A comparison of efficacy of femoral and tibial fractures healing treated by static and dynamic intramedullary nails

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Abstract

Introduction: Intramedullary nailing is synthesis and consolidation of fracture fragments with the main goal to gain strength and permanent placement of the implants. Two techniques of intramedullary osteosynthesis are used: with dynamic or with static intramedullary nail. Dynamization include conversion of static nail by removing screws from the longest fragment.

The aim of this study is to determine whether there is a difference in the speed and quality of healing of the type A and B fractures of the femur and tibia treated by static or dynamic intramedullary nails and to compare the results.

Methods: The study was conducted on a total of 129 patients with closed fractures of the diaphysis of the femur and tibia type A and type B. Patients were divided into two groups, based on the applied operating method, static or dynamic intramedullary osteosynthesis.

Results: The average number of weeks of healing femoral and tibial fractures was slightly in advantage of static intramedullary osteosynthesis, it was 17.08 weeks (SD=3.382). The average number of weeks of healing in 23 patients with fractures of the femur, treated by dynamic intramedullary osteosynthesis was 17.83 (SD=2.978).

Conclusion: We can conclude that static intramedullary nailing osteosynthesis unable movements between fragments which directly stimulates bone formation and formation of minimal callus. Static intramedullary ostesinthesys resolve the problem of stabilizing the fracture, limb shortening and rotation of fragments.

Keywords: fracture healing, intramedullary nailing, dynamic and static intramedullary nail.

Introduction

In 1943 Bohler said that the installation of the nail in the bony canal is osteosynthesis that will be used in a future. Indication for osteosynthesis with intramedullary nail are fractures of the middle part of the long bones, most of the transverse and short oblique fractures, mostly of femur and tibia. This kind of stabilization has three main advantages :

1. Closed fractures can be treated in a closed technique, i.e. without additional exposure of fragments and damage of soft tissues. Circulation supply of the fragments remains fully sustained, and it's expected bone to heal in a similar way as by the non surgical treatment. The incidence of infection with this technique of osteosynthesis was significantly reduced.
2. Early stability and early function of extremities are achieved by axial (biomechanically optimal) use of implants, in favorable circumstances; the patient will be mobilized almost immediately after surgery.
3. Third, which occurs regularly, are loosening nail into the medullary canal within a few months of use, thus encourages formation of biological callus growth and fracture crack that gradually accepts on greater force. The exception to this rule is statically embedded nail.

The ideal goal in intramedullary nailing osteosynthesis is achieved when the nail is inserted with elasticity in both fragments. The greater the

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area of contact between the implant and the inner cortical means greater stability of the complex, and thus a better stability of the fractured fragments. The last model of intramedullary nail has the shape of three-leafed clover with longitudinal slit, and so far it is the optimal solution. Also in addition, it is possible ingrowth of new blood vessels from the medullary canal. It is especially significant technological solutions - the top of the nail has a conical shape and breakthrough medullary canal, but also prevents notching the nail in the cortex during guidance through the medullary canal. At the other end is a separate opening in which the instrument hooks during the extraction of the intramedullary nails. There are different lengths and thicknesses of intramedullary nails, and its width is 0.9 to 1.0 mm. For each region there are special instruments. Intramedullary nailing osteosynthesis requires adequate technical conditions-instruments, x-rays in the room with one or two monitors, adequate operating table, experienced radiological technician, it is necessary that the patient is in the right position to do reposition of fractured fragments (1). Nowadays two techniques are mainly used, with static and with dynamic intramedullary nails: *Static intramedullary nails* use additional fixation with screws, which are inserted into the proximal, distal, or at both ends of the nail. When the nail is stabilized with screws at each end of nail, then fixation is static (2). This method avoids the problems losing of fixation, stabilization, shortening, rotation that occur in plain intramedullary nail. Axially unstable fractures are best treated by static intramedullary nailing. The most common indication for the locking pin is comminuted fractures. *Dynamic intramedullary nails* are used in axially stable fractures of the bone and as well as in delayed bone healing process. Dynamic intramedullary nail has two screws, in the distal fragment and in the proximal fragment one screw which is axially movable by longitudinal slot in the implant. Dynamic intramedullary nail control bending and rotational deformity of the bones and implants, but the main advantage is to provide almost complete transfer of axial pressure on the bone fragments. "Dynamization" is a process of converting static intramedullary osteosynthesis into dynamic intramedullary osteosynthesis. Dynamization requires removing farthest screw, 10-16 weeks after surgery. Earlier it was considered that the task of dynamization is to promote callus remodeling. Today's latest experimental studies and clinical studies do not consider dynamization as mandatory; some consider it detrimental to the healing time and frequent occurrence of limb shortening after dynamization. Majority believe that dynamization is necessary only in those cases where there is a permanent gap between the fragments, and the conversion from static to dynamic fixation is rarely necessary, especially in fractures of the femur (3). Preoperative planning and measurement of implants should be performed on radiography of the bone that is not injured. TMD method is the best, cheapest and most accurate of all methods in determining nail length (the tibial tubercle-medial malleolar distance - distance between the highest points on the medial malleolus of tibia and tibial tubercle). Diameter of nail is assessed by measuring the tibia or femur on the tightest spot of medullary canal, which can be determined on lateral radiographs. There are two types of intramedullary nails, rimmed and non rimmed type. Those who support non rimmed type of nails, highlight maleficent effects such as fat embolism from bone marrow into the lungs. This effect is not clinically significant in most patients; some authors suggest that the development of pulmonary complications may further connect with the associated chest injuries than with rimming of medullary canal. Potential advantages of non-rimmed technique over rimmed nail technique include shorter time of surgery, less blood loss and less disruption of endosteal blood supply in patients with severe closed injuries of soft tissues. Nowadays mostly it is preferred rimming technique and applications of rimmed type of nails, where there is no present significant damage of soft tissues. Rimming type of nails enables application of stronger implants with larger diameter. Non rimmed nail insertion usually requires nails with a diameter of 8-10 mm, depending on the medullary canal diameter and cannot be used in patients with medullary canal narrower than 8 mm. Application of intramedullary nail in the short tubular bones of wrist and feet is a failure. Setting intramedullary nails in children contraindicate due to open epiphyseal growth plates. The aims of this study is to determine whether there

is a difference in the speed and quality of healing of the simple fractures of the femur and tibia of type A and B treated by static or dynamic intramedullary osteosynthesis and to compare the results of healing of fractures of the femur and tibia treated by static or dynamic intramedullary osteosynthesis.

Methods

The study was conducted at the Clinic for Orthopaedic and Traumatology, Clical Center University Sarajevo from January 2004 to June 2009. The study was retrospective-prospective, manipulative, controlled. The study was conducted on a total of 129 patients with closed fractures of the diaphysis of the femur and tibia type A and type B, with different segments of bone, regardless of sex and age structure, with the exception of children under 14 years of age. Precisely there were 47 patients with femoral fractures and 82 patients with tibial fractures. Patients were divided into two groups, based on the applied operating method, static or dynamic intramedullary osteosynthesis:

1. Patients with fracture of the femur or tibia treated with static method of intramedullary nailing, where the static intramedullary nail fastened cross screws (3 or 4 screws) on both ends, and by that controls the axial and rotation instability and bending (24 patients with femoral fractures and 58 patients with tibial fractures)
2. Patients with fracture of the femur or tibia treated with dynamic method of intramedullary osteosynthesis (or patients whom had performed "dynamization"), which allows the complete axial pressure with control of bending and rotation.

By applying of intramedullary nail, it is important to achieve elastic fixation of long flexible fragment of long tubular bones, and so that only the shorter fragment is fixed with two transverse self-tapping screws for intramedullary implant. Mainly is used for axial stable nonunion fractures and bone (23 femoral fractures and 24 tibial fractures). Diagnostic performance of fracture healing of femur and tibia treated by static or dynamic intramedullary osteosynthesis is carried out at regular intervals, based on clinical and radiographic assessments. Clinical signs of healing, the rigidity and the absence of crepitation at the site of the fracture, the absence of pain at the site of the fracture during palpation and rough percussion, and absence of pain in full support and a walk, in comparison with the radiographic analysis that was performed in a study by Corrales, Morshed, Bhadari and Miclauie, the presence of cortical bypass on three of the four cortical fracture gap, are the definitive signs that process of fracture healing has finished at a median of three independent examiners. The percentage of identical or different answers that are presented in tables is directly dependent on several factors, primarily the experience of physician-investigator, technical conditions (quality radiograph, quality negatoscope, the light in the room where the examination is being conducted), the possibilities of perception (sight), stress, etc. The study was retrospective-prospective, manipulative, controlled. T-test was performed for analysis of statistically significant difference between groups. The research results are presented as absolute and relative values.

TABLE 1. Clinical and radiographic signs of fracture healing

HISTOLOGICAL SCALE (COMPLETE BONE FORMATION =10) TISSUE CALLUS DIFFERENTIATION				RADIOGRAPHIC SCALE OF CALLUS FORMATION IN FRACTURE GAP	
WITHOUT CALLUS	0	BLOOD CLOT AND GRANULATION TISSUE	0	WITHOUT CALLUS	0
SMALL TO MEDIUM CALLUS	1	FIBROUS CONNECTIVE TISSUE	1	SMALL TO MEDIUM CALLUS	1
MASSIVE CALLUS TISSUE	2	CONNECTIVE CARTILAGE TISSUE	2	MASSIVE CALLUS TISSUE	2
BRIDGING PERIOSTEAL CALLUS	3	APPEARANCE OF BONE	3	BRIDGING PERIOSTEAL CALLUS	3
MATURE CALLUS WITH INTRAFRAGMENTARY BAYPASS	4	FULLY BONE FORMATION	4	MATURE CALLUS WITH INTRAFRAGMENTARY BAYPASS	4
AFTER OWERGROWING CALLUS RESORPTION	5	COMPLETE RESTORATION OF DYAPHYSIS	5	AFTER OWERGROWING CALLUS RESORPTION	5

Results

According to the results of clinical and radiological study conducted by three independent examiners, the average number of healing of fractures of the femur and tibia expressed in the weeks go slightly in advantage of static intramedullary osteosynthesis and it was 17.08 weeks with a standard deviation of 3.382. The average number of weeks of healing in 23 patients with fractures of the femur, treated by dynamic intramedullary osteosynthesis was 17.83, with a standard deviation of 2.978. The difference in the number of weeks of healing of fractures of the femur, depending on the type of nail (dynamic-static) was not statistically significant. Value of t-test is: t = 0.897. According to the results, average number of weeks of bone healing of the tibial fractures were 14.02 in 82 patients treated with rimmed intramedullary

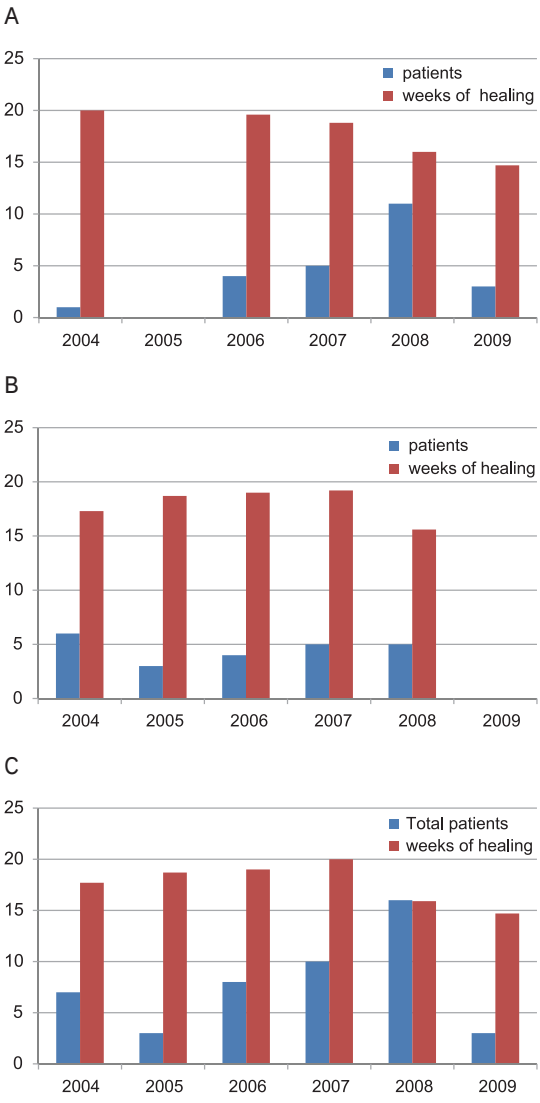

FIGURE 1. The average number of weeks of femoral fracture healing presented by the type of nail. (A) Patients treated by static indramedullary osteosynthesis. (B) Patients treated by dynamic indramedullary osteosynthesis. (C) Total number of treated patients.

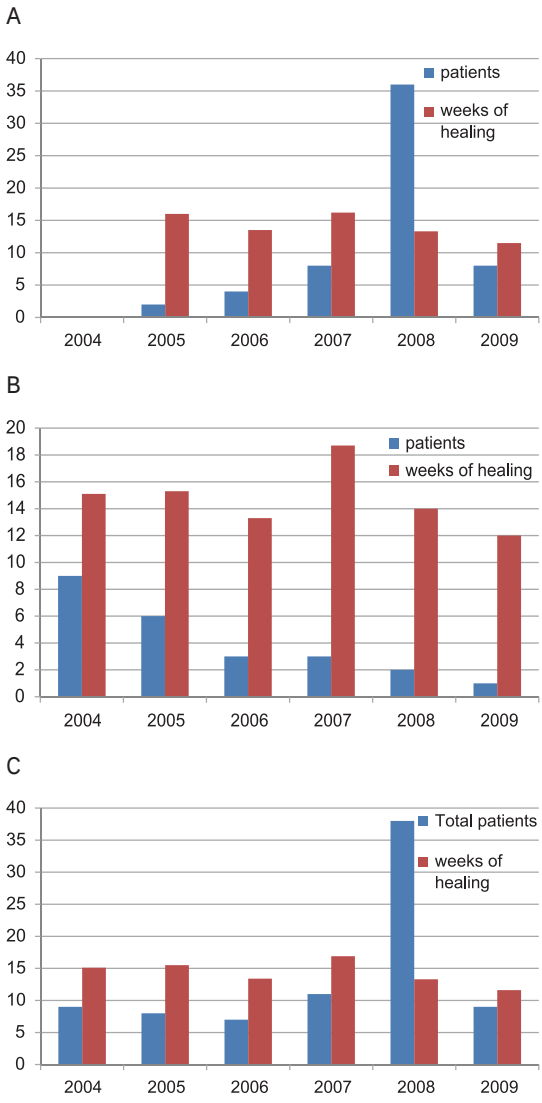

FIGURE 2. The average number of weeks of tibial fracture healing presented by the type of nail. (A) Patients treated by static indramedullary osteosynthesis. (B) Patients treated by dynamic indramedullary osteosynthesis. (C) Total number of treated patients.

TABLE 2. The average number of weeks of femoral fracture healing by a nail.

YEAR OF OPERATION	NUMBER OF PATIENTS	AVERAGE NUMBER OF WEEKS OF BONE HEALING	STANDARD DEVIATION SD
STATIC NAILS:			
2004.	1	20,0	0
2005.	-	-	-
2006.	4	19,6	5,196
2007.	5	18,8	3,633
2008.	11	16,00	1,789
2009.	3	14,67	2,309
TOTAL	24	17,08	3,382
DYNAMIC NAILS:			
2004.	6	17,33	2,665
2005.	3	18,67	2,309
2006.	4	19,00	3,464
2007.	5	19,20	3,033
2008.	5	15,6	3,847
2009.	-	-	-
TOTAL	23	17,83	2,978
TOTAL FEMUR STATIC + DYNAMIC			
2004.	7	17,71	1,982
2005.	3	18,67	2,309
2006.	8	19,00	4,242
2007.	10	19,99	3,00
2008.	16	15,87	2,39
2009.	3	14,67	2,31
TOTAL	47	17,44	3,04

TABLE 3. The average number of weeks of tibial fracture healing by the type of nail.

YEAR OF OPERATION	NUMBER OF PATIENTS	AVERAGE NUMBER OF WEEKS OF BONE HEALING	STANDARD DEVIATION SD
STATIC NAILS:			
2004.	-	-	-
2005.	2	16,0	0
2006..	4	13,5	13,43
2007.	8	16,25	2,49
2008.	36	13,28	4,38
2009.	8	11,5	3,66
TOTAL	58	13,55	2,89
DYNAMIC NAILS:			
2004.	9	15,11	2,47
2005.	6	15,33	3,27
2006.	3	13,33	2,31
2007.	3	18,67	4,62
2008.	2	14,0	8,48
2009.	1	12,0	0
TOTAL	24	15,17	3,46
TOTAL TIBIA (STATIC + DYNAMIC)			
2004.	9	15,11	2,47
2005.	8	15,5	2,60
2006.	7	13,43	3,659
2007.	11	16,91	3,48
2008.	38	13,32	4,33
2009.	9	11,56	3,26
TOTAL	82	14,02	3,17

nailing. Of this number, 58 were treated with a static intramedullary nail with an average healing time of 13.55 weeks, and 24 treated with dynamic intramedullary nail with an average healing time of 15.17 weeks. The difference in the number of weeks of tibial fracture healing, in dependence of the nail (dynamic-static), it was significant. Value of t-test is: $t = 2.227$, level of significance of $p < 0.05$.

Discussion

Intramedullary nail provide fragments stability and contributes to the process of osteogenesis. Biomechanical role of intramedullary nails is to keep the bone fragments in a good correlation, but also to prevent torsion and shear forces. It was considered that in a given moment should be provided an axial load transmission through the bone and fracture by the phenomenon of "dynamization", which accelerates osteogenesis by allowing micro-movements at the site of the fracture process, explanation was that the axial movements of fragments reduces fracture area, accelerates fracture callus maturation and remodeling of bone. Such recommendations for "dynamization" or converting static to dynamic intramedullary nailing for us surgeons are still unclear. It's constant dilemma, is the "dynamization" still needed, and when is the real indication and the optimal time for performing the same. Legacy of the 80's recommends to convert static into the dynamic form of intramedullary osteosynthesis in the period of 10-16 weeks, when the fibrous callus provide stability of the bone fragments, while other authors believe this procedure is unnecessary

or even harmful. Infections associated with implants for osteosynthesis according to the literature generally occur with prevalence of 5-10% (4). On the other hand it can be said that perfect intramedullary nail has not yet been designed. The assumption of stable ostesinthesys is the strength and permanent position of the implant that is well tolerated by the tissues. The objective of such osteosynthesis is a direct angiogenic bone formation in conditions of absolute stability of the fragments and good vascularization. The fact is that healing of cortical bone of the femur and tibia and begins periosteal and endosteal. A review of available literature and published articles, we found limitations in the number and quality of studies published in longitudinal evaluations of available radiological and clinical methods for detailed analysis of the processes of bone healing (4). Also, we found that lack of consensus among orthopedic surgeons in terms of the definition of fracture healing. Without valid and reliable indicators of clinical and radiological signs of fracture healing, the interpretation of the fracture treatment success is difficult (5) The question is, which method is the most commonly used to evaluate the healing of long bones? Grigoryan and associates in their study tried to assess the quantitative and qualitative characteristics of bone healing using volumetric computerized tomography (CT) and to compare the results obtained by conventional radiological methods to assess healing of long bones (4) McClelland and associates in their study made a comparison between radiological assess fracture healing and strength measurements (stiffness) of the layout (6). According to the method in which we are committed in this study, the author Corrales Morshed, Bhandaria & Miclaua shows the qualitative and quantitative fracture healing (3). Radiological Assessment of healing of fractures of the femur and tibia "cortical bridging" is based on data estimates healing each of the 4 cortical bone (anterior, posterior, medial and lateral) with a record of time until the appearance of callus, the time to the occurrence of mature callus fracture lines and loss of fracture line at different stages fracture healing, performed by three independent examiners (6 ; 1 ; 7). In our study it was reported an average of 73.64% of identical responses and 25.58% of different answers. Radiological assessment of fracture healing may be supplemented with bone densitometry and by measuring ultrasonic transmission. In certain cases of large callus due to the "fracture movements" it is possible to make additional mathematical processing generated callus summarized with clinical and radiological signs of fracture healing. Our research can be divided into the period of 2004-2007. when the results are summarized by the examiner, and was a retrospective study, and research since 2008. until the second half of 2009, which was a prospective study. As can be seen from the tables, the number of patients treated surgically with fractures of the femur or with tibial fracture of each year has increased, especially those treated with static intramedullary osteosynthesis. According to the results of clinical and radiological study conducted by three independent examiners, the average number of healing of fractures of the femur and tibia expressed in the weeks go slightly in favor of static intramedullary osteosynthesis and it was 17.08 weeks with a standard deviation of 3.382. The average number of weeks of healing in 23 patients with fractures of the femur, treated by dynamic intramedullary osteosynthesis was 17.83, with a standard deviation of 2.978. Significant is that the fractures are of type 3 2 A and 3 2 B according to the AO classification, had a slightly faster flow of healing in patients treated with intramedullary nailing with static method, which is in line with research Brumback, who investigated the healing of 87 shaft fractures of the femur with static intramedullary nails and scored bone healing in 98% of cases without translation into static dynamic intramedullary nailing. Similar research by D.Tigani, M.Favisini C.Stagni r: S.Boriani Pascarella, in a series of 179 closed fractures of the femur, has shown that the time to bone healing was significantly shorter in the that were treated with static intramedullary nail (103 days) compared with those treated with dynamic intramedullary nail (126 days). Another study conducted over a period of about 20 years in Bologna (Rizzoli Orthopaedic Institute and Hospital Pizzardi Maggiore Italy), showed that the bone healing time was shorter than in the group of patients were dynamization was not performed. According to the conclusions from the study by Wu and Chen, only half of segmental fractures of the femur with per-

formed "dynamization" has been successful, and they have suggested the use of bone grafting to fill spaces between the bone fragments for faster healing. Intramedullary nailing is basically designed for the reduction and stabilization of closed fractures of the femur and tibia, while fully preserving periosteal vascularization and soft tissue (1,7). Our research from 2004 until the second half of 2009. showed average of 14.02 weeks of bone healing of the fracture of the tibia in 82 treated with rimmed intramedullary nailing. Of this number, 58 was treated with a static intramedullary nail with an average healing time of 13.55 weeks, and 24 treated with dynamic intramedullary nail with an average healing time of 15.17 weeks. In this way, it was found out that the dynamic intramedullary nailing, or "dynamization", are indicated only with fractures of tibia, where there is a permanent gap between the bone fragments and with a reasonable risk of shortening and changes in axis of extremities, often breaking of screws or /and of whole nails, and it was confirmed in already published studies by Wayne State University, Department of Orthopedic Surgery, Detroit-Michigan from November 1986, as well as in study by Dagrenate in the late 80-ies and his in vivo experimental study. What this research has definitely been sort out in relation to similar studies is that all fractures of the femur and tibia healed in a very short time, if they were perfectly operatively treated in an optimal time by an experienced operating team in strict compliance with the indications, and where the fragments diastasis were less than 0.2 mm. Necessary transformation to higher levels of care, with a well-trained surgical and monitoring team (anesthesiologist, instruments, support staff, operating rooms, a physiatrist and physiotherapist) and secured the technical conditions for the operation, make the optimum conditions for carrying out the method of osteosynthesis. This team has to be continuously available from the existing staff, with compulsory continuous training. The results of this study showed that adequacy of our suspicions of doctrinal conduction "of dynamization", and additional hospitalization for surgery, of "static screw" removal in the period of 10-16 weeks. The significance is the same only in those cases where there is a bone fragment diastasis greater than 0.2 mm, and the conversion itself is rarely necessary in fractures of the femur. In the end, we would say that the study of treatment of fractures of the femur and tibia by static and dynamic intramedullary osteosynthesis showed all the good effects of early stabilization of fractures in relation to morbidity and length of hospitalization. The guarantee of success and quality of healing of fractures of the femur and tibia, treated by static and dynamic intramedullary osteosynthesis are proven low incidence of infection, high stability and strength of the fragments, the possibility of early mobilization of the patient with preservation of soft tissue and peripheral circulation.

Conclusions

Static intramedullary nailing unable movements between fragments which directly stimulates bone formation and formation of angiogenic minimal callus with sharp edges and a dense structure. Also static intramedullary ostesinthesys resolve the problem of stabilizing the fracture, limb shortening, rotation of bone fragments are the best recommendations for treatment are comminuted fractures. Dynamic intramedullary opsteosinethesys use of force on the fracture, causing bone resorption and thus looseness implants due to mechanical instability, which creates large (stimulus) callus with vague contours and turbulent structure.

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