New concept in external fixation

A new concept in external skeletal fixation is presented. A 3D unilateral system developed by Mitkovic has widely been investigated biomechanically in AO institute in Davos (Switzerland). Consists of three components only providing extremely simple application and dynamic fixation of bones and different joints. This simple external fixator functions as an accurate reduction device at the same time, minimizing need for fluoroscopy. Clinically this system has been applied to mere then 13 thousand patients in 43 clinics. This paper presents the results of its application for treatment of open fractures, war wounds with fractures and for comminuted and intraarticular closed fractures in the series of 597 patients. Overall average time for union time was 3.2 months. Overall success of fracture healing was 96.8% including open and closed fractures. Our study suggests that the use of this 3D unilateral system is suitable for routine use.

Key words: fracture, external fixation, Mitkovic external fixator, war wounds, nonunion

INTRODUCTION

During the last 30 years, external fixation using pins has usually been referred to as two-dimensional (2D) systems where all pins constituting one cluster of pins are in a single plane. If pins are parallel, as in most conventional external fixation devices, than anteroposterior (AP) and lateral (LL) stability are not balanced. Such a system is very stable in the plane of the pins but unstable in the perpendicular plane. The bending stiffness of human long bones has a balanced AP:LL ratio. Human tibia has higher stiffness in AP direction than in lateral direction. So 2D systems have opposite biomechanical features in comparison to biomechanical characteristics of human tibia. The disadvantage of the application of external fixators with parallel pins, which have to be at an accurate distance between each other at the same time, is that it is necessary to use special guidance. External fixation has become an important tool in treating polytraumatised patients. Closed reduction and decrease in fluoroscopy time are increasingly desirable in modern orthopaedic surgery. Intraarticular fractures are a problem and joint motion is desirable as soon as internal fixation is achieved. After 10 years of dynamic research in the field of external fixation, first author (MM) developed, in 1990*, one three-dimensional unilateral external fixation system that provides balanced three-dimensional stability, comparable to the natural stability of the long bones but more elastic. It has been applied to more than 13 thousand patients for management of peace and war fractures. Now we have competent results which can be useful for readers. * Mitkovic (registered trademark 1992)

MATERIAL - METHODS IN BIOMECHANICAL TESTING

The 3D external fixation system (Figs. 1 and 2), consists of three components: bar, carrier of the clamp and adjustable clamp. The system is highly mobile allowing 3D correction of any dislocation. High mobility is provided by the use of a new, original concept. Compression and distraction can be performed using removable compression-distraction device. High mobility of this system allows construction of frames for dynamic fixation of joints, without any additional component. This chess-like versatility enables surgeons to create frames according to the bone and soft tissue status. The pins are self-tapping and self-drilling in epiphysal and metaphysal areas; while predrilling is required in diaphysal area. The diameter of the pins is 6 mm; while the diameter in tread area can be 6 mm (for the femur and the tibia) and 4.5 mm (for the humerus). For forearm and children, a smaller size of the same fixator with 3.5 mm pin diameter is available.
Biomechanical investigations of this fixator have been performed in the AO institute in Davos (Switzerland). Two frames, from the same components of the same system were tested: one with conventional configuration (parallel pins in one plain) and second, using three-dimensional unilateral frame with 90-degree convergent orientations of the pins. The frame configurations were subjected to separate axial, torsion and bending loads by using 4-point bending test method on the “Instron” machine.

MATERIAL AND METHOD IN CLINICAL STUDY

Clinical material This study presents a series of 597 patients who sustained fresh fractures treated in Orthopaedics and Traumatology Clinic in the Clinical Centre Nis and in the Institute for Orthopaedic Surgery, Clinical Centre Belgrade, during the period of 2 years (1999-2001) with a follow up from 2-5 years (mean 3.8 years). Four hundred and fourteen were men and 173 were women. The average age was 32.6 years. A single fracture was present in 386 patients and 206 had multiple injuries. There were 231 closed fractures 361 open ones. Among open fractures, 312 were sustained in peace circumstances and 49 were war wounds with fractures. A successful result implied healing with less than 50 of angular or rotation deviation and less than 1 cm of shortening, the patient being fully capable of weight bearing without external support and having a full range of associated joint motion.

METHOD OF APPLICATION

Each pin is inserted independently, without any guidance or template. Distances and angles between pins are not limited and can be chosen according to the actual situation on the bone fragments and soft tissues. Convergent orientation of the pins (60°-90°) is desirable because of biomechanical advantages. Mitkovic external fixator system, itself is used as an accurate reduction device as well (technique not shown here).

RESULTS

In biomechanical testing, the frame with parallel pins (2D) has shown non-balanced AP:lateral stability, whereas AP displacement during 4-point bending test was 2.499 mm at 250 N force; and lateral displacement during 4-point bending test was 0.912 mm at 250 N force. The ratio was AP:lateral=1:2.74. Axial displacement was 2.932 mm under the axial loading of 200 N. Maximal torque during the loading of 10 Nm was 10.122 degrees. Frame with 90-degree convergent orientation of the pins (3D) has shown balanced AP:lateral stability; whereas AP displacement during 4-point bending test was 1.901 mm at 250 N force; and lateral displacement during 4-point bending test was 2.108 mm at 250 N force. The ratio was AP:lateral=1.1:1. Axial displacement was 1.801 mm under the axial loading of 200 N. Maximal torque during the loading of 10 Nm was 10.382 degrees. Torque stability was similar in all frames.
In clinical results, the overall success of fracture healing was 96.7%, including open and closed fractures. The rate of healing of fractures on different segments is shown in Table 1. Analysis of patient x-rays revealed periosteal callus formation circularly equally distributed around the fracture area. In 49 war wounds with fractures, all fractures healed. In 2 cases with 5-8 cm defect on the tibia, sliding graft using the same external fixator with removable compression-distraction device has been performed without complications. One of routine case is shown in fig. 3. Complications Pin-track infection occurred in 22 pins out of 2,723 (0.8%). Removal of the fixator because of pin-track infection has been performed in 5 patients (4 from the tibia and 1 from the femur) and treatment has been successfully completed using Sarmento bracing. There were 19 aseptic non-unions. As a non-union we assessed a fracture without healing after 6 months for the tibia, 7 months for the femur and 5 months for the radius and the ulna. Of 15 non-unions of the tibia, 9 have been solved using cancellous bone graft and 6 by removal of external fixator and bracing. All four non-unions of the femur (2), radius (1) and ulna (1) have been solved by conversion of external fixation to plating and cancellous bone grafting. There were 11 cases of joint stiffness (1.8%); 9 were resolved with physiotherapy and 2 had acceptable knee stiffness with motion range of 30° and 40° respectively. Four late angular deviations occurred after fixator removal, 2 in the upper femur and 2 in the distal tibia, all after comminuted fractures. Femoral angular deviation was corrected by internal fixation and tibial angular deviation was corrected by external re-fixation. Re-fractures occurred in 5 patients (0.8%). Three of them healed in plaster cast within 2 months, and two after new external fixation. Thus, there were 42 (7.0%) overall complications. Fracture treatment by means of 3D system was assessed as failure in 19 cases (3.3%). Of 49 war wounds with fractures, in 2 patients (4.08%) the result was assessed as failure because of knee stiffness after femoral fractures. There was no chronic osteitis.

DISCUSSION

External fixation, using high mobile devices, enables easier and less invasive fracture reduction and fracture fixation in comparison to internal fixation or external fixation by means of less mobile devices. Bone healing is much better monitored and achieved by means of external fixator. The main disadvantages of external fixation are pin-track infection and patient discomfort. New improvements of intramedullary fixation have been achieved recently, but, in the field where internal fixation is contraindicated, external fixation remains method of choice in providing optimal biomechanical conditions for bone healing. As fractures become increasingly complicated today, with comminution, intraarticular involvement, ipsilateral bone segments fractures, soft tissue damage etc., temporary support by means of external fixation is more and more often required, thus widening indications for external fixation. As it is widely recognized, usage of axial dynamisation of external fixation devices has brought progress in fracture treatment. Conventional external fixation devices with parallel pins either cannot provide freedom for independent application of the pins or secondary fragment dislocation may occur so that cementing of the articulating component is recommended as for Orthofix system. AO fixator using tube-to-tube frame can provide independent pin application but no single conventional device can provide articulated frame for different joints, without additional components, and be an accurate reduction device at the same time. Dynamic external fixation of joints, in cases of intraarticular fractures, is a promising method but has not been in widespread use so far. One of the main reasons is that there are only few such devices. External fixation system, shown in this paper, comprises 3 components only, but this system provides possibilities for dynamic frames to be created for different joints. It has been proven clinically, especially for the ankle, wrist
and elbow application. This system provides three-dimensional freedom for each pin application - in any direction and at any distance. The direction of pin application is not limited by external fixator itself. This feature provides easier and quicker application in comparison to other existing external fixation systems. In addition, two or more frames of this system can be connected dynamically, allowing joint motion and consequently better vascularisation, cartilage preservation and better fracture healing. This system, in wide routine use in many centres, has been applied in more than ten thousand five hundred patients so far. In the course of the past 8 years in wars in the territory of former Yugoslavia, it has been widely used in many centres as the main "War fixator". Grubor published series of five thousand external fixations of war wounds with fractures using 20 different conventional external fixation devices during the war in Bosnia and Herzegovina. He mentioned that four thousand of these 5000 fractures were treated by "Mitkovic" external fixator, concluding that this system was the most suitable from biomechanical and practical points of view. The design and 6-mm diameter of the pins decrease pin-tract infection whose complications rate has been relatively low (0.8%). The biomechanical characteristics provided by this external fixation system, including balanced 3D stability similar to the natural biomechanical characteristics of the long bones (4) but more elastic, and the possibility of axial dynamisation, provide shorter healing time and the high level of success (96.8%). The AP/lateral stiffness ratio, in the case of single-plane fixators (2D), is opposite in comparison to AP/lateral stiffness of the human tibia because this frame is less stable in AP then in lateral direction. Since this system is simultaneously versatile, extremely simple for application and management and provides biomechanical conditions similar to the natural biomechanical features of the long bones resulting in a high rate of fracture union in clinical practice, this system is very suitable for treatment of different types of open and closed fractures including complex fractures. This external fixation system has been copied by Aleksandar Tosic and broccoli by the design and 6-mm diameter of the pins decrease pin-tract infection whose complications rate has been relatively low (0.8%). The biomechanical characteristics provided by this external fixation system, including balanced 3D stability similar to the natural biomechanical characteristics of the long bones (4) but more elastic, and the possibility of axial dynamisation, provide shorter healing time and the high level of success (96.8%). The AP/lateral stiffness ratio, in the case of single-plane fixators (2D), is opposite in comparison to AP/lateral stiffness of the human tibia because this frame is less stable in AP then in lateral direction. Since this system is simultaneously versatile, extremely simple for application and management and provides biomechanical conditions similar to the natural biomechanical features of the long bones resulting in a high rate of fracture union in clinical practice, this system is very suitable for treatment of different types of open and closed fractures including complex fractures. This external fixation system has been copied by Aleksandar Tosic and brought in USA 1996, to be produced under his name (Tosic) without permission or apology to the inventor Mitkovic, who has published his invention in European patent bulletin with priority from 1992.

CONCLUSION

From the success obtained in the treatment of war fractures, 13 Orthopaedic surgeons, having used 20 different conventional external fixation systems, have concluded that 3D external fixation system shown in this paper was the most suitable system for treatment of massively injured people such as in war situations.

REZIME

U radu se prikazuje novi koncept u spolnoj fiksaciji i aparat za spolnu fiksaciju u koji je detaljno ispitano u AO institutu u Davosu (Svajcarska). Ovaj uređaj poznat kao spoljni fiksator Mitkovic sastoji se samo od 3 komponente i obezbeđuje krajnje pojednostavljenu primenu i dina-


