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Surgery of False Joints of Long Tubular Bones in Children Using the Shape Memory Materials

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Abstract

The article presents the clinical observations of 15 patients aged from 10 months to 14 years with the false joints of long tubular bones of various etiology after their elimination by pathological tissues resection, placing the osteogenic tissue in the defect zone, the structures based on porous nickelid titanium saturated with poorly differentiated cellular elements of mesenchymal origin, fixation of fragments by brackets of nickelid titanium with shape memory. In all cases the obtained result was satisfactory and functional.

1Introduction

False joints of long tubular bones in childhood can occur as a result of unsuccessfully conducted therapeutic measures regarding their fractures, as a consequence of the past osteomyelitis, an outcome of bone deformities surgical removal, tumor and tumor-like conditions and can have the congenital origin as well. Children treatment with this pathology is one of the main orthopedic challenges due to the lack of conservative therapy effectiveness and frequent relapses after the surgical interventions. The latter case results in repeated unsuccessful surgeries in patients which in some cases lead to physical injuries and limbs amputation. In order to ensure the conditions for bone fragments fusion in patients of the indicated category at present the operative methods with the application of different types transplant materials are widely spread (autogenous free, vascularized or revascularized, of allogenic origin in

combination with cell technologies) as well as fixation by means of intramedullary osteosynthesis, plate metal structures in combination with the external fixation devices or without them [1, 4-14]. The results of these technologies' application are often not efficient due to insufficient bone regeneration properties in the damage area, the inevitability of the partial or complete transplant resorption.

The aim of the study is to improve the efficiency of nonunion and false joints of lower extremities surgical removal in children on the basis of new medical technologies using the shape memory material.

2 Experimental

In order to provide secure fixation and the best possible conditions ensuring the regeneration in the damage area, the technologies of osteogenic tissue application [Patent of the Russian Federation № 2180812], finely granulated porous nickelid titanium [Patent of the Russian Federation № 2178277], biocompatible nickelid titanium implants with through permeable porosity as the fixing elements of fractured fragments of the structures made of nickelid titanium with shape memory effect were developed.

3 Results and discussion

The soft tissues in the lesion projection are transected, bone fragments are skeletonized and mobilized. During the tibia surgery the transverse fibula osteotomy is conducted. The pathological tissues between the fragments are dissected out, the sclerosal ends are refreshed, the medullary canals are opened up and expanded. Then the anatomic axis of the limb is restored. The bed for porous permeable nickelid titanium implant of the appropriate shape is formed by a power saw with translational movements in the area of the front surface of the damaged bone from the fragments edges. With the help of the mentioned above implant which was preliminary saturated by poorly-differentiated cellular elements of mesenchymal origin (for these purposes the latter was placed in the iliac crest thickness for 7–14 days depending on the patients' age), the limb shortening is eliminated if possible if there is any. The remaining bone spaces are filled with osteogenic tissue «grown» in the iliac crest thickness having the structure between the hyaline cartilage and coarse-fibered osseous tissue. In cases of insufficient number of the latter, it is used in the combination with fine-grained porous nickelid titanium with the particles' size from 1 to 2000 microns. The synthesis of fragments is performed with the fixing structures made of nickelid titanium with shape memory effect. To separate the bone tissue from the

possibility of connective and muscular tissues ingrowth into the osteal wound on the part of the soft tissues in patients with insufficient bone periosteum, the bone wound surface from all sides is covered with thin-profile mesh implant based on 50-60 microns thick nickelid titanium with the cell size 1-3 mm (Fig. 1). The soft tissues are laid into the place, the wound is sutured and drained. If required, the limb is immobilized by a plaster cast.

Fig. 1. The materials and structures of nickelid titanium used in the surgey of the false joints of long tubular bones

According to the developed technology, 15 patients of both sexes with pathological conditions aged from 10 months to 14 years were treated as indicated in Table 1.

Table 1. Distriburion of patients in accordance with nosological forms

Nosological form	Number of patients
Pseudarthrosis of the femur due to hematogenous osteomyelitis	2
Pseudarthrosis of the femur due to traumatic osteomyelitis	1
Congenital pseudarthrosis of the tibia	3
Pseudarthrosis of the tibia due to hematogenous osteomyelitis	2

Pseudarthrosis of the tibia due to traumatic osteomyelitis	3
Pseudarthrosis of clavicle due to traumatic injury	2
Pseudarthrosis of the ulna due to traumatic injury	2

During the preoperative period all the patients were performed the clinical examinations including the common blood and urine tests, the biochemical blood parameters were studied, X-ray diagnosis in the form of computed tomography of the lower extremity was carried out. If required, before the surgical intervention some procedures were performed directed to the normalization of physical body findings. The treatment outcomes were assessed on the basis of clinical observation, the postoperative control of the bone fragments standing was carried out by means of X-ray survey and computed radiography during 5-6 days, 1, 3, 6, 8, 12 months or more.

4 Results and discussion

In all cases the postoperative period was favorable, without any significant complications. The immediate postoperative period was accompanied by a slight inflammatory reaction in the intervention area which was mainly eliminated by 5-6 days, the primary wound healing was determined. On eliminating the inflammation and swelling of tissues in the intervention area (8-12 days) the movements in adjacent joints were restored, any negative effects associated with the surgery were not marked. The independent movements of the patients with the dosed load on the operated limb with the help of external support devices after the surgical intervention were determined on the tibia after 4-6 days, on the femur – 10-12 days. The full functional load in the operated patients on the tibia became possible in 3,5–4,5 months, on the femur – 4,5-5,5 months.

The X-ray analysis performed 5-6 days after the operation revealed the anatomical limb integrity, the absence of bone fragments displacements signs, the implant material standing and the satisfactory fixed elements. Radiologically the beginning of the bone regenerate formation in the zone of the former false joint was observed in a month after the surgery. During the next 3-6 months the increase in shadow intensity was detected, the indicated processes were over by the 8 month of follow-up.

On examination the patients after 12 months they had no complaints, the limbs movements were preserved in full, the functional disorders were not identified. The shortening of the operated limbs was up to 12 mm. The resorptive effects radiographically in the operation area were not determined. The eruption of the

implant material through the soft tissues was not observed. In figure 2-4 the clinical example is presented on pseudarthrosis of the left femur elimination in an 11 year-old patient which occurred due to hematogenous osteomyelitis.

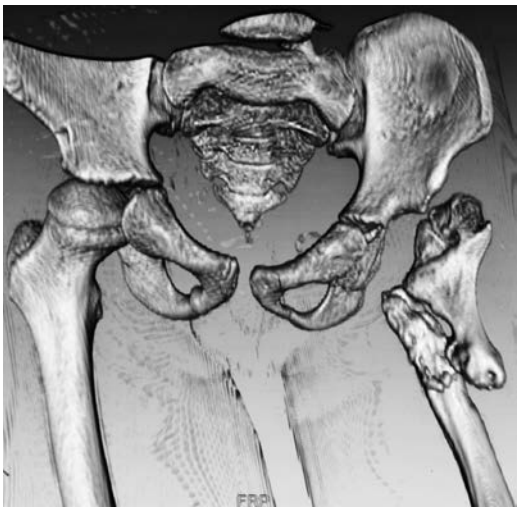
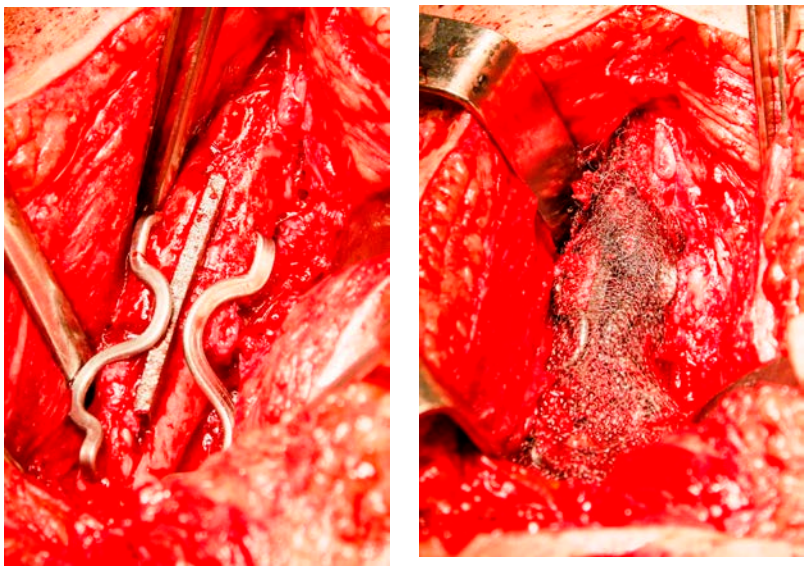


Fig.2. The X-ray of an 11 year-old patient with a dislocated head and the false joint of the left femur due to hematogenous osteomyelitis before the surgical treatment



a b

Fig.3. The state of the surgery wound of the patient: a – after the installation of the porous plate nickelid titanium saturated with osteogenic tissue and osteosynthesis; b – after the installation of the textile nickelid titanium implant

Fig. 4. The X-ray of the same patient 24 months after the surgical treatment

5 Summary

The analysis of surgical treatment results in children with false joints of lower extremities showed high efficiency of the developed technology. Due to biochemical and biomechanical compatibility of nickelid titanium with the body tissues unlike other materials (not showing the lag effect in terms of loading and unloading), the implants of this material after placement in tissue defects are not rejected and the connective tissues from the recipient areas in-grow through the porous structure of the implanted material without causing any aggressive reactions, forming a single organotypic regenerate with the latest one. The rod implants with the indicated characteristics have increased the mechanical regenerate properties in the area of the former defects after the fusion with bone structures. The osteogenic tissue placed in the area of bone defect due to high content of poorly differentiated bone elements of mesenchymal origin, the diffuse nutrients properties, apposition and interstitial growth, and anaerobic glycolysis, resistance to hypoxia conditions didn't resorb and its cells are actively involved in the reparative osteogenesis processes. Porous nickelid titanium in the form of fine granules is easy to use as it gives the opportunity to restore the defects of any configuration without time-consuming modeling of the implant corresponding to the shape of the defect. Its successful application for the defects restoration in combination with autografts is explained by the fact that in these situations it isrequired the less amount of osteogenic cells to produce a given regenerate volume in comparison with the transplantation. The fixed structures with the shape memory effect are easy to use, not time - consuming, provide the stable fixation of bone fragments, early functional possibilities which undoubtedly have a positive impact on the final outcome. Covering the bone connection area with textile thin-profile nickelid titanium especially in patients with insufficient bone periosteum prevents the in-growth of the connective and muscular tissues into the osteal wound.

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