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

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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

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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^{TM}) 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 75^0 and 90^0 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 (UMEX™) 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 75^0 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 UMEX™ 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

LIM KOK JENG

Oktober 2006

Pengerusi: **Megat Mohammad Hamdan bin Megat Ahmad, PhD**

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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 kormersil yang sedia ada, iaitu *Universal Mini External Fixator (UMEX^{TM})* telah dijalankan dari segi pretasi biomekaniknya dengan menggunakan tulang tibia mayat anjing.

Komponen reka bentuk untuk sistem prototaip ini termasuk rod penyambung (berukurn 200 mm panjang dan berdiameter 6mm), pengcengkam I (berdimensi 20x10x10 mm), pengcengkam II (berdiamensi 10x10x10 mm) dan pin penyambung tetep (berukuran 150 mm panjang dan berdiameter 4 mm). Sebahagian sahaja daripada pin itu dibebenangkan 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 (UMEX^{TM})*, 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^{TM} 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

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LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
APEF	Acrylic Pin External Fixation
AO/ASIF	Arbeitsgemeinschaft fur Osteosynthesefragen (Swiss) / Association for the Study of Internal Fixation
ASTM	American Society for Testing and Materials
CAD	Computer Aided Design
ESF	Extenal 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@75^0	Prototype of six pins with 60 mm in length between connecting bar and fracture bone with 75 degrees insertion
U:2p@30mm@90^0	UMEX^{TM} of two pins with 30 mm in length between connecting bar and fracture bone with 90 degrees insertion
U:2p@30mm@75^0	UMEX^{TM} of two pins with 30 mm in length between connecting bar and fracture bone with 75 degrees insertion
U:2p@60mm@90^0	UMEX^{TM} of two pins with 60 mm in length between connecting bar and fracture bone with 90 degrees insertion
U:2p@60mm@75^0	UMEX^{TM} of two pins with 60 mm in length between connecting bar and fracture bone with 75 degrees insertion
U:6p@30mm@90^0	UMEX^{TM} of six pins with 30 mm in length between connecting bar and fracture bone with 90 degrees insertion
U:6p@30mm@75^0	UMEX^{TM} of six pins with 30 mm in length between connecting bar and fracture bone with 75 degrees insertion
U:6p@60mm@90^0	UMEX^{TM} of six pins with 60 mm in length between connecting bar and fracture bone with 90 degrees insertion
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