

**STIFFNESS AND STRENGTH OF EXTERNAL SKELETAL FIXATOR FOR
ORTHOPEDIC TREATMENT OF ANIMALS**

By

LIM KOK JENG

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirement for the Degree of Master of Science**

March 2006

Dedicated to

*My Loving Parents and my dear brothers for their endless care and
comfort,*

Thank You

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

**STIFFNESS AND STRENGTH OF A MODIFIED EXTERNAL SKELETAL
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October 2006

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Faculty: Engineering

This study outlines the design of a cost effective external skeletal fixator which can be implanted on small animals. A modification for a commercially available Universal Mini External Fixator (UMEX™) has been done on the biomechanical performance by using a cadaver canine tibia.

The constituents of the design of the prototype system include a connecting bar (200 mm long and 6 mm in diameter), clamp I (dimension size in 20x10x10 mm), clamp II (dimension size in 10x10x10 mm), and transfixation pin (150 mm long and 4 mm in diameter). A negative profile partially threaded pin was designed because it is cheaper to manufacture.

For this experimental bone testing, 80 canine tibia bones harvested from 40 canines were collected from the Centre for Protected Animals in Setapak, Kuala Lumpur. All the tibia bones were freshly harvested within 2 hours, frozen and then thawed just prior to testing. The Instron universal testing machine was used to axially compress

the bone fragments. The specimen was attached to the machine with a steel-coring tool arrangement at either end and compressed at a constant displacement rate of 0.254 mm per second.

Five specimens of each configuration were tested on an Instron Universal Testing Machine by placing a steel plate under compression load, and then recording the load/deformation curve and load at failure. Three variables were arranged in the test and that were categories in two and six of number of pins, 30 mm and 60 mm for proximity of fixator to bone and 75° and 90° of angle of position in direction of fixation pin to the bone.

The degree of stiffness of this system was obtained from the load/displacement curve (N/mm). In preparation for the compression, six pins were inserted into the bone and then these pins were clamped to a connecting bar located 30 mm from the long bone. The average stiffness of this modified system was 29.525 N/mm. This is higher than the Universal Mini External Fixator (UMEXTM) which had a value of 12.774 N/mm. The results of this experiment works indicated that system arrangements greatly affect the degree of stiffness of the system.

Therefore, the optimum variable for the compressive testing is using the six pins with 30 mm of proximity and 75° of angle of position in fixation can obtain in the fracture bone application. This optimal of modified external skeletal fixator can achieve the maximum load in 438.84 N compare with UMEXTM fixator just achieve the maximum load in 126.36 N. It may result in a decreased rate of pin loosening and

thus prolong the function life of the external skeletal fixator system and lower the complication rate associated with its use.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**KETAHANAN DAN KEKUATAN DALAM PENGUBAHSUAIAN ALAT
PENGCENGKAM RANGKA LUARAN UNTUK RAWATAN ORTOPETIK
PADA HAIWAN**

Oleh

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Kajian ini adalah berkenaan dengan reka bentuk yang kos efektif alat pengcengkam rangka luaran yang boleh dipasangkan pada haiwan kecil. Pengubahsuaian reka bentuk ke atas produk komersil yang sedia ada, iaitu *Universal Mini External Fixator (UMEXTM)* telah dijalankan dari segi pretasi biomekaniknya dengan menggunakan tulang tibia mayat anjing.

Komponen reka bentuk untuk sistem prototaip ini termasuk rod penyambung (berukuran 200 mm panjang dan berdiameter 6mm), pengcengkam I (berdimensi 20x10x10 mm), pengcengkam II (berdimensi 10x10x10 mm) dan pin penyambung tetap (berukuran 150 mm panjang dan berdiameter 4 mm). Sebahagian sahaja daripada pin itu dibebankan secara profil negatif kerana kos pembuatannya adalah lebih rendah.

Untuk uji kaji tulang ini, sebanyak 80 batang tulang tibia telah diperolehi daripada 40 ekor anjing secara berasingan sebanyak 8 kali Pusat Perlindungan Haiwan di Setapak, Kual Lumpur. Setiap pengumpulan tulang tibia ini mengambil masa 2 jam dan dijalankan secara terus dari anjing yang baru mati dan seterusnya dibekukan. Tulang ini akan dicairkan pada suhu bilik sbelum uji kaji dijalankan. Mesin ujian universal *Instron* digunakan untuk menjalankan ujian mampatan secara paksian ke atas tulang sambungan. Kedua-dua hujung tulang yang telah dipasangkan piring keluli akan diletakkan di silinder mesin dan dimampatkan pada kadar gerakan tetap 0.254 mm sesaat.

Lima spesimen bagi setiap kes telah dikaji menggunakan mesin ujian universal *Inston* dengan meletakkan piring keluli di bawah tekanan mampatan. Seterusnya, graf beban/perbezaan jarak dapat diplotkan di mana beban maksimum sebelum sistem itu gagal direkodkan.dengan itu, kekerasan untuk sistem ini dapat diperolehi dari graf beban/perubahan bentuk ini. Terdapat tiga penentu digunakan dalam ujian ini seperti dua dan enam batang pin, ukuran dalam 30 mm dan 60 mm untuk jarak antara rangka dan tulang serta sudut arah dalam ukuran 75 darjah dan 90 darjah untuk pencucukan pin ke dalam tulang.

Dalam ujian mampatan ini, 3 pin akan dimasukkan ke dalam tulang dan seterusnya akan dicengkam pada rod penyambungyang diletakkan 30mm dari tulang yang lebih panjang. Purata kekerasan untu sistem rekaan baru ini adalah 29.525 N/mm. Nilai ini adalah lebih tinggi daripada nilai *Universal Mini External Fixator (UMEXTM)*, iaitu 12.744 N/mm. Keputusan uji kaji ini menunjukkan bahawa sistem susunan yang berbeza memberi kesan yang menonjol kepada kekerasan system itu.

Dengan itu, penentu beban maximum untuk ujian mampatan adalah enam batang pin dengan 30 mm daripada ukuran panjang dari rangka ke tulang serta 75 darjah arah pencucukan. Pengubahsuaian pencengkam rangka luar ini dapat mencapai beban maximum dengan 438.84 N berbanding dengan UMEX™ hanya mencapai 126.36 N dalam beban maximum. Kajian ini harap boleh mengurangkan kadar pengeluaran pin dan dapat memanjangkan tempoh pemakaian sistem pencengkam rangka luar serta mengurangkan pemakaian yang komplikasi dalam sistem ini.

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I certify that an Examination Committee met on 18th October 2006 to conduct the final examination of Lim Kok Jeng on his Master of Science thesis entitled “Stiffness and Strength of External Skeletal Fixator for Orthopedic Treatment of Animals” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

LIM KOK JENG

Date: 08 MARCH 2006

TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	ix
APPROVAL	xi
DECLARATION	xiii
LIST OF TABLES	xvi
LIST OF FIGURE	xvii
LIST OF ABBREVIATIONS	xxiii
CHAPTER	
1 INTRODUCTION	1.1
1.1 External Skeletal Fixation	1.1
1.2 Problem Statement	1.4
1.3 Aim and Objectives of Study	1.5
2 LITERATURE REVIEW	2.1
2.1 Definition of External Skeletal Fixation	2.1
2.1.1 History and Development	2.3
2.1.2 Current External Skeletal Fixation Devices	2.7
2.1.3 Current Configuration of External Skeletal Fixation	2.17
2.1.4 Principles of Application	2.22
2.1.5 Effect of Fixation Arrangement on Biomechanics	2.23
2.2 Terminology and Simple Mechanical Concept	2.26
2.2.1 Mechanical Loads on Bone	2.27
2.2.2 Mechanical Stress on Bone	2.28
2.3 Material and Structure Properties of Bone Tissue	2.28
2.3.1 Bone Material Constituents	2.28
2.3.2 Structural Stiffness	2.29
2.4 Mechanics of Bone Fractures	2.30
2.4.1 Common Bone Injuries and Fractures	2.30
2.4.2 Mechanism of Bone Failure	2.31
2.4.3 Tensile and Compression Testing of Bone	2.31
2.4.4 Mechanical Fracture Healing	2.35
2.4.5 Biological Fracture Healing	2.37
2.4.6 A Balanced Concept	2.38
2.5 Normal Forces and Moments of the Skeletal System	2.38
2.6 Stiffness Studies on Configurations of External Skeletal Fixation.	2.44
2.7 The Materials Selection Process	2.45
2.7.1 Material Selection	2.45
2.7.2 Stress/strain Curve	2.48
2.7.3 Fatigue	2.49
2.7.4 Force/deformation curve	2.50
2.7.5 Stainless Steel	2.51

2.7.6 Biomaterial	2.51
2.8 Pin Nomenclature	2.55
2.9 Fixation Pin Design	2.57
2.10 Pin Selection	2.59
2.11 Fixation Pin Insertion	2.62
2.12 Pathogenesis of Pin Loosening	2.67
2.13 Discussion	2.68
3 METHODOLOGY	3.1
3.1 General of Methodology	3.1
3.2 Specimen Preparation	3.7
3.2.1 Preservation	3.7
3.2.2 Cutting and Machining of Bone	3.7
3.3 Arranged Configurations for Testing	3.9
3.3.1 Procedures of Testing in Laboratory	3.13
3.4 Discussion	3.20
4 DESIGN AND DEVELOPMENT OF EXTERNAL SKELETAL FIXATION	4.1
4.1 An Overview	4.1
4.2 Parts of External Skeletal Fixator	4.4
4.2.1 Connecting Bar	4.4
4.2.2 Clamp I	4.5
4.2.3 Clamp II	4.6
4.2.4 Transfixation Pin	4.7
4.3 Detailed Description of External Skeletal Fixator	4.7
4.4 Design Criteria of External Skeletal Fixator	4.9
4.5 Discussion	4.11
5 RESULTS AND DISCUSSION	5.1
5.1 Load/Deformation Curve in Testing	5.2
5.2 Comparison of Maximum Load on Three Variable Testing	5.34
5.3 Rigidity of External Skeletal Fixation	5.53
5.4 Overall Discussion	5.61
6 CONCLUSION AND RECOMMENDATION	6.1
6.1 Conclusion	6.1
6.2 Recommendation	6.2
REFERENCES	R.1
APPENDICES	A.1
BIODATA OF THE AUTHOR	B.1

LIST OF TABLES

Table		Page
2.1	History and Development of All Type of Design	2.5
3.1	The difference of the cost effective between both systems	3.5
3.2	Arranged Configuration for Testing in External Skeletal Fixator	3.9
4.1	A table shows the difference between the design of prototype and UMEX™ external skeletal fixator.	4.9
5.1	Results of Compression Testing on 8 Cases between Prototype and Universal Mini External Fixator (UMEX)	5.34
5.2	Results of Stiffness on 8 Cases between Prototype and Universal Mini External Fixator	5.53
A.1	Mechanical Properties of Canine Cortical Bones Tested by Compression, Tensile, and Torsional Testing (All at the tissue level)	A.1
A.2	Bending Properties of Canine Cortical Bones at the All Tissue Level	A.4
A.3	Mechanical Properties of Stainless Steels Tested by Compression, Tensile, and Torsional Testing	A.6

LIST OF FIGURES

Figure		Page
2.1	(A) Small, (B) medium, (C) large Kirschner.	2.10
2.2	(A) The IMEX-SK single clamp tightened to grip the fixation pin and the rod. (B) Portion of the disassembled clamp.	2.11
2.3	Clamp. The Securos clamp consists of three components: a U-shaped component, a head, and a bolt. This clamp snaps transversely onto a connecting rod and provides a very rigid connection with a fixation pin.	2.13
2.4	Aiming instrument. An Aiming instrument is used to predrill pinholes, guide fixation pins into the pilot hole, and place full pins accurately to the opposite connecting bar.	2.14
2.5	APEF flexible acrylic columns. The APEF system features acrylic columns in place of the more familiar clamp and connecting bar arrangement. The acrylic columns are created “in situ” by pouring liquid acrylic into a flexible plastic mould placed over the pins.	2.16
2.6	Single-connecting-bar type I configuration	2.18
2.7	Double-connecting-bar type I configuration	2.18
2.8	Unilateral, biplanar (quadrilateral, type I) fixator	2.19
2.9	Double-connecting-clamp type I configuration	2.20
2.10	Type II (full-pin or bilateral) configuration	2.21
2.11	Modified type II configuration	2.21
2.12	Type III (trilateral) configuration	2.22
2.13	Fixator pin type. Four different types of ESF pins placed in a cutaway section of bone. (A) Smooth, trocar pointed pins are cheap to produce but have minimal resistance to pullout. (B) Negative-thread pins are somewhat resistant to pullout but have a weakness at the end of the threaded portion. Frequently, this “stress-riser” comes to lie adjacent to the near cortex – the very place where strain is greatest. (C) Ellis pins have a short length of negative thread so that the stress-riser at the end of the thread lies within the medullary cavity, where, hopefully, it is mechanically protected. (D) Positive-thread pins are very resistant to pullout and are much less prone to breakage than negative-threaded pins.	2.26

Many surgeons use nothing but positive-threaded pins in their fixators.

2.14	Relative bone strength in resisting in resisting compression, tension, and shear	2.27
2.15	Structures of cortical and trabecular bone	2.29
2.16	Types of fractures	2.30
2.17	Geometric properties of test specimens commonly used in biomechanical testing.	2.32
2.18	Trabecular bone specimen preparation for tensile or compressive mechanical testing. Steps include slicing of the bone section, X-raying of slices to avoid and percracks of specimens, cutting of cubic specimen with band saw and coring cylindrical specimens, density analysis using QCT, alignment of specimen in sockets, and final preparation of reduced diameter gauge section using a low-speed lathe.	2.33
2.19	Typical stress-strain curve for tensile test.	2.34
2.20	Typical stress-strain curve with visible yielding.	2.35
2.21	When a structure is loaded in shear, lines originally at right angles on a plane surface within the structure change their orientation, and the angle becomes obtuse or acute. This angular deformation indicates shear strain.	2.39
2.22	Generation of tension, compression, and shear stresses associated with an axially applied compressive load.	2.39
2.23	Balance of moments generated about the carpel joint. The ground reaction force (FG) acts about the moment arm (dg), causing a cranial bending moment ($FG \times dg$). To maintain normal posture, this moment must be balanced by a moment generated from contraction of the flexor carpi ulnaris ($Fm \times dm$).	2.40
2.24	Opposite moments acting about the nut in the center of the two wrenches. A moment is equal to the magnitude of the force (F1 and F2), times the perpendicular distance from the point of interest (nut) to the line of the force (d1 and d2). The sum of the moments must equal zero for equilibrium.	2.40
2.25	Eccentric or concentric loading of bony columns. If the joint load application is not in line with the column of bone, a bending moment is produced. If the joint load is in line with the center of the bony column, an axial load is produced.	2.42

2.26	Physiological bending.	2.43
2.27	Tensile, compressive, and shear stresses associated with a torsional force.	2.43
2.28	Comparative bending strength of connecting rods used with different sizes of the K-E fixator and small and large IMEX-SK fixators. Al, aluminium; CFC, carbon-fiber composite; SS, stainless steel; Ti, titanium.	2.46
2.29	The ultimate stress and modulus are shown by this curve and represent the material properties	2.49
2.30	An S/N curve	2.50
2.31	A force/deformation curve represented structural properties	2.50
2.32	Fixation Pins. End-threaded and center-threaded fixation pins. The threaded profile is a buttress thread that decreases the amount of bon removed. They are made of spring-hardened 316L stainless steel, making them much stiffer than a standard Steinmann pin.	2.56
3.1	Flow chart outlines the research methodology	3.3
3.2	All the specimens were cored using a steel-coring tool.	3.8
3.3	For modified external skeletal fixator, six pins were placed perpendicular to the fracture bone. The length of pin between the fracture bones to connecting bar was 30 mm.	3.11
3.4	For UMEX™ external skeletal fixator, six pins were placed perpendicular to the fracture bone. The length of pin between the fracture bones to connecting bar was 30mm.	3.11
3.5	A steel coring tool was designed to be fixed on each fragment bone to stabilise the bone and each bone end was covered by a black plastic cap for halal purpose.	3.12
3.6	A 20mm full diameter section was removed from the centre of the bone to create instability.	3.15
3.7	The Instron universal testing machine	3.16
3.8	The bending response and stiffness will record in the digital oscilloscope, which was couple to a mini-floppy disc drive that allow for data storage.	3.16
3.9	The specimen (modified ESF) was attached to the Instron unit with a steel-coring tool arrangement at both ends.	3.17

3.10	The machine compresses at a constant displacement rate of 0.010 inches (0.254mm) per second for modified ESF.	3.17
3.11	When the axial compression was applied, the modified ESF responded by bending in the direction of least resistance.	3.18
3.12	The specimen (UMEX™ ESF) was attached to the Instron unit with a steel-coring tool arrangement at both ends.	3.18
3.13	The machine compresses at a constant displacement rate of 0.010 inches (0.254mm) per second for UME™X ESF.	3.19
3.14	When the axial compression was applied, the UMEX™ ESF responded by bending in the direction of least resistance.	3.19
4.1	Photos image of the external skeletal fixator is use to the patient.	4.2
4.2	Photo image of the present front and back view of external skeletal fixation	4.3
4.3	Connecting Bar	4.4
4.4	Clamp I	4.5
4.5	M5 Set Screws	4.5
4.6	Allen Key	4.6
4.7	Clamp II	4.6
4.8	Transfixation Pin	4.7
5.1	Graph showing compression load versus displacement for P:2p@30mm@90 ⁰	5.2
5.2	Graph showing compression load versus displacement for P:2p@30mm@75 ⁰	5.4
5.3	Graph showing compression load versus displacement for P:2p@60mm@90 ⁰	5.6
5.4	Graph showing compression load versus displacement for P:2p@60mm@75 ⁰	5.8
5.5	Graph showing compression load versus displacement for P:6p@30mm@90 ⁰	5.10
5.6	Graph showing compression load versus displacement for P:6p@30mm@75 ⁰	5.12

- 5.7 Graph showing compression load versus displacement for 5.14
P:6p@60mm@90⁰
- 5.8 Graph showing compression load versus displacement for 5.16
P:6p@60mm@75⁰
- 5.9 Graph showing compression load versus displacement for 5.18
U:2p@30mm@90⁰
- 5.10 Graph showing compression load versus displacement for 5.20
U:2p@30mm@75⁰.
- 5.11 Graph showing compression load versus displacement for 5.22
U:2p@60mm@90⁰.
- 5.12 Graph showing compression load versus displacement for 5.24
U:2p@60mm@75⁰
- 5.13 Graph showing compression load versus displacement for 5.26
U:6p@30mm@90⁰
- 5.14 Graph showing compression load versus displacement for 5.28
U:6p@30mm@75⁰
- 5.15 Graph showing compression load versus displacement for 5.30
U:6p@60mm@90⁰
- 5.16 Graph showing compression load versus displacement for 5.32
U:6p@60mm@75⁰
- 5.17 Graph showing mean of compressive load versus number of pins 5.35
for P:30mm@90⁰ and U:30mm@90⁰
- 5.18 Graph showing mean of compressive load versus number of pins 5.37
for P:30mm@75⁰ and U:30mm@75⁰
- 5.19 Graph showing mean of compressive load versus number of pins 5.38
for P:60mm@90⁰ and U:60mm@90⁰
- 5.20 Graph showing mean of compressive load versus number of pins 5.40
for P:60mm@75⁰ and U:60mm@75⁰
- 5.21 Graph showing mean of compressive load versus angle of pins for 5.42
P:2p@30mm and U:2p@30mm
- 5.22 Graph showing mean of compressive load versus angle of pins for 5.44
P:2p@60mm and U:2p@60mm
- 5.23 Graph showing mean of compressive load versus angle of pins for 5.45

P:6p@30mm and U:6p@30mm

- 5.24 Graph showing mean of compressive load versus angle of pins for P:6p@60mm and U:6p@60mm 5.46
- 5.25 Graph showing mean of compressive load versus distance of pins for P:2p@90⁰ and U:2p@90⁰ 5.47
- 5.26 Graph showing mean of compressive load versus distance of pins for P:2p@75⁰ and U:2p@75⁰ 5.49
- 5.27 Graph showing mean of compressive load versus distance of pins for P:6p@90⁰ and U:6p@90⁰ 5.50
- 5.28 Graph showing mean of compressive load versus distance of pins for P:6p@75⁰ and U:6p@75⁰ 5.51
- 5.29 Graph showing mean of compressive load versus displacement for P:2p@30mm@90⁰ and U:2p@30mm@90⁰ 5.54
- 5.30 Graph showing mean of compressive load versus displacement for P:2p@30mm@75⁰ and U:2p@30mm@75⁰ 5.55
- 5.31 Graph showing mean of compressive load versus displacement for P:2p@60mm@90⁰ and U:2p@60mm@90⁰ 5.56
- 5.32 Graph showing mean of compressive load versus displacement for P:2p@60mm@75⁰ and U:2p@60mm@75⁰ 5.57
- 5.33 Graph showing mean of compressive load versus displacement for P:6p@30mm@90⁰ and U:6p@30mm@90⁰ 5.58
- 5.34 Graph showing mean of compressive load versus displacement for P:6p@30mm@75⁰ and U:6p@30mm@75⁰ 5.59
- 5.35 Graph showing mean of compressive load versus displacement for P:6p@60mm@90⁰ and U:6p@60mm@90⁰ 5.60
- 5.36 Graph showing mean of compressive load versus displacement for P:6p@60mm@75⁰ and U:6p@60mm@75⁰ 5.61
- 5.37 A photo image shows as a representative of the entire test showing the fracture or failure of the sample. 5.66

LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
APEF	Acrylic Pin External Fixation
AO/ASIF	Arbeitsgemeinschaft für Osteosynthesefragen (Swiss) / Association for the Study of Internal Fixation
ASTM	American Society for Testing and Materials
CAD	Computer Aided Design
ESF	External Skeletal Fixator
FCC	Face Centred Cubic
ITMA	Institute Technology Malaysia Advance
IUTM	INSTRON Universal Testing Machine
K-E	Kirschner-Ehmer
PBI	Pin Bone Interface
UPM	Universiti Putra Malaysia
UMEX TM	Universal Mini External Fixator
P:2p@30mm@90 ⁰	Prototype of two pins with 30 mm in length between connecting bar and fracture bone with 90 degrees insertion
P:2p@30mm@75 ⁰	Prototype of two pins with 30 mm in length between connecting bar and fracture bone with 75 degrees insertion
P:2p@60mm@90 ⁰	Prototype of two pins with 60 mm in length between connecting bar and fracture bone with 90 degrees insertion
P:2p@60mm@75 ⁰	Prototype of two pins with 60 mm in length between connecting bar and fracture bone with 75 degrees insertion
P:6p@30mm@90 ⁰	Prototype of six pins with 30 mm in length between connecting bar and fracture bone with 90 degrees insertion
P:6p@30mm@75 ⁰	Prototype of six pins with 30 mm in length between connecting bar and fracture bone with 75 degrees insertion
P:6p@60mm@90 ⁰	Prototype of six pins with 60 mm in length between

- connecting bar and fracture bone with 90 degrees insertion
- P:6p@60mm@75⁰ Prototype of six pins with 60 mm in length between connecting bar and fracture bone with 75 degrees insertion
- U:2p@30mm@90⁰ UMEX™ of two pins with 30 mm in length between connecting bar and fracture bone with 90 degrees insertion
- U:2p@30mm@75⁰ UMEX™ of two pins with 30 mm in length between connecting bar and fracture bone with 75 degrees insertion
- U:2p@60mm@90⁰ UMEX™ of two pins with 60 mm in length between connecting bar and fracture bone with 90 degrees insertion
- U:2p@60mm@75⁰ UMEX™ of two pins with 60 mm in length between connecting bar and fracture bone with 75 degrees insertion
- U:6p@30mm@90⁰ UMEX™ of six pins with 30 mm in length between connecting bar and fracture bone with 90 degrees insertion
- U:6p@30mm@75⁰ UMEX™ of six pins with 30 mm in length between connecting bar and fracture bone with 75 degrees insertion
- U:6p@60mm@90⁰ UMEX™ of six pins with 60 mm in length between connecting bar and fracture bone with 90 degrees insertion
- U:6p@60mm@75⁰ UMEX™ of six pins with 60 mm in length between connecting bar and fracture bone with 75 degrees insertion