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Advantages of Modified Osteosynthesis in Treatment of Osteoporotic Long Bones Fractures – Experimental Model

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A B S T R A C T

In surgery of fractured long bones, a patient suffering from osteoporosis represents constant challenge to a surgeon and applied material and instruments that need to destroy as little as possible of an already damaged bone. One potential way of increasing the contact surface between the implants and osteoporotic bone is injection of bone cement (methyl-metacrilat, Palakos) into a prepared screw bed. This method of osteosynthesis was therefore subjected to experimental research to prove that application of modified osteosynthesis using bone cement in treatment of fractures in osteoporotic patients has advantage over the standard method of osteosynthesis because this modified method enables significantly greater firmness and stability of the osteosynthesis, which is the essential precondition of a successful fracture healing. The research was carried out on six macerated cadaveric preparations of a shin bone from the osteological collection from Institute for Anatomy, School of Medicine, University »J. J. Strossmayer«. All samples of long bones were artificially broken in the middle part of the diaphysis and then standard osteosynthesis and modified osteosynthesis with screws filled with bone cement were performed on the samples. Results show that under identical static action of the moment of torsion in the modified osteosynthesis torsion angle deviation is lower than in the standard osteosynthesis. In modified osteosynthesis with bone cement the first results for angle of torsion deviation greater than 0.2 degrees were noticed after 120 minutes, while in the standard method of osteosynthesis they were noticed already in the first minute.

Key words: *osteosynthesis, long bone fracture, osteoporosis*

Introduction

In operative treatment of a bone fracture the main goal is to ensure permanent stability of bone fragments while simultaneously allowing active movements of the muscles and joints of the injured extremity until the fracture is completely healed. Permanent stabilization of bone fragments is the basic rule in surgical treatment, which is accomplished by application of standard technique of osteosynthesis according to the AO principles. The AO method of interfragmental compression and AO method of placement of the guiding wire are the basic AO methods that enable active and painless movement shortly after the surgery[1]. Unlike the method of interfragmental compression, the method of placement of the guiding wire cannot result in absolute stability of bone fragments, which leads to secondary healing of the fracture and development of a smaller or greater callus in the area of the fracture fissure. On the other hand, the AO method of interfragmental compression based on the principle of being overstretched ensures permanent stabilization of bone fragments while the fracture heals without a callus that can be seen radiographically[2,3]. Taking into account local mechanical relations, maintaining of the circulation in bone fragments and in the surrounding soft tissue, as well as meticulous surgical technique, the AO method of osteosynthesis applying interfragmental compression ensures active and painless

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movement of the surrounding muscles and joints, which is the main precondition in prevention of fracture diseases[1].

Static and dynamic interfragmental compression is achieved by applying the standard AO metal implants: screw, plate, wire and external fixator. Laws of biomechanics clearly indicate that in order to obtain permanently stable osteosynthesis it is necessary to achieve the greatest possible pressure between the bone fragments and/or large enough contact surface between the metal implants and the bone to achieve greatest possible local strain.

In cases when bone tissue has normal density, normally developed trabecular structure as well as normal minerals and organic matrix ratio, cortical and spongious part of a bone is firm. In bones of such structure only great mechanical force can cause fracture. Moreover, it is significantly easier to obtain osteosynthesis of a fracture in a bone that has normal quantitative and qualitative structure. Developed and dense spongious tissue on the one hand and hard corticalis on the other hand ensure firm and stable stronghold for a screw. Thus, it is possible to achieve great local strain between the screw and the bone and/or great pressure between bone fragments.

On the other hand, when the bone corticalis is thin, spongious tissue has few gracile trabeculae, bone tissue is fragile due to decreased bone density and changed trabecular structure and minerals and organic matrix ratio is also changed, the bone has significantly lower elasticity. Described bone structure is characteristic for osteoporosis. In osteoporotic bone the screw cannot have firm, permanent and stable stronghold. Achieved local strain between the screw and the bone is extremely low, and pressure between bone fragments is inadequate for permanently stable osteosynthesis. Osteosynthetic material becomes loosened very soon, which leads to further complications in postoperative treatment: need for additional and prolonged immobilization, late verticalization, rehabilitation and loading and finally unsatisfactory functional result.

It is extremely difficult to obtain stable retention of fragments applying standard implants and standard surgical technique of osteosynthesis in osteoporotic patients. Their postoperative treatment is therefore significantly prolonged, marked by longer hospitalization and need for additional long-lasting immobilization. Healing of the fracture is slowed down, and it takes longer to achieve partial and full load. Complications are frequent, such as loosening of the osteosynthetic material, breakage of metal implants, prolonged healing and psuedoarthrosis.

For all the stated facts it is necessary to develop special methodology and technique of osteosynthesis in fracture treatment in osteoporotic patients. Furthermore, it is necessary to find the way to increase the contact surface between the metal implants and the bone to enable greatest possible strain and thus a stable osteosynthesis that will prevent development of microfractures and loosening of screws and/or osteosynthetic material.

One potential way of increasing the contact surface between the implants and osteoporotic bone is injection of bone cement (methyl-metacrilat, Palakos) into a prepared screw bed. This method of osteosynthesis was therefore subjected to experimental research to prove that application of modified osteosynthesis using bone cement in treatment of fractures in osteoporotic patients has advantage over the standard method of osteosynthesis because this modified method enables significantly greater firmness and stability of the osteosynthesis, which is the essential precondition of a successful fracture healing.

Materials and Methods

The research was carried out on six macerated cadaveric preparations of a shin bone from the osteological collection from Institute for Anatomy, School of Medicine, University »J. J. Strossmayer«.

Macerated cadaveric samples were radiologically defined (Figure 1) with radiogrametric characteristics (cortex thickness, cortical index) and bone density obtained by double photon densitometry (Figure 2). The density of the bone mass was approximately equally low in all samples. Research on model of cadaveric long bone was conducted on a specially designed device for investigation of biomechanical characteristics regarding static-dynamic load[5,6]. All samples of long bones were artificially broken in the middle part of the diaphysis and then standard osteosynthesis and modified osteosynthesis with screws filled with bone cement were performed on the samples.

To determine the difference between these two methods of osteosynthesis the magnitude of elastic deformation under the action of axial force and moment of torsion at three different intensity levels were measured. Investigation was performed on a special measuring device which had technical possibilities to measure the torsion angle deviation with a laser beam, mirror and screen (Figure 3). The purpose was to determine the magnitude

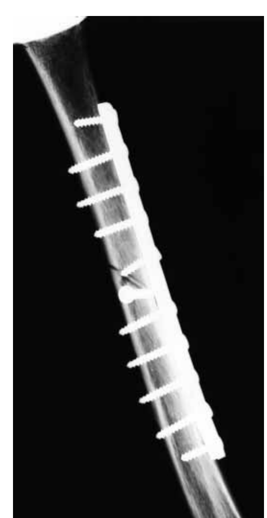

Fig. 1. Radiography of standard osteosynthesis.

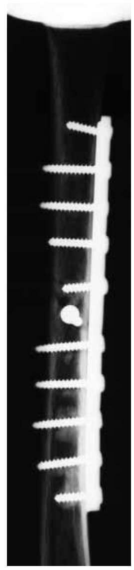

Fig. 2. Radiography of modified osteosynthesis.

of the axial force and moment of torsion which may be exerted on a macerated cadaveric shin bone in both static and dynamic way without causing fracture and/or state of permanent deformation[6]. Measurement of deformation was taken at one point at the distal end of the shin bone, more precisely at a lower inner malleolus.

Axial force was 400 [N] and three values of torsion moment were observed: 2.94 [Nm], 3.92 [Nm] and 4.90 [Nm]. The result of such axial and torsion load was dominant deformation of torsion. The greater the moment of torsion was, the greater was deformation, which was linearly increasing, as well as angle of torsion deviation. When static load was removed macerated cadaveric shin bone returned to its initial position, which means that there was no permanent deformation due to elastic quality of the bone.

Macerated cadaveric shin bone was investigated concerning dynamic load with axial force of 100 [N] and regularly interrupted moment of torsion of 3 [Nm]. During a thirty-minute period the measured angle of torsion (deformation) showed the equal value of 2.5 degrees. When dynamic load was removed, the macerated cadaveric shin bone returned to its initial position, which means that there was no permanent deformation due to elastic quality of the bone.

Results

Standard osteosynthesis was performed on six samples of broken macerated cadaveric shin bone according to the AO principles and subsequently the samples were subjected to investigation of their resistance to static action of mechanical factors. Identical investigation was carried out on six samples on which modified osteosynthesis with bone cement was performed. Linear correlation between the moment of force and deformation in the form of torsion angle can be noticed. Namely, the torsion angle increased regularly with the increase of the external load. Standard osteosynthesis showed greater deviation of the torsion angle in the range from 0.25 to 0.35 degrees in relation to modified osteosynthesis with bone cement, which confirmed greater firmness of the bone treated with this method.

The results obtained in the experimental research on macerated cadaveric shin bone confirmed greater firmness, toghness and stability of the modified osteosynthesis. From the statistical Box-Plot diagram it is evident that under identical static action of the moment of torsion

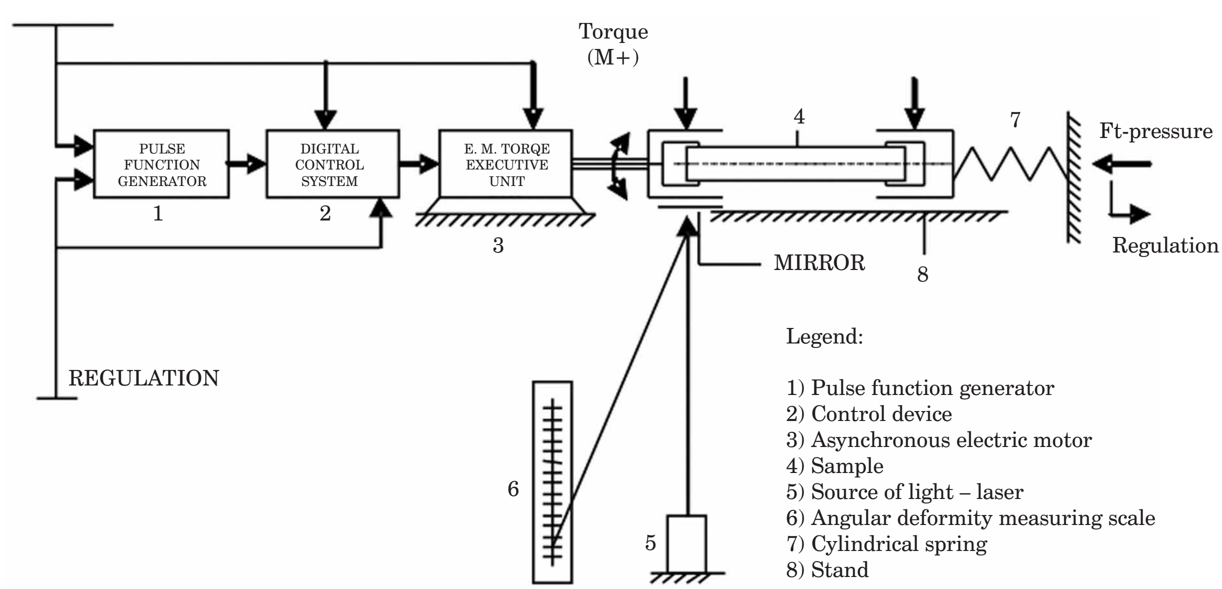

Fig. 3. Draft of device for measuring sample angular deformity.

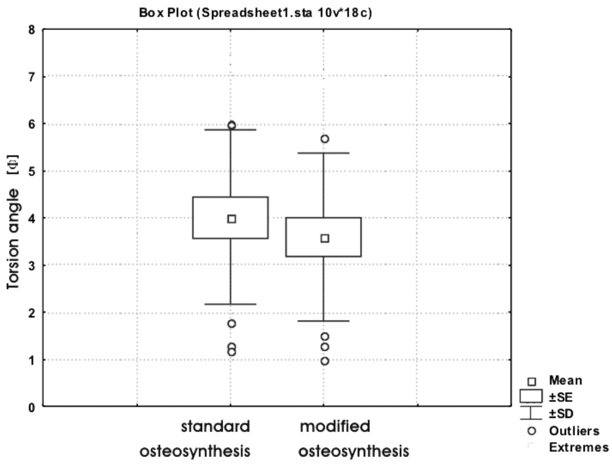

Fig. 4. Average torque deformity under static load.

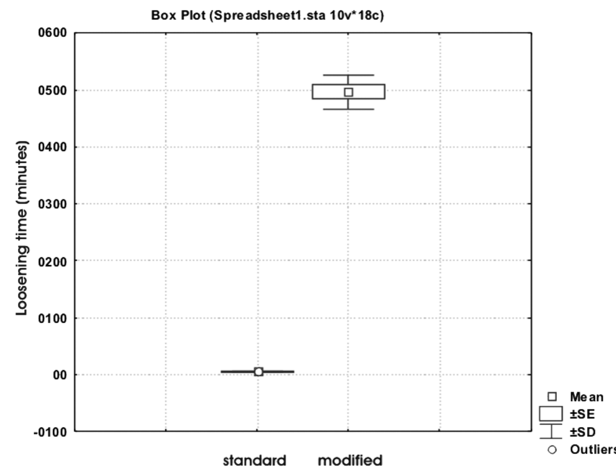

Fig. 5. Osteosyntesis loosening time under dynamic torque load.

in the modified osteosynthesis torsion angle deviation is lower than in the standard osteosynthesis (Figure 4).

The results of experimental dynamic investigations that were performed on another six samples present comparison of samples response after two types of osteosynthesis: standard and modified. Since the time period up to the loosening in the modified ostesynthesis is relatively long, the time period for determined angle of torsion deviation is given in logarithmic measures. In modified osteosynthesis with bone cement the first results for angle of torsion deviation greater than 0.2 degrees were noticed after 120 minutes, while in the standard method of osteosynthesis they were noticed already in the first minute.

The results obtained in experimental research on macerated cadaveric shin bone confirmed significantly greater firmness, toughness and stability of modified osteosynthesis under action of dynamic load. In modified osteosynthesis the mean value of time passed until angle of torsion deviation was greater than 0.2 degrees was on average 600 minutes, while in the standard osteosynthesis the angle of torsion deviation over 0.2 degrees was noticed already in the first minute (Figure 5).

Discussion

Osteoporosis is a disease or a condition developed because of what we may call thinning of a bone caused by a loss of bone mass due to depletion of calcium and bone protein. Therefore, osteoporosis is a predisposition for frequent fractures of the vertebrae and long bones that show a tendency for slow and inefficient healing. The disease is typically developed in old age, more often in post-menopausal women. Shin bone fractures are among the most frequent within long bones, with the annual incidence of open fracture in 11.5 persons per 100 000, whereby 40% of fractures were the fractures of lower extremities[7]. Methods of treatment of long bone fractures can be divided into conservative and operative, in accordance with the AO classification of fractures which is used to decide which method of treatment will be applied. Shin bone fractures may occur on all parts of the bone. The most frequent fracture sites are tibial plateau, shin bone diaphysis and fractures of medial malleolus.

The fact that we have a patient suffering from osteoporosis represents constant challenge to a surgeon and applied material and instruments that need to destroy as little as possible of an already damaged bone. Treatment methods have evolved throughout history; from initial rigid plates[8–10], dynamic compressive plates[11–13], intramedullar nails[14,15,24], external fixations[16] over to the latest methods of intramedullary fixations that unite best characteristics of all mentioned osteosynthetic materials, such as intramedullary nails along with Schanz screws[17]. Among other methods of treatment of long bone fractures in osteoporotic patients is the method that applies special kinds of bone cement to increase the contact surface and firmness of the osteosynthetic material and bone[18,19]. Based on experimental investigations of mechanical resistance to static action of mechanical factors in standard and modified method of osteosynthesis of the fracture of cadaveric macerated shin bone, our research undeniably confirmed that modified osteosynthesis showed greater firmness, toughness and stability. The results obtained in both static and dynamic model of load corresponded with the clinical results of several authors who mentioned application of modified osteosynthesis in treatment of a bone fracture or defect by numerous authors[20–23]. In our opinion application of this experimental model of research and measurement conducted in this study confirmed greater resistance of the modified method of osteosynthesis to the forces of torsion. Consequently, based on the results of our research and the results of clinical research by other authors, we would recommend the method of modified osteosynthesis for treatment of long bone fractures in osteoporotic patients.

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PREDNOSTI MODIFICIRANE OSTEOSINTEZE U LIJEČENJU OSTEOPOROTSKIH FRAKTURA DUGIH KOSTIJU – EKSPERIMENTALNI MODEL

SAŽETAK

U kirurgiji fraktura dugih kostiju pacijenta koji boluje od osteoporoze predstavlja stalan izazov za kirurga, upotrijebljeni materijal i instrumente koji trebaju uništiti što manje od već oštećene kosti. Potencijalni način za povećanje kontaktne površine između implantata i osteoporotične kosti injiciranje je koštanog cementa (metil-metakrilat, Palakos) u priređeno ležište vijka. Stoga je ova metoda osteosinteze podvrgnuta eksperimentalnom istraživanju, kako bi se dokazalo da korištenje modificirane osteosinteze pomoću koštanog cementa u liječenju prijeloma pacijenata koji boluju od osteoporoze ima prednost nad standardnom osteosintezom, jer modificirana metoda omogućuje značajnu čvrstoću i stabilnost osteosinteze, što je osnovni preduvjet uspješnog liječenja prijeloma. Istraživanje je provedeno na šest maceriranih kadaveričnih preparata goljenične kosti osteološke zbirke Katedre za anatomiju Medicinskog fakulteta Sveučilišta J. J. Strossmayera u Osijeku. Svi uzorci dugih kostiju umjetno su prelomljeni na središnjem dijelu dijafize i tada je učinjena standardna i modificirana osteosinteza s vijcima ispunjenim koštanim cementom. Rezultati pokazuju da je pod jednakim torzijskim momentom statičke sile u modificiranoj osteosintezi devijacija torzijskog kuta manja nego kod standardne osteosinteze. Kod modificirane osteosinteze s koštanim cementom odstupanje kuta torzije veće od 0,2 stupnja primijećeno je nakon 120 minuta, dok je kod standardne osteosinteze uočeno unutar prve minute.