KOŠTANA TRANSPLANTACIJA U ORTOPEDSKOJ HIRURGIJI

PREGLEDNI RAD — REVIEW ARTICLE

BONE TRANSPLANTATION IN ORTHOPAEDIC SURGERY

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SAŽETAK

Osteoni su osnovne jedinice koštanog tkiva. Četiri tipa koštanih ćelija su odgovorna za izgradnju koštanog matriksa, njegovo održavanje i remodelaciju kosti. To su osteoprogenitorske ćelije, osteoblasti, osteociti i osteoklasti. Glavna uloga kosti je u izgradnji skeleta koji pruža potporu, omogućava održavanje stalnog telesnog oblika i kretanje, što se ustvari postiže složenim sistemom poluga na koje deluju mišićne sile u tačkama pripojišta.

Nastanak preloma dovodi do procesa zapaljenja, zarastanja, te remodelovanja koji može vratiti povređenu kost u njeno prvobitno stanje. U današnje vreme sve češće se suočavamo sa defektima različite veličine i etiologije, koji povećavaju potrebu za usavšavanjem koštane transplantacije. Ova procedura podrazumeva hiruršku tehniku kojom se postavlja nova kost ili odgovarajuća zamena na mesto između ili oko prelomljenih fragmenata ili u predelu defekta kako bi se potpomoglo zarastanje kosti.

Koštana transplantacija je moguća jer koštano tkivo, za razliku od većine drugih, ima sposobnost da se u potpunosti regeneriše ukoliko mu se obezbede adekvatni uslovi i prostor u koji će prorasti. Osnovni biološki mehanizmi koji opravdavaju i objašnjavaju princip funkcionisanja i upotrebe koštane transplantacije su osteokondukcija, osteoindukcija i osteogeneza, ali se takođe govori i o pojmu osteopromocije.

Autogeni transplantati predstavljaju „zlatni standard", ali usled povećane potrebe danas se prevashodno koriste alotransplantati iz koštane banke, dok se sve više teži razvoju sintetskih zamena, čija bi aplikacija bila moguća i minimalno invazivnim tehnikama.

Ključne reči: koštani graft, koštani defekti, osteokondukcija, osteoindukcija

ABSTRACT

Osteons are the basic units of bone tissue. Four types of bone cells are responsible for building the bone matrix, maintaining it and remodeling the bone. Those are osteoprogenitor cells, osteoblasts, osteocytes, and osteoclasts. The main role of the bone is in the construction of the skeleton that provides support and enables the maintenance of a constant body shape and movement, which is achieved by a complex system of levers influenced by muscle forces at the attachment points.

A fracture leads to the process of inflammation, healing and, remodeling that can restore the injured bone to its original state. Nowadays, we are more and more often faced with defects of different size and etiology, which increase the need for bone transplantation. This procedure involves a surgical technique that places a new bone or a suitable substitute between or around the fractured fragments or in the area of the defect to promote bone healing.

Bone transplantation is possible because bone tissue, unlike most other tissues, has the ability to fully regenerate if it is provided with adequate conditions and the space in which it will grow. The basic biological mechanisms that justify and explain the principle and utilization of bone grafting are osteoconduction, osteoinduction, and osteogenesis, but the idea of osteopromotion is also worth mentioning.

Autografts represent the "gold standard", but due to an increased need allografts from bone banks are primarily used nowadays, while the development of synthetic replacements is the primary research interest, especially the development of the form which could be applied with the use of minimally invasive techniques.

Keywords: bone graft, bone defects, osteoconduction, osteoinduction

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UVOD

Savremena ortopedija sve češće se susreće sa problemom zbrinjavanja koštanih defekata različitih veličina i etiologije. Oni nastaju na više načina, te se viđaju kao defekti kod brojnih tumorima sličnih lezija, posle resekcija delova kosti zbog benignih ili malignih tumora i kao posledica traumatskog gubitka kosti, odnosno opsežnih resekcija kod post-traumatskih osteomijelitisa. Osnovni cilj u lečenju ovih stanja jeste očuvanje ekstremiteta, te uspostavljanje najvišeg mogućeg stepena funkcionalnosti [1].

U literaturi su opisane različite metode nadoknade koštanih defekata. Jedna od najduže poznatih i najviše primenjivanih je metoda koštane transplatacije [2]. Koštano tkivo je, zbog svojih karakterisitika, veoma pogodno za transplantaciju, te ne čudi podatak da je ovo tkivo drugo najčešće transplantirano u SAD [3]. Sa razvojem disciplina koje povećavaju bezbednost i uspešnost lečenja (pre svega prevencije transmisivnih bolesti i unapređenja tkivne podudarnosti) ova metoda posebno dobija na značaju, naročito imajući u vidu da alternativne metode (metoda koštanog transporta po Ilizarovu, aloplastične procedure) imaju svoja ograničenja, pre svega nemogućnost da se primene na svim segmentima skeleta, kao i nepodesnost za lečenje mlađih pacijenata [4].

Koštana transplatacija podrazumeva hiruršku proceduru kojom se postavlja nova kost ili drugi materijal na mesto između ili oko fragmenata polomljene kosti ili u predelu defekta sa ciljem da se potpomogne njeno zarastanje, odnosno prerastanje. Koštanim transplantatom se zamenjuje nedostajuća kost upotrebom materijala iz tela samog pacijenta, prirodnim kadaveričnim ili alotransplantatom, ali i veštačkom, sintetskom ili prirodnom zamenom za kost [5]. Koristi se u lečenju preloma koji su kompleksni, predstavljaju značajan rizik za život pacijenta ili preloma koji ne uspevaju pravilno da zarastu [6]. Takođe, svoju primenu nalazi i kod nadoknade defekata kostiju nastalih usled kongenitalnih deformacija, traumatskih povreda ili resekcija delova kosti zbog raznih vrsta tumora ili koštanih infekcija. Važno je napomenuti da su metode koštane transplantacije, osim kod ortopedskih hirurga, u upotrebi i u neurohirurgiji, stomatologiji, oralnoj i maksilofacijalnoj hirurgiji [7].

BIOLOGIJA KOŠTANOG TKIVA

Koštano tkivo je specijalizovano vezivno tkivo, koje se sastoji iz ćelija i vanćelijskog matriksa. Izrazitu čvrstinu i tvrdoću koštanom tkivu daje specifična struktura vanćelijskog matriksa koji sadrži visok procenat minerala. Matriks je primarno sastavljen od proteina kolagena, koji čini organski deo, i neorganskog dela

INTRODUCTION

Modern orthopedics is more and more frequently faced with the problem of treating bone defects of varying size and etiology. These defects occur in several ways and can be found as defects in various tumor-like lesions, after resection of parts of bone due to benign or malignant tumors, and as a consequence of traumatic bone loss, i.e., extensive resections in post-traumatic osteomyelitis. The main goal in the treatment of these conditions is to preserve extremities and to establish the highest possible level of functionality [1].

Different methods of treating bone defects have been presented in literature, bone transplantation being one of the best-known and most frequently applied ones [2]. Due to its characteristics, bone tissue is very suitable for transplantation, so the fact that this tissue is the second most frequently transplanted in the USA comes as no surprise [3]. With the development of disciplines that increase the safety and success of treatment (primarily the prevention of communicable diseases and the improvement of tissue compatibility), this method becomes particularly important, especially if we know that alternative methods (the bone transport technique using the Ilizarov method, alloplasty) have their limitations, such as not being applicable to all segments of the skeleton and not being adequate for treating younger patients [4].

Bone transplantation is a surgical procedure which involves placing a new bone or other material between or around the fragments of the broken bone or in the area of the defect with the aim of supporting its healing or regeneration. A missing bone is replaced by a bone graft using material from the very patient's body or an allograft, but also an artificial, synthetic or natural bone substitute [5]. It is used in treating fractures which are complex, pose a significant risk to the patient's life or have failed to heal properly [6]. It is also used with the aim of compensating for bone defects caused by congenital deformities, traumatic injuries, or resection of parts of bone due to various types of tumor or bone infections. It is important to mention that apart from orthopedic surgery, bone transplantation methods are used in neurosurgery, dentistry, and oral and maxillofacial surgery [7].

THE BIOLOGY OF BONE TISSUE

Bone tissue is a specialized connective tissue consisted of cells and extracellular matrix. A specific structure of the extracellular matrix, which contains a high percentage of minerals, provides bone tissue with exquisite firmness and hardness. The matrix is primarily composed of collagen, which forms its organic part, and the inorganic part made of crystals similar to hydroxysačinjenog od kristala sličnih hidroksiapatitu, koji pored kalcijuma i fosfata sadrži i depozite karbonata, natrijum citrata i magnezijuma [8,9]. Glavna uloga kosti je u izgradnji skeleta koji pruža potporu, omogućava održavanje stalnog telesnog oblika i kretanje, jer je skelet ustvari složeni sistem poluga na koji deluju mišićne sile u tačkama pripojišta [7,9,10].

Četiri tipa koštanih ćelija se nalaze unutar i oko ovog matriksa. Zajedno, ova četiri tipa ćelija su odgovorna za izgradnju koštanog matriksa, njegovo održavanje i remodelovanje kosti ukoliko je potrebno. Četiri tipa ćelija su: (1) osteoprogenitorske ćelije koje oblažu koštane površine i imaju sposobnost diferencijacije u osteoblaste; (2) osteoblasti koji stvaraju koštani matriks; (3) osteociti, zrele koštane ćelije okružene koštanim tkivom, koje učestvuju u signalnim putevima koštane homeostaze; i (4) osteoklasti, ćelije koje resorbuju kost i uklanjaju koštano tkivo [7,10-13].

KOŠTANA TRANSPLANTACIJA I BIOLOŠKI MEHANIZMI

Koštana transplantacija je moguća jer koštano tkivo, za razliku od većine drugih tkiva, ima sposobnost da se u potpunosti regeneriše ukoliko mu se obezbedi prostor u koji će prorasti. Kako izvorna kost raste, ona će vremenom u potpunosti zameniti transplantirani materijal, rezultirajući potpuno integrisanim delom nove kosti. Osnovni biološki mehanizmi koji opravdavaju i objašnjavaju princip funkcionisanja i upotrebe koštane transplantacije su osteokondukcija, osteoindukcija i osteogeneza, ali se takođe, govori i o pojmu osteopromocije.

Osteokondukcija je sposobnost koštanog grafta da služi kao potporna struktura za prorastanje krvnih sudova i nove kosti koja potiče od matične loze kosti [14]. Osteoblasti sa ivica defekta na koji se stavlja transplantat koriste taj materijal kao osnovu na koju će se širiti i stvarati novu kost. Osnovni uslov neophodan za koštani transplantat je da poseduje osobinu osteokonduktivnosti [3,15,16].

Osteoindukcija uključuje stimulaciju osteoprogenitornih ćelija da se diferenciraju u osteoblaste koji zatim otpočinju formiranje nove kosti. Najčešće izučavani osteoinduktivni ćelijski medijatori su koštani morfogenetički proteini (BMPs). Koštani transplantat koji je kako osteokonduktivan tako i osteoinduktivan neće služiti samo kao potpora za već postojeće osteoblaste, već će pokrenuti i formiranje novih osteoblasta, teoretski dovodeći do brže integracije grafta [3,15,16].

Osteopromocija podrazumeva povećanje osteoinduktivnosti, bez posedovanja konkretnih osteoinduktivnih osobina. Na primer, pojedini derivati matriksa dovode do povećane osteoinduktivne aktivnosti demi-

apatite which, in addition to calcium and phosphate, also contains deposits of carbonate, sodium citrate and magnesium [8,9]. The main role of the bone is in the construction of the skeleton that provides support, and enables the maintenance of a constant body shape and movement, which is achieved by a complex system of levers influenced by muscle forces at the attachment points [7,9,10].

There are four types of bone cells situated inside and around this matrix. These four types are together responsible for building the bone matrix, maintaining it, and remodeling bone if necessary. The four types of cells are the following: (1) osteoprogenitor cells that line bone surfaces and have the ability of differentiating into osteoblasts; (2) osteoblasts that make up the bone matrix; (3) osteocytes, mature bone cells surrounded by bone tissue, which participate in signal pathways of bone homeostasis; and (4) osteoclasts, cells that degrade bone and remove bone tissue [7,10-13].

BONE TRANSPLANTATION AND BIOLOGICAL MECHANISMS

Bone transplantation is possible because bone tissue, unlike most other tissues, is capable of regenerating completely if it is provided with the space to grow into. As the original bone grows, it will eventually completely replace the transplanted material resulting in a fully integrated piece of new bone. The basic biological principles that justify and explain the principle of functioning and the use of bone transplantation are osteoconduction, osteoinduction, and osteogenesis, but osteopromotion is also worth discussing.

Osteoconduction is the ability of a bone graft to serve as a scaffold for the ingrowth of blood vessels and the new bone originating from stem cells [14]. Osteoblasts from the edges of the defect where the graft is placed use the material as the basis onto which it will spread creating a new bone. The basic condition a bone graft needs to have is to possess the characteristic of osteoconductivity [3,15,16].

Osteoinduction involves stimulating osteoprogenitory cells to differentiate into osteoblasts which then initiate the formation of a new bone. The most frequently examined osteoinductive cell mediators are bone morphogenetic proteins (BMPs). Bone graft which is both osteoconductive and osteoinductive will not only serve as a scaffold for the existing osteoblasts, but it will also initiate the formation of new osteoblasts, theoretically leading to a faster integration of the graft [3,15,16].

Osteopromotion implies an increase in osteoinductivity without possessing specific osteoinductive characteristics. For example, certain matrix derivatives neralizovanih smrznutih suvih koštanih alograftova, ali neće stimulisati de novo koštani rast [3,15,16].

Osteogeneza je sposobnost celularnih elemenata unutar grafta koji prežive transplantaciju da stvaraju novu kost. Do nje dolazi kada vitalni osteoblasti koji potiču iz koštanog transplantata doprinose formiranju nove kosti zajedno sa koštanim rastom nastalim putem druga dva mehanizma [3,15,16].

IZBOR GRAFTA

Kortikalni koštani transplantati se pre svega primenjuju radi strukturne podrške, dok se spongiozni transplantati koriste u cilju postizanja osteogeneze [5]. Strukturalna podrška i osteogeneza takođe mogu biti kombinovane, što predstavlja jednu od glavnih prednosti korišćenja koštanih transplantata. Ipak, mora se reći da su ova dva faktora varijabilna u zavisnosti od stukture kosti [17].

Većina ćelijskih elemenata transplantata (posebno kortikalnih) izumire i biva postupno zamenjena prerastanjem, gde graft suštinski predstavlja samo potpornu strukturu za formiranje nove kosti. Kod tvrde kortikalne kosti, ovaj proces zamene se odvija značajno sporije nego kod spongioznih transplantata. Iako spongiozna kost poseduje veću moć osteogeneze, nije dovoljno čvrsta da pruži efikasnu strukturalnu podršku. U situaciji kada hirurg mora da odabere graft ili kombinaciju transplantata on uvek na umu mora imati ove dve fundamentalne razlike u strukturi kosti. Kada dođe do sjedinjavanja grafta sa recipijentnom kosti i kada postane dovoljno čvrst da dozvoli neometanu upotrebu tog dela tela, dolazi do remodelacije koštane strukture u skladu sa funkcionalnim zahtevima [14].

Upotreba koštanih transplantata je široka, te se oni mogu upotrebljavati (1) u cilju popunjavanja koštane šupljine i defekata uzrokovanih različitim patološkim procesima, u prvom redu cista, benignih i malignih tumora, (2) da se premoste zglobovi i obezbedi artrodeza, (3) da se premoste veliki defekti i uspostavi kontinuitet dugih kostiju, (4) da se obezbede koštani blokovi kako bi se ograničila amplituda pokreta u zglobovima, (5) da se postigne zarastanje kod pseudoartroza, (6) da se pospeši zarastanje i popune defekti kod odloženog zarastanja, lošeg zarastanja, svežih fraktura ili osteotomije [14,17,18].

Autologna ili autogena koštana transplantacija je ona kod koje su donor i primalac transplantata ista osoba. Deo kosti se može uzeti sa neesencijalnih kostiju, kao na primer sa krila ilijačne kosti, fibule, tibije ili, što se u oralnoj i maksilofacijalnoj hirurgijiј češće primenjuje, sa mandibularne simfize ili koronoidnog procesusa mandibule [3,18,19].

lead to increased osteoinductive activity of demineralized freeze-dried bone allografts, but they will not stimulate de novo bone growth [3,15,16].

Osteogenesis is the ability of cellular elements within a graft which survived the transplantation to form a new bone. It occurs when vital osteoblasts derived from the bone graft contribute to the formation of new bone along with bone growth produced by other two mechanisms [3,15,16].

THE CHOICE OF GRAFT

Cortical bone grafts are primarily used for structural support, whereas cancellous grafts are used for the purpose of osteogenesis [5]. Structural support and osteogenesis can be combined as well, which is one of the main advantages of using bone grafts. However, it must be mentioned that these two factors are variable depending on the bone structure [17].

Most of the cellular elements of grafts (especially the cortical ones) are dying out and are gradually replaced by overgrowth where the graft essentially represents a scaffolding structure for the formation of new bone. In case of tough cortical bone, this replacement process is significantly slower than in cancellous grafts. Although cancellous bone possesses a greater power of osteogenesis, it is not tough enough to provide efficient structural support. In the situation when the surgeon has to choose a graft or a combination of grafts, they must always keep in mind these two fundamental differences in bone structure. When the graft unites with the recipient bone and when it gets strong enough to allow unhindered use of that part of the body, remodeling of bone structure occurs in accordance with functional requirements [14].

The use of bone grafts is wide and they can be used (1) to fill bone cavities and defects caused by various pathological processes, such as cysts, benign and malignant tumors in the first place, (2) to bridge joints and provide arthrodesis, (3) to bridge large defects and provide the continuity of long bones, (4) to provide bone blocks for limiting the range of motion of joints, (5) to achieve healing in pseudoarthrosis, (6) to promote healing and fill the defect areas in delayed healing, impaired healing, fresh fractures, or osteotomy [14,17,18].

In autologous or autogenous bone transplantation the donor and the transplant recipient are the same person. A part of bone can be taken from nonessential bones, such as the wing of ilium, the fibula, the tibia, or from the mandibular symphysis or the mandibular coronoid process, which is more often done in the field of oral and maxillofacial surgery [3,18,19].

VASKULARIZACIJA GRAFTA

Svaka kost zahteva snabdevanje krvlju na mestu transplantacije. U zavisnosti od mesta transplantacije i veličine grafta dodatna vaskularizacija može biti potrebna. Važna je distinkcija između nevaskularizovanih koštanih graftova, koji se kao slobodni delovi kosti, bez pripadajuće vaskualrizacije, prenose na donorsko mesto, i vaskularizovanih koštanih elemenata, koji se na recipijentno mesto prenose povezani sa krvnim sudovima. Vaskularizovani koštani graftovi mogu biti slobodni, kada se zajedno sa koštanim elementom učini i ekstrakcija pripadajućeg dela periosta i odgovarajućeg krvnog suda, te se na recipijentnom mestu učini vaskualrna anestomoza pripadajućeg krvnog suda [20–22]. Kod vezanog vaskularizovanog koštanog grafta sprovodi se transpozicija koštanog elementa koji ostaje vezan za svoju neurovaskularnu peteljku koja nastavlja da ga ishranjuje na recipijentnom mestu [14]. Vezani koštani transplantati jedini imaju očuvanu vaskularizaciju i inervaciju sa matičnom lozom [21–23]. Aktivno učestvuju u reparativnoj regeneraciji i biološkoj stimulaciji osteogeneze. Oni su vitalni i otporni na infekciju. Međutim, vezani koštani transplantati imaju ograničenu primenu, zahtevaju naprednu mikrovaskularnu tehniku i nisu bez morbiditeta na mestu uzimanja grafta. Shodno tome, sve češće se primenjuje koštano-periostalna dekortikacija krajeva fragmenata [23,24].

AUTOLOGNA TRANSPLANTACIJA

Široku primenu dobio je metod slobodne koštane autoplastike. Prednost tog metoda se sastoji u tome što se transplantat neophodnih razmera može lako uzeti iz mnogih delova skeleta. Osim toga, postupak operacije je jednostavan. Slobodno presađeni transplantat je kompatibilan sa organizmom recipijenta i postaje aktivni stimulator reparativne osteogeneze. On se brzo pregrađuje i popunjava od matične loze novoformiranim tkivom [23]. Kada se primenjuje takva vrsta grafta, autogena kost je najpoželjnija iz razloga što postoji najmanji rizik od odbacivanja grafta. Kao što je prikazano u Tabeli 1, ovakav graft je osteokonduktivan, osteoinduktivan, a dovodi i do osteogeneze.

Autotransplantacija koštanog tkiva takođe se može izvršiti iz bez čvrste koštane strukture, na primer korišćenjem kosti sastrugane sa krila ilijačne kosti ili isitnjene odstranjene glave butne kosti. U ovom slučaju dolazi do osteoindukcije i osteogeneze, dok osteokondukcija izostaje usled nepostojanja čvrste koštane strukture.

Negativni aspekt autologne transplantacije je taj što uzimanje koštanog autotransplantata ipak predstavlja dopunsku operaciju koju bolesnici teško podnose i koja zahteva dodatni hirurški rez, što može pred-

GRAFT VASCULARIZATION

Each bone needs to be supplied with blood at the transplant site. Depending on the transplantation site and the size of the graft, additional vascularization may be necessary. It is important to distinguish between non-vascularized bone grafts, which are transferred to the donor site as free parts of the bone without associated vascularization, and vascularized bone elements, which are transferred to the recipient site connected to blood vessels. Vascularized bone grafts can be free when the associated part of periosteum and the corresponding blood vessel are extracted together with the bone element, and a vascular anastomosis of the associated blood vessel is performed at the recipient site [20–22]. In case of pedicled vascularized bone grafts, there is a transposition of bone element which remains linked to its neurovascular pedicle that continues to feed it at the recipient site [14]. Pedicled bone grafts are the only ones with preserved vascularization and innervation stem cells [21–23]. They actively participate in reparative regeneration and biological stimulation of osteogenesis. They are vital and resistant to infection. However, the application of pedicled bone grafts is limited, they require an advanced microvascular technique and there is the problem of donor site morbidity. For this reason, osteoperiosteal decortication at the ends of the fragments is more and more often applied [23,24].

AUTOLOGOUS TRANSPLANTATION

The method of free bone autoplasty has been widely used. The advantage of this method is that a graft of required proportions can be easily taken from many different parts of the skeleton. Apart from this, the surgical procedure itself is simple. A free bone graft is compatible with the recipient's organism and becomes an active stimulator of reparative osteogenesis. It is quickly rebuilt and filled with new tissue formed from stem cells. [23] When applying this type of graft, autogenous bone is the most preferred choice because of the lowest risk of graft rejection. As presented in Table 1, such a graft is osteoconductive, osteoinductive, and it leads to osteogenesis.

Autologous bone grafting can also be performed without a solid bone structure, for example by using bone scraped from the wing of ilium or the removed femoral head. In this case, osteoinduction and osteogenesis occur, whereas there is no osteoconduction due to the absence of a solid bone structure.

The negative aspect of autologous transplantation is the fact that harvesting a bone autograft is still an additional surgical procedure which is difficult for patients and which means an additional surgical incision

Tabela 1. Uporedni prikaz karakteristika različitih koštanih transplantata

Table 1. Comparative presentation of the characteristics of different bone grafts

Koštani transplantat / *Bone Graft*	Strukturalna čvrstina / *Structural integrity*	Osteokondukcija / *Osteoconduction*	Osteoindukcija / *Osteoinduction*	Osteogeneza / *Osteogenesis*
Autogeni / *Autogenic*				
Spongiozni / *Cancellous*	-	+++	+++	+++
Kortiklani / *Cortical*	+++	++	++	++
Alogeni / *Allogenic*				
Spongiozni / *Cancellous*				
Smrznuti / *Frozen-preserved*	-	++	+	-
Smrznuti suvi/ *Freeze-dried*	-	++	+	-
Kortikalni / *Cortical*				
Smrznuti / *Frozen-preserved*	+++	+	-	-
Smrznuti suvi / *Freeze-dried*	+	+	-	-

stavljati potencijalnu lokaciju za postoperativni bol i komplikacije, a pored toga ponekad je to i nemoguće uraditi zbog propratnih oboljenja [3,25–27]. Osim toga, treba istaći postojanje ogrnaičenja u veličini autografta koji je moguće bezbedno uzeti od pacijenta, dok je količina alografta koji je moguće implantirati teorijski neograničena.

Sa savremenim razvojem hirurgije, autoplastika već ne može da zadovolji narasle potrebe koštanoplastičnog materijala. To objašnjava stalnu težnju za pronalaženjem takvog plastičnog materijala koji može da zameni koštane autotransplantate. Eksperimentalnim i kliničkim radom utvrđeno je da u uslovima niskih temperatura koštano tkivo uzeto od donora i posle određenog vremena ima očuvanu morfološku strukturu i biološku aktivnost. Koštani alotransplantati se sporo resorbuju i zamenjuju novim koštanim tkivom [23].

ALOTRANSPLANTATI I KSENOTRANSPLANTATI

Alogeni graft ili alograft je graft koji je takođe dobijen iz ljudskog organizma, ali ne od samog pacijenta, već od druge individue. Pre razvoja koštane banke, alotransplantati su bili korišćeni samo u slučajevima kada su autologni transplantati bili nedostupni ili kada ih je bilo nemoguće koristiti. Kod dece, uobičajna donorska mesta ne obezbeđuju dovoljno kortikalne kosti za premošćavanje defekata, ili ne sadrže dovoljno spongiozne kosti da bi se popunile velike šupljine ili ciste. Opasnost od povređivanja fize se takođe mora uzeti u obzir. Graftovi za decu se obično uzimaju od njihovih roditelja. Veliki strukturalni alograftovi se godinama uspešno koriste u revizionoj hirurgiji zglobova, kod periprotetičkih preloma dugih kostiju i rekonstrukciji nakon tumorskih resekcija [5,28–30]. U novije vreme

that may be a potential site of postoperative pain and complications and which is sometimes even impossible to perform because of comorbidities [3,25–27]. Apart from this, it should be noted that there are limits concerning the size of autograft that can be safely harvested from a patient, whereas the amount of allograft that can be implanted is practically unlimited.

With the development in the field of surgery, autoplasty can no longer meet the growing needs of osteoplastic material. This explains the constant striving to find the plastic material that would replace bone autografts. Through experimental and clinical work, it has been found that in low temperatures bone tissue harvested from a donor has a preserved morphological structure and biological activity even after some time. Bone allografts are slowly resorbed and replaced by new bone tissue [23].

ALLOGRAFTS AND XENOGRAFTS

An allogenic bone graft or allograft is also a graft obtained from the human organism, but is harvested from another person, not the patient himself/herself. Before bone banks, allografts were used only in cases when autologous grafts were unavailable or when it was impossible to use them. In children, the usual donor sites do not provide enough cortical bone for bridging the defect or they do not contain enough cancellous bone to fill large cavities or cysts. The risk of injuring the physis must also be taken into consideration. Grafts for children are usually harvested from their parents. Large structural allografts have been successfully used for years in revision joint replacement, periprosthetic fractures of long bones, and reconstruction after tumor resection surgery [5,28–30]. Recently there have been pokušava se sa upotrebom osteohondralnih alografto-va u lečenju distalne osteonekroze femura [14,31].

Kada razmatramo koštane alograftove to se može odnositi na (1) svežu ili sveže smrznutu kost, (2) smrznuti suvi koštani alograft (FDBA), ili (3) demineralizovani smrznuti suvi koštani alograft (DFDBA) [14,29,32].

Imajući u vidu nedostatke auto- i alogenih koštanih transplantata, u početku razvoja koštane transplantacije pokušano je sa upotrebom heterogene kosti, tj. ksenotransplantata – životinjske kosti (najčešće goveđe), ali se gotovo uvek dolazilo do nezadovoljavajućih rezultata. Materijal je manje ili više zadržavao svoju originalnu formu, ponašajući se kao unutrašnji klin, pri tom ne stimulišući koštanu genezu i često izazivajući neželjenu imunu reakciju na strano telo [14,33].

SINTETSKI TRANSPLANTATI

Intresovanje za sintetske varijante koštanih transplantata raste iz godine u godinu. Trenutno se u upotrebi ili u procesu kliničkog ispitivanja nalazi nekolicina takvih materija. Veštačka kost se može napraviti od keramičkih supstanci kao što su kalcijum fosfati (npr. hidroksiapatit, trikalcijum fosfat ili njihova kombinacija, kalcijum fosfatni cementi), bioaktivno staklo i kalcijum sulfat, koji su svi u određenoj meri biološki aktivni u zavisnosti od njihove rastvorljivosti u fiziološkom okruženju [30,34–36]. Ovi materijali mogu biti natopljeni faktorima rasta, jonima poput stroncijuma ili pomešani sa aspiratom koštane srži u cilju povećanja njihove biološke aktivnosti.

ZAKLJUČAK

Autologni spongiozni i kortikalni transplantati i dalje predstavljaju zlatni standard sa kojim se porede svi ostali oblici graftova, [3,14] ali ne sme se zanemariti činjenica da je kod sintetskih graftova rizik od infekcije i odbacivanja značajno manji, dok su mehaničke osobine u skladu sa koštanim.

Sukob interesa: Nije prijavljen.

attempts at using osteochondral allografts in treating osteonecrosis of the distal femur [14,31].

Bone allografts may refer to (1) fresh or fresh-frozen bone, (2) freeze-dried bone allograft (FDBA), or (3) demineralized freeze-dried bone allograft (DFDBA). [14,29,32].

Having in mind the shortcomings of autografts and allografts, at the beginning of bone transplantation an attempt was made to use heterogeneous bones, i.e., xenografts – animal bones (most often beef bones), but unsatisfactory results were almost always obtained. The material more or less retained its original form, acting as an internal wedge, but it did not stimulate bone genesis and it often caused unwanted immune foreign body reaction [14,33].

SYNTHETIC GRAFTS

There has been an increasing interest for synthetic bone graft materials. At the moment, several materials are either used or clinically tested. Artificial bone can be made from substances such as calcium phosphates (e.g.,. hydroxyapatite, tricalcium phosphate, or their combination – calcium phosphate cements), bioactive glass, and calcium sulphate which are all biologically active to a certain extent depending on their solubility in physiological environment [30,34–36]. These materials can be impregnated with growth factors, ions such as strontium or they can be mixed with bone marrow aspirate with the aim of increasing their biological activity.

CONCLUSION

Autologous cancellous and cortical grafts still represent the gold standard all other grafts are compared with [3,14]. However, we must not ignore the fact that with synthetic grafts the risk of infection and rejection is significantly lower, while their mechanical characteristics are in line with bone characteristics.

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