

REPLACEMENT OF DEFECTS AFTER RESECTION OF BENIGN TUMORS AND TUMOR-LIKE DISEASES OF TUBULAR BONES OF LIMBS BY CERAMIC MATERIAL BASED ON BIOACTIVE GLASS

31 patients with tumors of bone undergone intraosseous resection, the defect was replaced by the material based on bioactive glass. Localization – long and short tubular bones of limbs. Morphologically were found aneurysmal bone cyst, fibrous dysplasia, enhondroma, giant cell tumor of bone, solitary bone cyst, Chondroblastoma, hondromiksoïdna fibroma, fibrous histiocytoma, lipoma and aseptic necrosis of the bone. A morphological study of bone after bioglass implantation was performed. After the operations, complications were found in 6.4% of patients to relapse. Radiological and morphological studies on the basis of bioactive glass material is characterized by osteoconductive and osseointegration. Replacement with ceramic bone began after 1.5 months, was manifested by accumulation on the surface of the bioglass active osteoblasts, bone, and the bone area was 7.3% more than in the area of fibroreticular tissue.

Keywords: bioactive glass, ceramic implant materials, benign tumor of long bone, tumor-like diseases of tubular bones

INTRODUCTION

The main treatment of tumors and tumor-like diseases of tubular bones is surgical treatment. Open economical operation includes intraosseous bone resection of the tumor or curettage in case of tumor diseases. The course of disease and the nature of surgical intervention in these diseases have certain features that often require the use of different implant materials for bone replacement resection. These features combine observed central location of the metaphysis of long bones, including 82.2% of benign tumors localized in long bones, mainly the young age of patients (11.4 % of children), the large size of the defect, the threat or the occurrence of pathological fracture.

To replace bone defect it is common to use auto-, allotransplants or implant comprising calcium sulfate (Coetzee AS et al., 1980), hydroxyapatite [1], (Holmes RE et al. 1986), tricalcium phosphate [3] (Rey C. 1991; V. Protsenko, 1998), bioactive glass [4,5], polymethylmethacrylate bone cement [7,8], calcium phosphate cement [6,7] (Constantz BR et al. 1995), carbon biomaterials [9] composite materials [9, 10], etc .. These osteoconductive materials are biologically compatible, they contribute to the formation of new bone tis-

sue. Their effectiveness as substitutes for autografts in filling bone defects has been proved by various clinical and experimental researches.

A number of researches describe the effect of formation of new bone in experiments on entire surface of bioactive glass (Larry Hench, 1969), and its use in the clinical research to fill large bone defects (Beckham C. A et al., 1971, Hench L.L., 2013). Some authors obtained better results in the implantation of ceramic materials while adding autografts [5] and platelet-rich plasma [2]. The significant thickening of the cortical layer took place in the bioactive glass group compared with a group of patients with autograft during 8 months of observations [5]. A positive result is defined by two important features of the pore diameter and porosity. The minimum size of 100 microns is optimal for bone ingrowth, while the pore size of 200 μ contributes to the development of mature osteon. The interconnectivity is important, because the blind pockets limit blood supply to the bone which grows.

The aim of the study is to show the effectiveness of substitution defects by composite material based on bioactive glass in the course of tumor diseases and benign tumors of long bones of the extremities.

Materials and Methods

During the period from 2010 to 2016, bone and plastic surgery procedures with the use of material based on bioactive glass – Biokompozit-Syntekost (BCS), benign tumors and tumor-like bone diseases, were performed in 31 patients aged from 12 to 56, average age – 29 ± 5 years old. Of these, 48% were men and 51 women %. Implant material (certificate of state registration № 3653/2005 dated 28 January 2005) was synthesized in the Institute of Materials Science named after I.M. Frantsevich of NAS of Ukraine and used in the form of granule.

Localization of bone tumors is presented in Table 1. Histological diagnosis of bone tumors is presented in Table 2.

All patients underwent surgery: intraosseous bone tumor resection and replacement of the specified material defect, 2 patients in combination with autoplasty and 1 in pathological fractures of the humerus in the background aneurysmal cysts in combination

Table 1

Localization of bone tumors

Localization	number of patients, n=31	%
proximal humerus	4	12,1
diaphysis of the humerus	1	3,0
distal humerus metaphysis	0	0,0
proximal femoral metaphysis	3	9,1
diaphysis femur	1	3,0
distal femoral metaphysis	10	30,3
proximal tibia metaphysis	3	9,1
diaphysis of the tibia	3	9,1
phalanxes of fingers	3	9,1
bones of the foot	5	15,2
Total:	33*	100,0

*

In 3 patients with tumors 2 adjacent locations took place.

Table 2

Histological diagnosis of bone tumors

Diagnosis	number of patients	%
Aneurismal bone cyst	7	23
Fibrous dysplasia	6	19
Enhondroma	5	16
Giant cell tumor of bone	3	10
Solitary bone cyst	3	10
Hondromiksoid fibroma	2	6
Hondroblastoma	2	6
Fibrous histiocytoma	1	3
Aseptic necrosis	2	6
Lipoma of bone	1	3
Total:	31	100,0

Table 3

Results of treatment

Index	Syntekost, n=31	Kerhap-M, n=85
Inflammatory processes	0	2, 2,35%
Relapse	1, 3,2%	1, 2,1%
Bed-day	12±4,2	24,3±5,7

with metal osteosynthesis. The results of treatment were compared to the group of 85 patients with benign tumors of bone, in whom postoperative bone defect was replaced with ceramic material based on hydroxyapatite (Kerhap-M). Bone tissue of patients was investigated using methods of light microscopy after the surgery for bone grafting defect using BCS. Bone morphometry was conducted in 10 patients and 20 experimental animals after implantation of the material "Syntekost." Clinical examples of treatment results using a material based on bioactive glass shown in Figures 1 and 2.

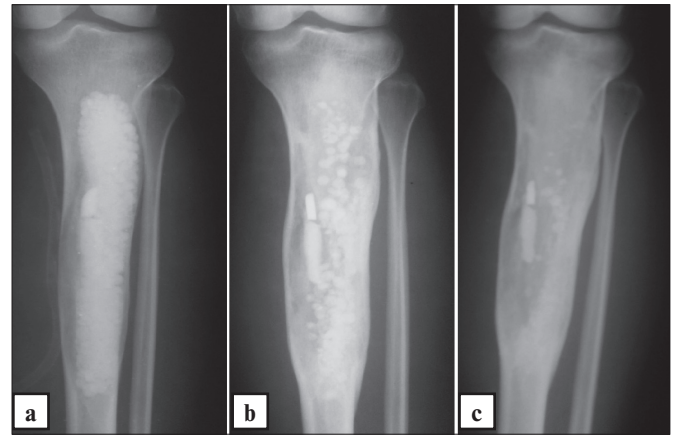


Fig. 1. Patient 18 years old. Fibrous dysplasia of the proximal metaphysis and diaphysis of the tibia, after post intraosseous resection and bone defect plastic ceramic material. Radiographs a) immediately after surgery, b) 12 months after the operation, c) 24 months after the operation. There is a ceramic material alteration at the site of implantation.

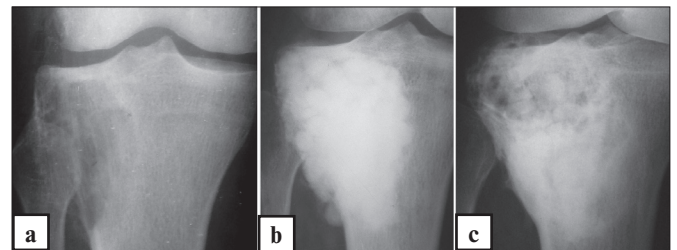


Fig. 2. Patient, 57 years old. Giant cell tumor of the proximal tibia metaphysis, post intraosseous resection and bone defect plastic ceramic material. X-ray a) before surgery, b) 2 weeks after the operation, c) 12 months after the operation. There is a ceramic material alteration at the site of implantation.

RESULTS

As a result of bone and plastic surgery for benign tumors and tumor-like bone disease in 31 patients, complications of the wound were not found. To replace the destroyed tumor cortical layer of bone, and strengthen the bone window, a porous BCS plate was used with a thickness of 1-3mm, of the size of 0,5x1cm to 1,5x5 cm, the average area $3,9 \pm 1,7\text{cm}^2$. The average volume of intraosseous defect after resection was $50.5 \pm 13,6\text{ cm}^3$ (1-148 cm³) and the number of wasted material was $34,9 \pm 7,3\text{ g}$ (7-80h).

The results of treatment in the two groups is presented in Table 3.

Relapse tumors was found in 1 (3.2%) patients with hondroblastoma and in 1 (3.2%) with fibrous dysplasia. They undergone surgical removal of tumors and recurrence of similar replacement bone defect. In the dynamics using X-ray and morphological studies, alteration and replacement of plastic material newly formed bone tissue was observed. Bed-day was $12 \pm 4,2$ days. Patients used the operated limb on average

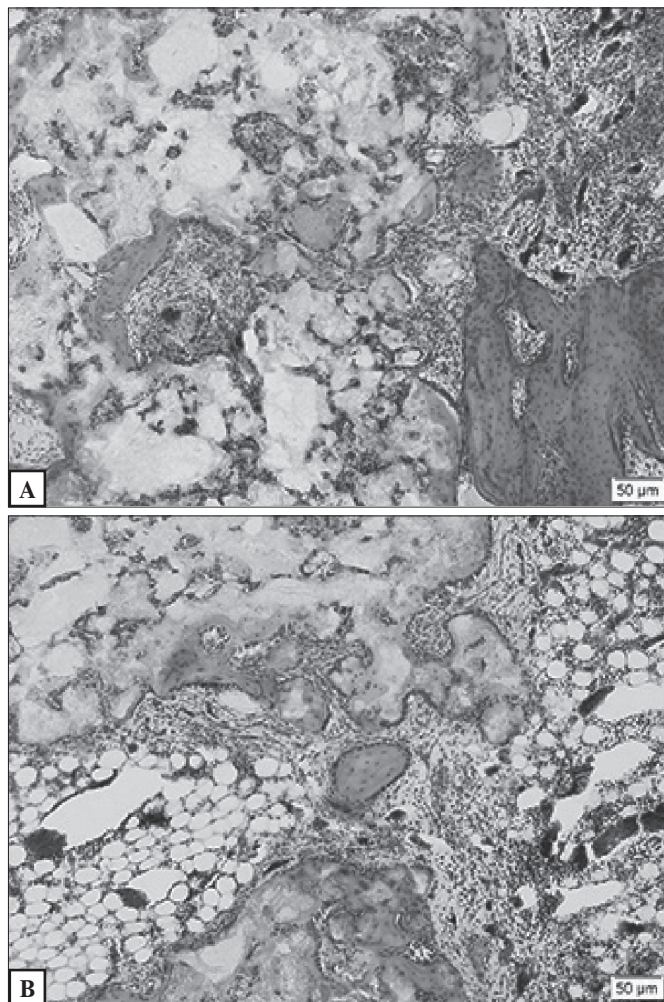


Fig. 3. A) particles of bioglass surrounded by newly formed bone trabeculae and fibroreticular tissue in the canal of the bone marrow. B) Foci of yellow bone marrow adjacent to biomaterials (hematoxylin-eosin, 200×). Directly on bioglass isolated osteoclasts were found, forming resorptive cavity in which osteoblasts grew (Fig. 3). Osteoblasts were located on the bioglass surface forming osteoid.

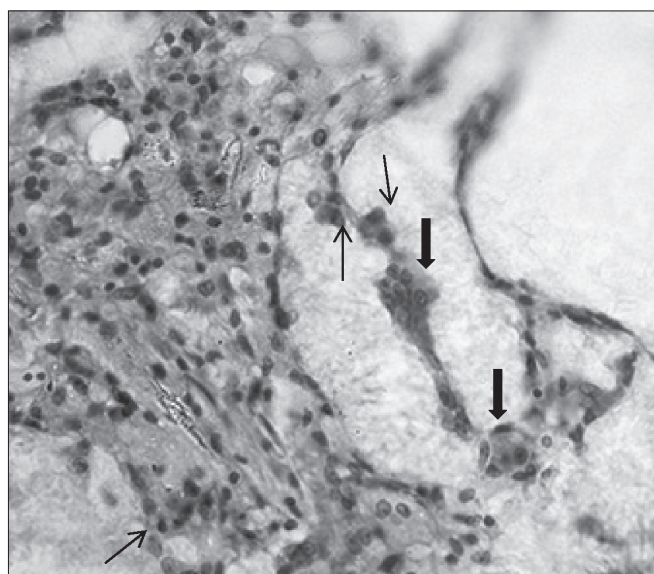


Fig. 4. Osteoclasts (thick arrow) and osteoblasts (thin arrow) on the surface of a biomaterial. (hematoxylin-eosin, 400×).

within 1.5-2.5 months. The appearance of bone tissue in morphologic preparations of BCS was observed through 1,5-3months, Kerhap-M – 3-6 months.

In laboratory animals among implanted particles of bioactive glass, the bone trabeculae of different shapes and sizes were located in a narrow layers with a high density of osteocytes (Fig. 3a, b). Short bone trabeculae were found in fibroreticular tissue, indicating the potency of osteogenic tissue.

Location of osteoclasts and osteoblasts on the surface of a biomaterial shows its high biocompatibility with bone tissue. Adjacent to bioglass fibroreticular tissue had fibroblastic cells of different maturity, isolated macrophages and osteoblasts, which were located directly on the biomaterial particles (Fig. 4). Based on morphometry tissue areas in the defect located in the cortex, we found that bone area was 7.3% compared with the area fibroreticular tissue.

CONCLUSION

The obtained morphological data indicate that the material based on bioactive glass – BCS – is characterized with osteoconductive and osseointegration, which manifested itself in the formation of active osteoblasts and bone on its surface. Replacement by newly created bone tissue depends on the BCS after implantation. The use of material based on bioactive glass in bone and plastic surgery in benign tumors of the long bones has some advantages, in particular, treatment duration reduces, significant bone defects get restored.

LITERATURE

1. Tamai, N., Myoui, A., Kudawara, I., Ueda, T., & Yoshikawa, H. (January 01, 2010). Novel fully interconnected porous hydroxyapatite ceramic in surgical treatment of benign bone tumor. *Journal of Orthopaedic Science : Official Journal of the Japanese Orthopaedic Association*, 15, 4, 560-8.
2. Trindade-Suedam, I. K., de, M. J. A., Faeda, R. S., Leite, F. R., Tosoni, G. M., Neto, C. B., Marcantonio, E. J., ... Scaf, G. (January 01, 2010). Bioglass associated with leukocyte-poor platelet-rich plasma in the rabbit maxillary sinus: histomorphometric, densitometric, and fractal analysis. *The Journal of Oral Implantology*, 36, 5, 333-43. Seto, S., Muramatsu, K., Hashimoto, T., Tominaga, Y., & Taguchi, T. (January 01, 2013). A new β -tricalcium phosphate with uniform triple superporous structure as a filling material after curettage of bone tumor. *Anticancer Research*, 33, 11, 5075-81.
3. Lindfors, N. C., Heikkilä, J. T., Koski, I., Mattila, K., & Aho, A. J. (July 01, 2009). Bioactive glass and autogenous bone as bone graft substitutes in benign bone tumors. *Journal of Biomedical Materials Research Part B: Applied Biomaterials*, 1, 131-136.
4. Lindfors, N. C., Koski, I., Heikkilä, J. T., Mattila, K.,

- & Aho, A. J. (January 01, 2010). A prospective randomized 14-year follow-up study of bioactive glass and autogenous bone as bone graft substitutes in benign bone tumors. *Journal of Biomedical Materials Research. Part B, Applied Biomaterials*, 94, 1, 157-64.
5. Matsumine, A., Kusuzaki, K., Matsubara, T., Okamura, A., Okuyama, N., Miyazaki, S., Shintani, K., ... Uchida, A. (March 01, 2006). Calcium phosphate cement in musculoskeletal tumor surgery. *Journal of Surgical Oncology*, 93, 3, 212-220.
 6. Okada, Y., Kawanabe, K., Fujita, H., Nishio, K., & Nakamura, T. (December 05, 1999). Repair of segmental bone defects using bioactive bone cement: Comparison with PMMA bone cement. *Journal of Biomedical Materials Research*, 47, 3, 353-359.
 7. Liu, B. M., Li, M., Yin, B. S., Zou, J. Y., Zhang, W. G., & Wang, S. Y. (January 01, 2015). Effects of Incorporating Carboxymethyl Chitosan into PMMA Bone Cement Containing Methotrexate. *Plos One*, 10, 12.)
 8. Тяжелов О. А. Экспериментально-теоретическое обоснование новых технологий остеосинтеза и замещение дефектов костей имплантатами на основе углерода / О. А. Тяжелов, В. И. Тарасенко, И. В. Гурин [и др.] // Ортопедия, травматология и протезирование. — 2008. — № 4. — С. 41-46
 9. Розенфельд Л. Г. Биоактивный керамический наноккомпозит синтекость и перспективы его применения для пластики костной ткани / Л. Г. Розенфельд, В. А. Дубок, А. Б. Брик, А. В. Шинкарук // Мистецтво лікування. — 2008. — № 50 (4). — С. 98-71.
 10. Герцен І. Г. Фосфорно-кальцієвий композит-сучасний матеріал для пластики дефектів кісток / І. Г. Герцен // Вісник морської медицини. — 2009. — № 2. — С. 85-88.

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Заміщення дефектів після резекцій доброякісних пухлин та пухлиноподібних захворювань трубчастих кісток кінцівок керамічним матеріалом на основі біоактивного скла

У 31 пацієнтів, з новоутвореннями кісток, виконано внутрішньокісткова резекцію кістки з пухлиною, заміщення дефекту матеріалом на основі біоактивного скла. Локалізація — довгі та короткі трубчасті кістки кінцівок. Морфологічно зустрічались аневризмальна кісткова кіста, фіброзна дисплазія, енхондрома,

гігантклітинна пухлина кістки, солітарна кісткова кіста, хондробластома, хондроміксозна фіброма, фіброзна гістіоцитома, ліпома кістки та асептичний некроз. Проведене морфологічне дослідження кісткової тканини після імплантації біоскла. Після операцій, ускладнень не виявлено, рецидив — у 6,4% пацієнтів. При рентгенологічному та морфологічному дослідженнях матеріал на основі біоактивного скла характеризувався остеокондуктивністю та остеоінтеграцією. Заміщення кераміки кістковою тканиною відбувалось з 1,5 міс. проявлялось скопченням на поверхні біоскла активних остеобластів, кісткової тканини, а площа кісткової тканини була на 7,3% більше в порівнянні з площею фіброретикулярної тканини.

Ключові слова: біоактивне скло, імплантація керамічних матеріалів, доброякісні пухлини довгих кісток, пухлиноподібні захворювання кісток.

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Замещение дефектов после резекции доброкачественных опухолей и опухолеподобных заболеваний трубчатых костей конечностей керамическим материалом на основе биоактивного стекла

У 31 пациента с новообразованиями костей, выполнена внутрикостная резекция кости с опухолью и замещение дефекта материалом на основе биоактивного стекла. Локализация — длинные и короткие трубчатые кости конечностей. Морфологически встречались аневризмальна костная киста, фиброзная дисплазия, энхондрома, гигантоклеточная опухоль кости, солитарная костная киста, хондробластома, хондромиксоидна фіброма, фіброзна гістіоцитома, ліпома кости и асептический некроз. Проведено морфологическое исследование костной ткани после имплантации биостекла. После операций, осложнений не выявлено, рецидив — у 6,4% пациентов. При рентгенологическом и морфологическом исследованиях материал на основе биоактивного стекла характеризовался остеокондуктивностью и остеоинтеграцией. Замещение керамической костной тканью начиналось с 1,5 мес., проявлялось скоплением на поверхности биостекла активных остеобластов, костной ткани, а площадь костной ткани была на 7,3% больше по сравнению с площадью фиброретикулярной тканью.

Ключевые слова: биоактивное стекло, имплантация керамических материалов, доброкачественные опухоли длинных костей, опухолеподобные заболевания костей.