 21, 2, 255–262**).

**Słowa kluczowe:** rozszczep wargi, wyrostka zębodołowego i podniebienia, rekonstrukcja wyrostka zębodołowego, przeszczep kości.

Cleft of the lip, alveolar process and palate belongs to the most common congenital deformities affecting the facial region. Its incidence varies

depending on population. The highest prevalence rates concern native Americans and Indians, where 3 to 4 children are born with cleft defect per 1,000

births. In Caucasians, the defect occurs less often and affects 1 to 2 newborns per 1,000 births. It is more common in males, with the prevalence ratio of 3:2 [1].

The etiology of the deformity is believed to be multifactorial, i.e. the incidence of the defect is associated with a cumulative effect of numerous genes and environmental factors [2–4]. The causative role of genetic factors is confirmable in about 20% of cases, and the exogenous factors, such as nutritional deficits, hormonal and metabolic disturbances, immunological, infectious, chemical and drug effects, in only about 10% of cases [5].

Restoration of the anatomical continuity of the cleft structures and their normal functioning is a complex and multistage procedure and it requires the cooperation of a surgeon, orthodontist, phoniatrist, otolaryngologist, speech therapist, pediatrician and dentist. The treatment starts after birth, continues throughout the whole developmental period, and often is prolonged into adulthood. Final evaluation of the outcomes of therapy is possible after termination of the child's development. The so-called therapeutic protocols still differ, which results in a multitude of surgical modalities and therapeutic programs: Randall [6], Millard [7], Skoog [8], Langenbeck [9], Veau [10], Wardill [11], Schweckendieck [12], Kobus [13–16], Malek and Psaume [17], Malek [18] and Perco [19].

In Poland there are 600 to 900 new cleft cases a year. Full severity defects – unilateral or bilateral complete clefts of the lip, alveolar process and palate associated with disturbances in the respiratory function and impairment of sucking, swallowing, chewing, hearing and speech constitute 40% of them [1].

## Morphology of the Deformity

In unilateral complete cleft of the lip and alveolar process the cleft gap involves both structures, reaching the incisor foramen. It divides the maxilla and lip into two uneven parts. The bigger part, including the philtrum and the intermaxillary bone is moved upwards, anteriorly and towards the contralateral side. The less developed part which is on the side of the cleft is moved backwards. The alveolar process on the ridges of the gap is lowered. The defect is associated with disturbed odontogenesis. The change in the direction of tooth eruption from vertical to slanting or horizontal affects mostly the second incisor. Sometimes the teeth buds are lacking or double. The incisors and canines which are in abnormal position are usually less developed (Fig. 1).

In bilateral complete cleft of the lip, the medial part, the prolabium, is shortened in the vertical dimension and deprived of the muscle. The vestibule is shallow. The cleft fissures divide the maxilla into three parts: two lateral and one medial. The medial part is often formed by the hypoplastic intermaxillary bone which is joined to the vomer only by means of the vomer-premaxillary suture, usually mobile and protruding anteriorly. The lateral parts are moved backwards and upwards.

The vestibulo-nasal fistula constitutes a pathological junction of the oral vestibule with the nasal cavity.

Closure of the parts of the cleft alveolar bone by means of autogenic spongy bone grafting is referred to as alveolar osteoplasty. The bone is most often harvested from the iliac crest. A successful outcome of the surgery depends largely on the volume of the healed bone.

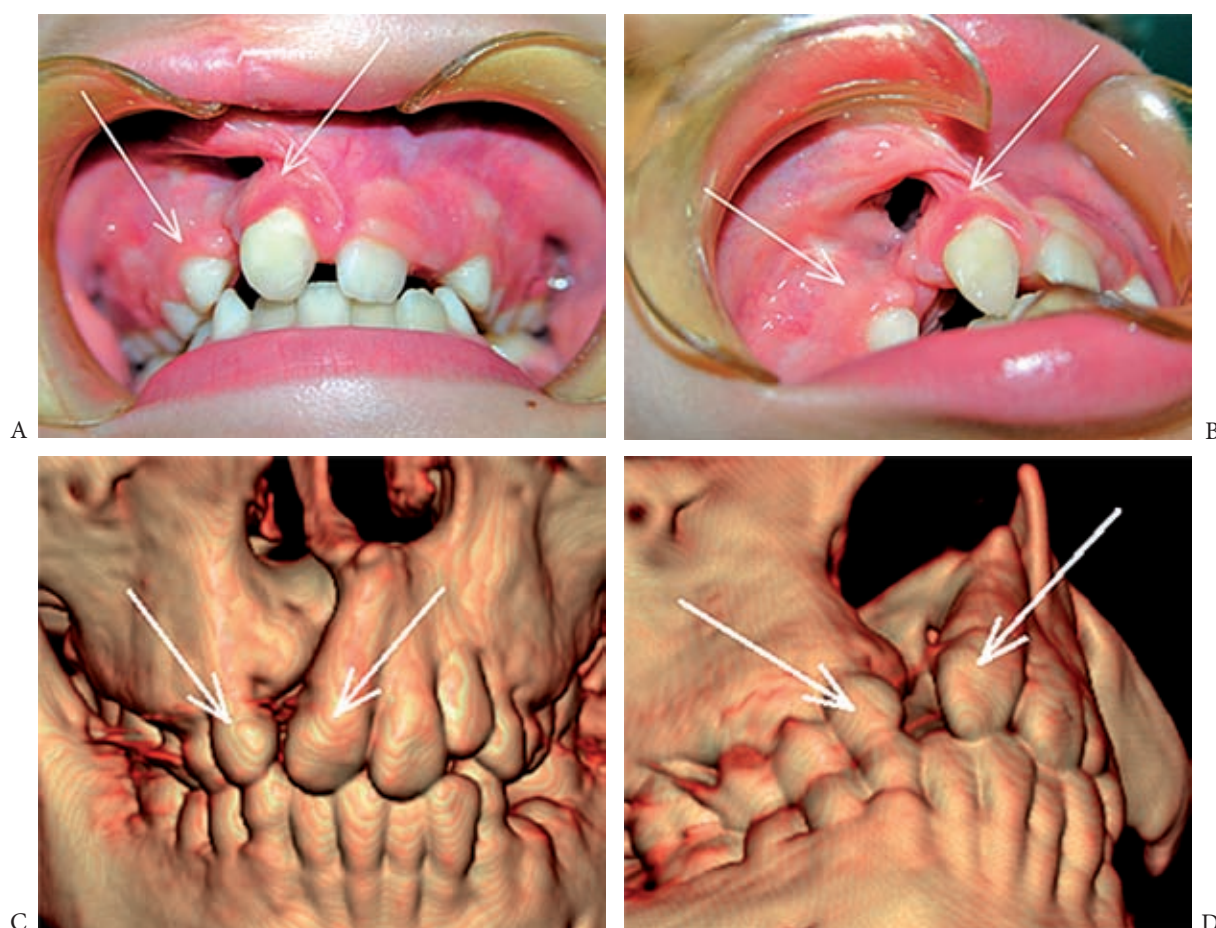
## Alveolar Osteoplasty

Depending on the stage of maxillary development at the time of repair surgery, the following modalities are used:

- primary osteoplasty performed prior to the development of deciduous teeth, most commonly associated with suturing the cleft lip, at the age of up to 2 years;
- early osteoplasty (deciduous dentition period, ages 2–5);
- secondary osteoplasty (mixed dentition period during exchange of the deciduous teeth to permanent dentition, ages 7–13);
- late osteoplasty (permanent dentition).

The first reports on alveolar osteoplasty come from 1955 [20]. Schmid, Nordin and Johansson, who filled the gap of the alveolar cleft with autogenic tibial bone grafts (primary osteoplasty) in the procedure of primary lip closure performed at the age of 6 months. A similar therapeutic modality was also recommended by Schrudde and Stellmach [21]. In 1962, Brauer, Cronin and Reaves described a detailed treatment plan for unilateral clefts. Several weeks after reconstruction of the lip the authors carried out intense orthodontic treatment, the aim of which was to form the alveolar process arch prior to placement of a bone graft into the cleft gap [22].

In the '60s, Skoog proposed associating the lip surgery with simultaneous closure of the alveolar cleft with mucoperiosteal flaps without filling the cleft with the graft – boneless bone grafting. The method made it possible to avoid the inconveniences associated with bone graft harvesting. The bone formation occurred alongside the periosteal flap thanks to which the gap underwent partial fill-



**Fig. 1.** Intraoral picture (A, B) of patient D.G., aged 8, with complete cleft of the lip, alveolar process and palate. The arrows mark ridges of the alveolar cleft. Corresponding VRT (C, D) picture presents the image of the bone gap

**Ryc. 1.** Zdjęcia wewnątrzustne (A, B) pacjenta D.G., lat 8, z całkowitym rozszczepem wargi, wyrostka zębodołowego i podniebienia. Strzałkami zaznaczono brzozy szczeliny wzrostka zębodołowego. Odpowiadające im zdjęcia trójwymiarowe VRT (C, D) przedstawiają obraz szczeliny kostnej

ing with bone tissue in about 60% of patients [23]. However, studies carried out by Rintal revealed that 72% of patients required secondary osteoplasty [24]. The method was also abandoned in view of observed deformities and developmental defects of the maxilla.

Taking into account the negative opinions by Friede and Johanson, who observed developmental deformities of the maxilla in their patients, simultaneous bone grafting and lip closure was considered harmful and abandoned by the majority of authors [25].

The idea of filling the clefts with bone grafts revived after a publication by Boyne and Sands [26] and Scandinavian authors Abyholm and Bergland [27]. Based on several-decade clinical observations, it was acknowledged that the operations should be performed at a later age. According to their opinion, secondary osteoplasty between the ages 8–11 does not lead to maxillary hypotrophy as the growth of the medial part of the face is almost completed at this stage. Growth of the maxilla in

the transverse and saggital planes is almost totally completed by the age of 8, just like the growth of the alveolar process in the vertical plane, which is stimulated by permanent tooth eruption. Thus secondary alveolar osteoplasty was introduced to cleft therapy programs together with orthodontic treatment prior to and after the surgery. Some clinical centers introduce protocols of early osteoplasty at the age of 2 [28].

The healed graft stabilizes segments of the cleft alveolar process and preserves the occlusal conditions achieved in orthodontic treatment. It also constitutes a bone platform for the collapsed base of the ala nasi.

Reconstruction of the alveolar process enables restoration of dental defects by means of implants or prosthodontic treatment and prepares for possible orthognathic surgery on the maxilla.

According to Optiz, [29] the decision on bone grafting should be taken on the basis of radiological assessment of the developmental stage of the root of a lateral incisor adjoining to the cleft gap.



The stage when half of the root has been formed is an optimal time for osteoplasty. The growth of a tooth and its eruption throughout the graft stimulates the vertical growth of the alveolar process. In lateral incisor aplasia, the decision about the timing of the operation is based on the developmental stage of the canine root. This surgery is advocated at the stage when the root reaches from 1/2 to 2/3 of its length. Orthodontic therapy carried out prior to the surgery should align the upper incisors, broaden the dental arch and correct posterior crossbite.

## Cleft Surgical Technique

The alveolar process fissure is filled with autogenic spongy bone harvested from the iliac crest, or, less commonly, from the cranial bone. In the past, other alternatives were used such as compact bone from the rib, tibia, or the chin, which are presently abandoned, as are preserved heterogenic and xenogenic bone grafts.

The surgery is carried out under general endotracheal anesthesia. In the surgical protocol applied by authors' clinic, after deflection of the compact bone lamellae, spongy bone chips are harvested from the iliac crest with a bone curette and soaked with PRP (platelet-rich plasma) obtained from the patient's blood prior to the surgery. The prepared bone is grafted to the recipient site.

Mucoperiosteal flaps are created by incising the anterior surface of the alveolar process, alongside the cleft ridge (Fig. 2B). The flaps are then elevated from the bone, rotated 180° and sutured, and the internal layer is formed (Fig. 2C). The cleft fissure is filled with the bone graft (Fig. 2D and E) and covered with a broadly mobilized mucous flap from the oral vestibule and the upper lip (Fig. 2F). Also, another method is presented for the incision of mucous flaps used for covering of the graft-filled cleft fissure, moved from the lateral sides of the alveolar process [30].

In patients with a well-developed maxilla, the bone graft is also placed in the region of the piriform aperture on the side of the cleft in order to provide support and elevation for the ala nasi base. In patients with associated maxillary hypotrophy, the graft is also placed in the region of the piriform aperture on the intact side and on the anterior surface of the alveolar process.

For the first two days after surgery, the patients treated in authors' ward are nourished parenterally. In subsequent days they are given a soft diet which is continued for 4 weeks.

The outcome of the surgery is considered satisfactory when a sufficient volume of normally remodeled bone tissue is achieved. In the process

of spongy bone graft healing, the volume of the regenerated bone is lower than the graft volume. Sometimes, when the volume is too low, the surgery has to be repeated. Knowledge of factors associated with the bone graft healing process should lead to inhibition of its resorption and makes it possible to limit the amount of harvested bone. These factors were identified in studies concerning graft healing [31].

The most intense regeneration occurs in cases of fresh autogenic spongy bone grafts due to their open, porous structure, facilitating penetration of the budding blood vessels, as well as to more potent osteoconductive and osteoinductive properties and the presence of live cells.

Remodeling of an allogenic graft takes longer than integration of an autogenic graft, which is associated with the immunological barrier which does not induce graft rejection, but delays its incorporation.

The process of remodeling is most prolonged in cases of an allogenic or a xenogenic biostatic graft, which may be additionally deprived of osteoinductive properties as a result of bone morphogenetic protein (BMP) destruction in the processes of conservation and sterilization.

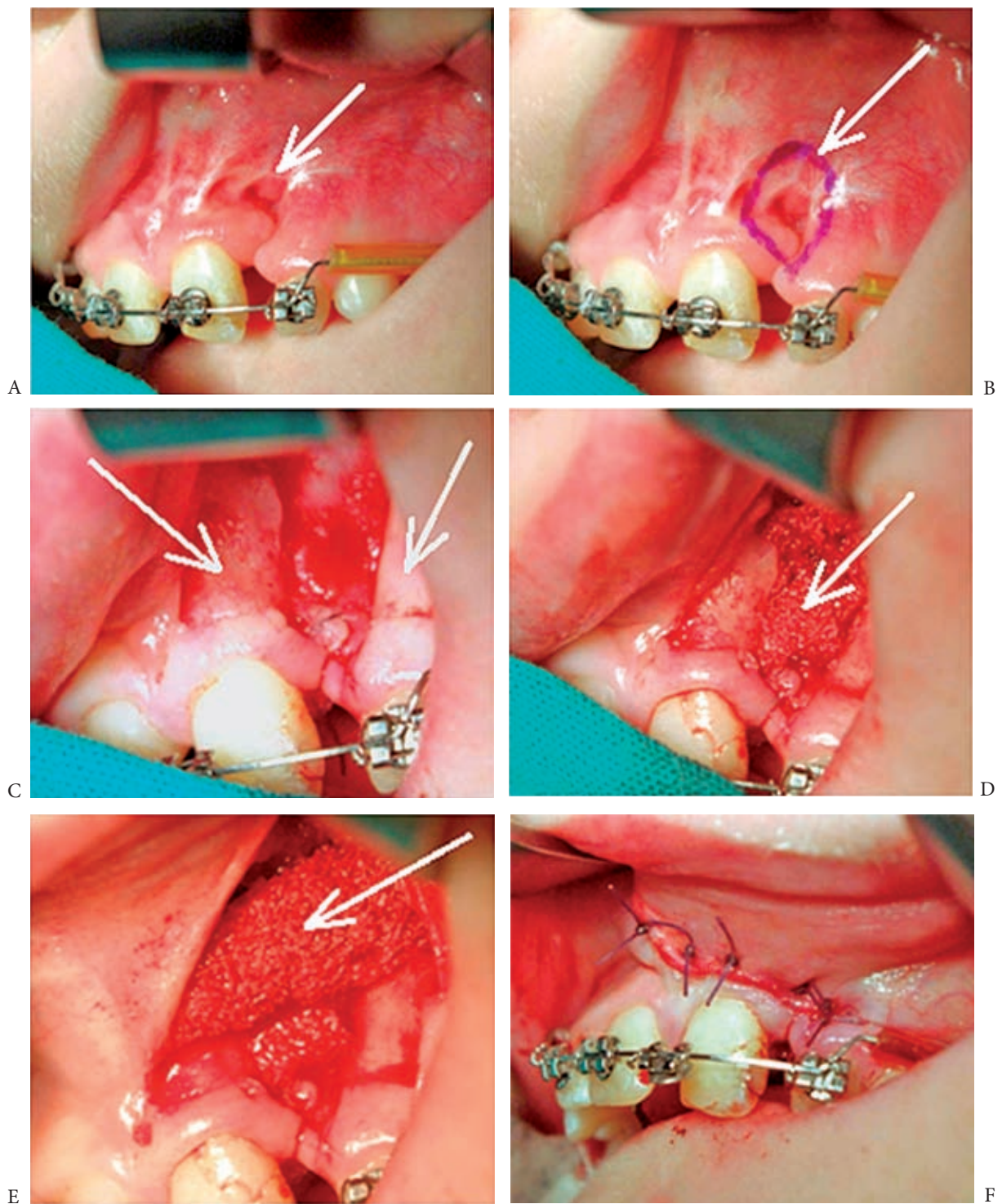
Immediate contact of the graft with the underlying bone and the periosteum enables penetration of the graft with blood vessels and osteogenic cells from the host bone and periosteum. Lack of adhesion precludes bone remodeling and evokes the same consequences as failure to maintain graft stabilization.

Stability of the graft in relation to the adjoining bone fragments is essential for normal angiogenesis. Mobility occurring between the adhesion surfaces of the graft and bone in the recipient site hampers the process and causes resorption of the graft, its infection and formation of a sequester.

Loading of the bone is the most important factor affecting its remodeling. A graft implanted into a loaded site reveals lower loss of volume and enhanced increase of density. Placement of a graft in an unloaded site, e.g. to fill contour deficits, results in an increased resorption [32].

Disturbances in blood supply and low O<sub>2</sub> partial pressure in the recipient site may lead to the formation of cartilage tissue followed by its resorption and substitution by osseous tissue, which delays bone regeneration or prevents bone formation [33].

The process of tissue regeneration is more rapid and more effective in a young organism due to the high dynamics of cell differentiation and maturation. In an adolescent, the repair cell to bone-building cell ratio is 1:100,000, while at the age of 80 it is 1:1,200,000 [31].



**Fig. 2.** Subsequent stages of the alveolar osteoplasty in a 11-year-old patient with cleft of the left side. A – gap in the alveolar process, B – marked incision line of the mucoperiosteal flaps surrounding the alveolar process gap, C – internal layer formed by split and reversed mucoperiosteal flaps. The arrows mark bone fissure ridges. D – the cleft gap filled with autogenic spongy bone chips, E – spongy bone chips placed on the interior surface of the alveolar process, F – cleft gap filled with graft and covered with mucosal flap

**Ryc. 2.** Etapy ostoplastyki wyrostka zębodołowego u 11-letniego pacjenta z rozszczepem lewostronnym: A) szczelina w wyrostku zębodołowym; B) zaznaczona markerem linia nacięcia płatów śluzówkowo okostnowych wokół szczeliny w wyrostku zębodołowym; C) warstwa wewnętrzna odtworzona poprzez odwarstwienie i odwrócone płaty śluzówkowo okostnowe. Strzałkami zaznaczono brzoży szczeliny kostnej; D) szczelina rozszczepu wypełniona wiórami autogennej kości gąbczastej; E) wióry kości gąbczastej aponowane na przednią powierzchnię wyrostka zębodołowego; F) szczelina kostna wypełniona przeszczepem i pokryta płatem śluzówkowym

Diseases that might have a negative effect on bone regeneration (hormonal and nutritional disturbances, and inborn diseases such as Turner syndrome and homocystinuria) impede or prevent healing of the graft.

Genetic predispositions determine the individual volume and density of the bone mass.

Studies carried out in the past seemed to confirm the belief that transfer of a bone formed on a cartilage base, e.g. from the iliac crest, to an unloaded site such as the maxillary alveolar process, leads to an enhanced resorption and decreased volume of the bone. Such a loss was not observed when a membranous bone was used, e.g. cranial bones. Presently reported findings covering many years of observation do not confirm this belief. The site of spongy bone graft harvesting does not seem to affect the degree of its resorption in the recipient site [34].

Consolidation of the graft into a homogenous structure with the host bone takes place on the contact surface between both tissues.

The "creeping substitution" described by Axhausen [35] is initiated by blood vessel penetration of the graft from the side of the adjacent bone and its periosteum. Until they are formed, the processes of osteolysis and resorption of the graft intercellular substance predominate in the acid and anoxic environment in the recipient site, initially with the participation of macrophages and monocytes and later with osteoclasts. Resorption of the graft, without subsequent reconstruction, continues until blood supply is created. The revascularized graft is characterized by lowered oxygen gradient and increased pH, which causes the predominating activity of phagocytes to decrease and is followed by intense activation of the osteogenic cells into osteoblasts. From this stage the processes of degradation and formation of new bone tissue are balanced. The graft undergoes remodeling into a new bone – regeneration. In unfavorable conditions, when revascularization is delayed for various reasons, the lysis and graft resorption processes are also prolonged, leading to a decrease in the graft volume and eventually to its complete resorption. Lukash investigated the relationship between graft angiogenesis and the degree of its resorption in poorly vascularized tissues submitted to irradiation, and in non-irradiated tissues with normal blood supply. The author demonstrated that bone grafts implanted into irradiated tissues underwent late or no revascularization and the loss of their volume due to resorption was much more significant than in the case of grafts placed in a non-irradiated site. In sites where graft revascularization failed to occur, the graft underwent complete resorption or elimination [33].

According to many authors dealing with implantology, osteoplasty with the use of autogenic bone alone is an improper modality due to significant resorption of the bone.

In order to create better osteoconductive conditions, bone grafting was associated with the use of Bio-Oss biomaterial. The biological apatite prepared from bovine bone with identical morphology, porosity and chemical structure as human bone, serves as scaffolding for newly formed bone tissue.

Resorption of the xenograft occurs less rapidly than of the natural graft matrix, thanks to which the volume of the regenerated bone is maintained at a constant level. Moreover, the crystalline structure of the matrix provides good stabilization of the graft and creates favorable conditions for its revascularization.

Bovine bioapatite in combination with platelet-rich plasma and autogenic bone grafts, which is a source of osteocytes and osteoblasts, has found wide application in implantology [36]. However, it is not clear whether the use of biomaterials is completely safe in children with ongoing odontogenesis and what effect this could have on eruption of permanent teeth neighboring the cleft. Available literature does not contain any reports on the use of other preparations than the patient's own bone in the secondary osteoplasty of the alveolar process.

Bioresorbable collagen barrier membranes (Bio Guide, Ossix), covering the bone graft or the bioapatite, are used in guided bone regeneration. Their role is to block the inflow of connective tissue cells and epithelial cells to the bone gap. The method has been well documented in numerous clinical and experimental studies on animals. Used mainly in implantology, resorbable barrier membranes increase the volume and density of the regenerated bone [37].

Also, bone morphogenetic proteins (BMPs) have recently become a common modality used to augment bone regeneration. However, their short half-life causing rapid elimination from the site of administration as well as the high costs of acquisition constitute significant limitations to their use in everyday clinical practice. Another solution aimed at enhancement of bone graft healing is based on the use of recombinant growth factors: rhTGF- $\beta$ , rhIGF and rhPDGF. However, studies are advancing at the preclinical stage, which precludes their application. The knowledge of growth factors present in thrombocytes is sufficient to use them in medical practice [31]. The use of autogenic platelet-rich plasma (PRP) as a source of growth factors proposed by Marx et al. and Lynch in 1999, is recommended in the enhancement of bone regeneration processes [38, 39]. Released platelet



granular mediators act in a definite sequence and affect the processes of proliferation and differentiation on a feedback basis. It was shown that the regeneration process is enhanced in autogenic and allogenic bone grafts soaked with platelet-rich plasma in comparison to grafts which were not PRP-soaked. The findings of clinical, radiological and histological studies carried out after soaking the graft with platelet-rich plasma confirmed increased density of the regenerated bone tissue. The platelets are isolated from the patient's blood collected immediately before the osteoplasty and condensed by means of thrombopheresis. Their natural biological environment includes plasma fibrin, which undergoes consolidation in the process of clotting, as well as the adhesion molecules adhesin and integrin, which control the adhesion of cells. Autologic platelet mass is commonly used in centers dealing with tissue regeneration, especially of the bone tissue.

Studies on the use of isolated stem cells in bone reconstruction demonstrated that they may

transform into osteoblasts and osteoclasts, stimulating osteogenesis and osteolysis. Induction of pluripotent cell differentiation into bone cell lines outside the organism, without the effect of regulatory mechanisms, is impracticable at the present level of knowledge.

Also, the most effective method enabling reconstruction of the alveolar process without bone grafting is still being sought. The method of maxillary bone transport distraction proposed by Mitsugi may become an alternative for bone grafting to the alveolar cleft [40].

Many centers are advancing studies on local and general growth factors which, based on more and more perfect biomaterials, have already found application in enhancing bone regeneration processes. However this intense research does not cover the needs of alveolar osteoplasty in cleft defects, but more commercially desirable and rapidly progressing implantology. Nevertheless, the findings of this research will undoubtedly affect the therapy of cleft patients.

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