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# Examination of Stability of Osteo-Syntetic Matherial By Software Bone Stimulator

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## ABSTRACT

**Introduction.** Software simulator model (SSM) is a computer program written in one of the many programming languages. Based on the given input data on mathematical biomechanical model of bones and on various osteosynthesis material models, it calculates and provides the required output results of dilatation (mm) at the site of the fracture in relation to the applied axial and a lateral force (N).

**Aim of the study.** To examine the budget voltage and deformation of the compressive forces and bending simulator software model in dynamic compression plate (DCP), dynamic locked extension compression plate (LCP), locked intramedullary nail (LIN) and Mitkovic internal fixator (MIF).

**Material and methods.** CATIA software was used to create a 3D model of the DCP, the LCP, MIF, LIN, while ANSYS (SCA) software was used for the calculation of stress and strain for the pressure and bending. The tested material was loaded by compression forces up to 500 N and bending forces up to 250N.

**Results.** Results of biomechanical tests on SCA showed that, according to biomechanical stability, LIN was in the first rank, with coefficient ranking KLIN = 0.1950. Subsequently, there was TDCP with KDCP=0.1970, MIF with KMIF=0.2238 and LCP with KLCP=0.2394.

**Discussion.** Based on the input data, mathematical model is formed and it uses the entered data, calculates and edits the required results. There is a tendency in today's world to make the standardization of software testing, so that tested results are easily applied and interpreted in scientific research purposes.

**Conclusion.** First in rank by biomechanical stability was LIN with coefficient ranking KLIN = 0.1950. Subsequently, there was DCP with KDCP=0.1970, MIF with KMIF=0.2238 and LCP with KLCP=0.2394.

**Key words:** biomechanics, dynamic compression plate, CATIA software, ANSYS.

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## Introduction

Nowadays, there are many internal and external methods of stabilization of fractures. After surgical access to the fracture, for internal stabilization, an osteosynthesis implant that stabilizes the bone fracture is used. The implants are made of bioinert metals which don't cause complications due to incompatibilities with the tissue. Nowadays, designed implants are used in a way that their construction causes minimum damage to vascularization of bones and the integrity of the periosteum.[1,2]

Osteosynthesis materials with which the internal fixation is the most frequently performed are as follows: dynamic compression plate - DCP, locking compression plate – LCP, Mitkovic internal fixator – MIF, locked intramedullary nailing – LIN.

DCP has specially designed holes for screws, whose tightening makes the fragments closer to each other, allowing the creation of axial compression. The hole for screw allows the implantation of screws at an angle up to 25°.[2]

LCP plate has screw holes similar to DCP plate, but on one side, there is threaded hole for the screw which does not allow the application of the abovementioned at the angle.

LCP panel allows the positioning of the standard screw with a spherical head, as well as newly developed safety screw with a head that is notched and is embedding in the screw holes in the panels.[3]

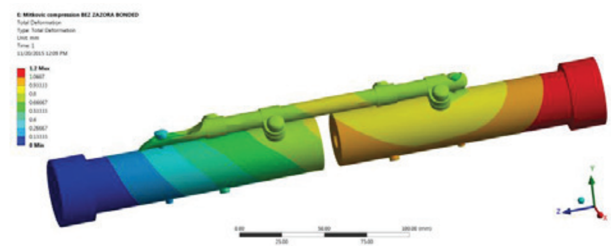
LCP panel allows a combination of standard screw with a spherical head and screw with a head that embeds, which prevents loosening between the screw and the plate better than the DCP. Screws trapped in the plate give stability without the need for the panel to be positioned on the bone.[2,3]

Mitković internal fixator – MIF is placed along the bone without the periostal of fragments and with minimal damage to soft tissue.

There are four mobile terminals that glide along the carrier. The carrier is 1 mm away from the periosteum. The terminals are fixed with screws in multiple planes. In these locations, only one internal fixator is in contact with periosteum diaphysis. Screws are placed proximally and distally to the carrier. Distally placed screws allow spontaneous dynamization.[4]

Such stability is achieved with the usage of fragments and tranquility of the focus of the fracture. With the verticalization of patients, the proximal fragment travels to the distal causing the compression among the fragments of the focus of the fracture and thus enhancing the process of osteogenesis. (Picture 1.)

**Picture 1.** Software model of Mitković internal fixator



LIN should be thick enough to create stable osteosynthesis, and the screw on the end of a nail secures the same in the cortex, preventing rotational, torsional movement between the bone fragments.

In addition to biological factors in the rehabilitation of fracture, biomechanical impact is critical in histogenesis and maturation of the callus. The broken bone is exposed to very complex sets of gravity, inertial and muscle power. Therefore, the location of the fracture is exposed to constant forces of compression, decompression, bending and torsion. This is the reason why there are different strains in the area of the fracture. What is the exact size of the dilatation of healing is not yet clearly defined, but majority of authors believe that it does not exceed 1 mm.[1-5]

Selection of osteosynthesis material to stabilize the fracture is one of the important conditions for bone recovery.[5,6]

## Aim of the study

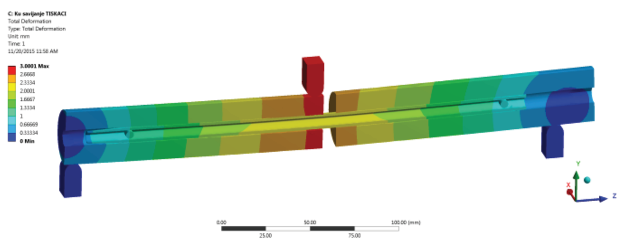
To examine the budget voltage and deformation of the compressive forces and bending simulator software models in the DCP, the LCP, LIN, MIF. Furthermore, to reach the conclusion which one, out of the studied implants for osteosynthesis software models, has the best biomechanical characteristics to stabilize the fracture.

## Material end Methods

CATIA software was used to create a 3D model, and for the calculation of stress and strain for the pressure and bending, ANSYS software was used. Stress analysis and strain analysis was performed by finite element analysis (FEA). The tested osteosynthesis material is loaded by the compression forces of up to 500 N, and bending forces to 250N. In addition, we monitored the force of deformation, which occurred due to the force of the pressure, compression or flexing, and on these bases, we evaluated stability.

Geometrically identical, anatomically shaped models with a diameter of 30 mm, length 100 mm, with a fracture crack of 10 mm were used for the experimental study. The software program contains the following values: elasticity, high elasticity, plasticity, firmness, hardness, toughness, vibration and torsion bones. These models allow identical biochemical conditions for all the tests, the tests of osteosynthesis materials. (Picture 2.)

**Picture.2. Software model of locked intramedullary nail - test inglateral force**



The ranking of various osteosynthesis materials DCP, the LCP, LIM and MIF was done specifically for the tests on the SSM model. The ranking was done by determining the minimum coefficient ranking based on the arithmetic average (mean) dilatation (stroke) in millimeters for the case of different weight coefficients of arithmetic means including: weight coefficient for the pressure Kp = 0.5; weighting coefficient for bending in one plane K1 = 0.25; weighting coefficient for bending in the second plane K2 = 0.25. The coefficient ranking for each of the tested osteosynthesis material SCA simulator was determined according to the algorithm:

$$K_i = Min_i(K_p * \overline{X_p} + K_1 * \overline{X_1} + K_2 * \overline{X_2})$$

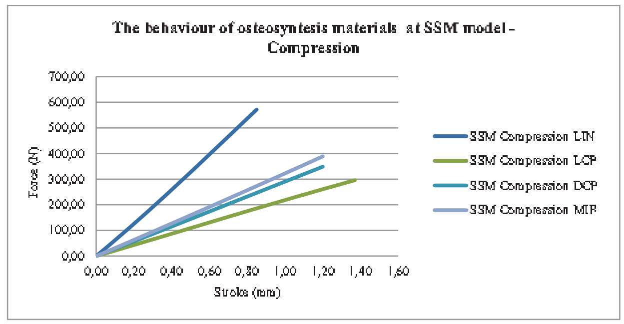
where:

- Ki – coefficient ranking each osteosynthesis materials;
- i – LIN; DCP; LCP; MIF osteosynthesis material designation;
- $\overline{X_p}$ – arithmetic average of dilatation (mm) for the pressure force;
- Kp – Coefficient of pressure force;
- $\overline{X_1}$ – the arithmetic mean of dilatation (mm) for the force bending in one plane;
- K1 – coefficient of bending forces on one plane;
- $\overline{X_2}$ – the arithmetic mean of dilatation (mm) for the force bending in the second plane;
- K2 – coefficient of bending forces in the second plane;

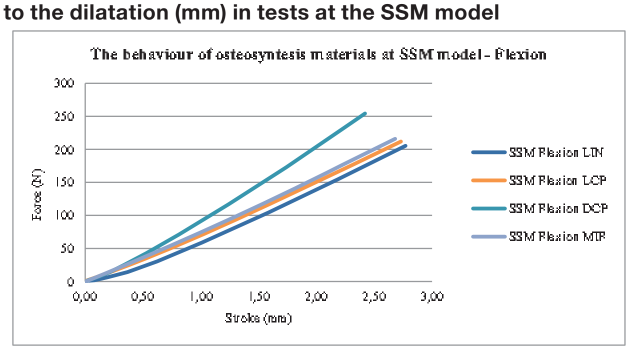
## Results

Tested osteosynthetic material was burdened by compression forces up to 500 N and bending forces to 250N. The size of dilatation (deformation) was monitored in millimeters, depending on the force of the compression (Graph 1) and lateral bending forces. (Graph 2).

**Graph 1. The distribution of the compression force (N) in relation to the dilatation (mm) in tests at the SSM model compressing forces.**




**Graph 2. The distribution of the bending force (N) in relation to the dilatation (mm) in tests at the SSM model**




Based on the weight coefficients force: Pressure Kp = 0.5; Bending in one plane K1 = 0.25; Bending the second plane K2 = 0.25, the rank of biomechanical stability of the tested osteosynthesis material was obtained. As a measurement of biomechanical stability, the arithmetic mean dilatation of the tested osteosynthesis material in relation to the force was adopted. (Table 1.)

**Table 1. Test results on the SCA Simulator software CATIA and ANSYS**

| Range | Osteosynthesis material – SSM model | Coefficient Range |
|---|---|---|
| 1 | LIN | 0.1950 |
| 2 | DCP | 0.1970 |
| 3 | IFM | 0.2238 |
| 4 | LCP | 0.2394 |

From Table 1. it is evident that the first in the ranking by biomechanical stability was LIN coefficient ranking KLIN=0.1950. Then it followed the DCP with KDCP=0.1970, MIF with KMIF=0.2238 and LCP sa KLCP=0,2394.

## Discussion

SCA SSM model is a computer program written in one of many programming languages. It describes the default input data, calculates medium and provides the required outputs. If you do not possess an original mathematical and computer simulator, in some cases, depending on what is being tested, a similar software program can be used as well. Based on the input data a mathematical model is formed and it uses the data entered, calculates and edits the required results. In today's world, there is a tendency to make the standardization of software testing, so that test results are easily applied and interpreted in scientific research purposes.[7] It used to be internal fixation with a plate which achieved absolute stability of the broken bone fragments and did not allow micro movements between fragments. Such stabilization of the fracture sometimes resulted in loosening of the implants and postponement in healing or nonunion bone.[7]

Maximum load, that is the force compression that the cortical bone of the femur adults prior fractures can bear, according to Reilly is 205 ± 17.3 Mpa or shear force is 71 ± 2.6 Mpa. Maximum load prior to the fracture the femur upon the force of the tension is 53 ± 10.7 Mpa or compression forces is 131 ± 20.7 Mpa.[8]

Energy spreads like a wave through the bone, and the speed of this wave burdens bones at about 3000 m/s. It takes 15 J of energy for fracture of the tibia diaphysis or femoral shaft fractures in adults. The energy released when a person weighing 70 kg falls to the ground from a standing position is about 500 J. The ability to absorb energy is possessed by eccentrically muscle contractions and deformation of soft tissue that prevents bone fractures in the insignificant, small declines among younger, while that is not possible in the elderly.[9]

Last in a series of "biological" novelties AO groups in Davos is LCP panel, made according to the principles of limited contact surface with the cortex. Dual form of holes and the possibility of using two types of screws is typical for the newly designed plate. Compression dynamic osteosynthesis is accomplished by classical screws and openings. Next to the classic, carved openings are placed. By the extraction of new screws into them, the panel becomes an internal fixator, and the fragments are fixed on the principle of elastic stable osteosynthesis. LCP-plate fixture can be applied to the location of the fracture classically or with minimal invasive osteosynthesis. [10]

OnurBaşcı examined biomechanical stability of femur fractures by AO classification type A1, A2, A3 with LIN and LCP in twenty one left femur from a cadaver. The first group consisted of seven femur stabilized with LCP plate, the second group, stabilized with LIN, was consisted of the same number, while the third group was consisted of seven stabilized femurs with the LCP and LIN. The group stabilized with LCP was relatively resistant to torsional load test ($p = 0.949$) when compared to the group stabilized with LIN, which was relatively more resistant to the axial compression rate ($p = 0.225$) than the group stabilized with the LCP. The third group was significantly more resistant compared to the second group in the axial ($p = 0.003$), torsion ($p = 0.008$). Thanks to its high biomechanical stability that allows early mobility, LCP and LIN in combination could be the treatment of choice in complicated A3 osteoporotic fractures of the distal femur in young people and adults.[11]

On the tibia of the sheep, Bunyamin A. and associates examined the biomechanical stability properties of longitudinal and inclined fractures. They stabilized fractures with straight and spiral DCP. This kind of stabilized fracture was exposed to a force of axial compression, bending and torsion. Statistically there was a significant difference which has confirmed that the DCP provided better stabilization. Spiral plate upon the effect of torsion forces has greater strength and resilience than the DCP plate. In vitro biomechanical studies have shown different responses under different loads. In the near future, recent biomechanical analysis may encourage the use of spiral DCP to stabilize the fracture. [12]

Experimental research on the model of the impact and movement of fragments of the femur stabilized with Küntscher intramedullary rod was conducted. Group A was stabilized with not folded Küntscher nail, while groups B and C were stabilized with folded Küntscher nail in which the free space below the trochanter major between the nail and the cortex was 100 mm. Based on the tests, there was a realization that the maximum value of displacement in the frontal plane of the distal femur was 1.86mm, while the minimum was in the sagittal plane of the proximal femur 0.08mm. Achieved values in any level, did not exceed the acceptable movement up to 3 mm in order to prevent bone consolidation. [13]

Restoration fracture was caused by a controlled axial load and micro movements. The volume of that axial load and micro movements is not yet clearly defined. With the fracture healing, it would be ideal to grow the load of the bone and reduce the load on the osteosynthesis material. This gradual change of axial load and micro movements can be achieved by using timely dynamization with the DCP, the LCP, MIF and LIN.

## Conclusion

The SSM model – SCA simulator (software CATIA and ANSYS) contains values for the following: elasticity, high elasticity, plasticity, firmness, hardness, toughness, and vibration and torsion bones. These models allow identical biochemical conditions for all the tests, the test osteosynthesis material. In today's world, there is a tendency to make the standardization of software testing, so that test results are easily applied and interpreted in scientific research purposes.

Test results of biomechanical stability on the basis of dilation on the fracture at SCA simulator showed that the LIN was the first in ranking with the coefficient ranking KLIN=0.1950, then follows DCP with KDCP=0.1970, MIF with KMIF=0.2238 and LCP with KLCP=0.2394.

LIN has a slight advantage in the treatment of diaphyseal transverse, spiral and comminuted fractures compared to the DCP, LCP and MIF.

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# Ispitivanje stabilnosti osteosintetskog materijala softverskim simulatorom kosti


## SAŽETAK

**Uvod.** Softverski model simulatora (SCA) je računarski program pisan na jednom od mnogobrojnih programskih jezika. Na osnovu zadanih ulaznih podataka na matematičkom biomehaničkom modelu kosti i na modelima raznih osteosintetskih materijala, on izračunava i daje tražene izlazne rezultaze o diletaciji (mm) na mjestu preloma u odnosu na primjenjenu aksijalnu i bočnu silu (N).

**Cilj rada.** Istražiti proračun napona i deformaciju na sile pritiska i savijanja na simulatoru softverskog modela kod dinamičko kompresivne ploče (DCP), dinamičko kopresivne zaključane ploče (LCP), intermedularnog zaključanog klina (LIN) i unutrašnjeg fiksatora po Mitkoviću (IFM).

**Ispitanici i metode.** Za izradu 3D modela DCP, LCP, IFM, LIN, korišten je softver CATIA, a za proračun napona i deformacija za pritisak i savijanje, softver ANSYS (SCA). Ispitivani materijal opterećen je silama kompresije do 500 N i silama savijanja do 250 N.

**Rezultati istraživanja.** Rezultati biomehaničkog ispitivanja na SCA pokazuju da je, po biomehaničkoj stabilnosti, na prvom mjestu LIN sa koeficijentom ranga KLIN=0,1950. Zatim slijede DCP sa KDCP=0,1970, IFM sa KIFM=0,2238 i LCP sa KLCP=0,2394.

**Diskusija.** Na osnovu ulaznih podataka, formira se matematički model koji korištenjem unesenih podataka izračunava i edituje tražene rezultate. U svijetu je danas tendencija da se napravi standarizacija softverskog ispitivanja, kako bi se ispitivani rezultati mogli jednostavno primjenjivati i tumačiti u naučno-istraživačke svrhe.

**Zaključak.** Prvi u rangu po biomehaničkoj stabilnosati je LIN, sa koeficijentom ranga KLIN=0,1950. Zatim slijede DCP sa KDCP=0,1970, IFM sa KIFM=0,2238 i LCP sa KLCP=0,2394.


**Ključne riječi:** biomehanika, dinamičko kompresivne ploče, softver CATIA i ANSYS.