DESIGNING A NEW CONCEPT OF LC-DCP BROAD TYPE BONE PLATE

MUHAMMAD KAMAL ASYRAF BIN PUBIN

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ABSTRACT

Bone plate design has evolved dramatically in recent years. The main research of the study is to improve the previous design of the Dynamic Compression Plate (DCP) broad type bone plates that was used in bone fracture as internal fixation. The DCP bone plate has been superseded by new plating system that claim a reduced interface contact between the plate and the underlying bone. It is believed that contact reduction can reduce the risk of Ischaemia – deficiency of blood in a part, usually due to functional constriction or actual obstruction of blood vessel that could lead to other side effect on the patient. To develop the new proposed design, CAD (Computer Aided Design) software is used to design and simulate the model. The interface characteristics of the actual Dynamic Compression Plate (DCP) and the new Low-Contact Dynamic Compression Plate (LC-DCP) plating systems have been analyzed using a Finite Element Analysis (FEA) software. The final result of model simulation is displayed in form of stress von Mises, and heat transfer distribution. The maximum value of von-Mises stress for the new LC-DCP is 768195.2 N/m^2 and heat transfer distribution temperature is 57.15 °C. The LC-DCP system was consistently lower, in terms of interface contact, than the DCP in each of the CAD model tested.

ABSTRAK

Rekaan plat tulang telah berubah secara menyeluruh sejajar dengan perkembangan teknologi kejuruteraan dan perubatan sejak beberapa tahun kebelakangan ini. Tujuan utama kajian ini dijalankan adalah untuk memperbaiki rekaan Plat Tulang Mampatan Dinamik jenis lebar yang berfungsi untuk memperbaiki kecederaan tulang secara dalaman. Plat Tulang Mampatan Dinamik telah diubahsuai dengan system plat baru yang mempunyai permukaan yang dikurangkan di antara plat serta tulang yang terletak di bawahnya. Adalah dipercayai bahawa dengan pengurangan luas permukaan bersentuhan tersebut, maka ia dijangka akan dapat mengurangkan masalah 'Ischemia', iaitu masalah kerosakan salur darah (pembuluh darah) yang terletak di bawah set plat dengan tulang tersebut. Kerosakan pembuluh darah di bawah plat tulang menyebabkan sel-sel tulang pada bahagian tersebut tidak mendapat bekalan darah dan seterusnya menjurus kepada masalah pereputan tulang (Osteporosis) setempat di bahagian yang terlibat. Perisian CAD 3D digunakan untuk membina dan menggambarkan model plat tulang tersebut. Dalam kajian ini, ciri-ciri permukaan Plat Tulang Mampatan Dinamik serta Plat Tulang Mampatan Dinamik Dengan Pengurangan Permukaan telah di analisis menggunakan perisian Finite Element Analysis (FEA). Keputusan analisis adalah dalam bentuk daya von-Mises serta penyebaran haba. Nilai maksimum daya von-Mises yang dicatatkan pada plat tulang Mampatan Dinamik Dengan Pengurangan Permukaan adalah 768195.2 N/m^2 manakala penyeberan haba telah memberikan nilai iaitu pada suhu 57.15 °C. Plat Tulang Mampatan Dinamik Dengan Pengurangan Permukaan mempunyai pengurangan dari segi luas permukaan bersentuhan berbanding dengan Plat Tulang Mampatan Dinamik pada setiap model CAD 3D yang di kaji.

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CHAPTER 1

INTRODUCTION

1.1 Project title

Designing a new concept of LC-DCP broad type bone plate.

1.2 Objectives

The objective of this project is to design a new concept of broad type LC-DCP bone plate and analyze the bone plate stress and heat transfer analysis

1.3 Project scopes

Scopes of project:

1. Conducting literature review on LC-DCP bone plate.
2. Conceptual design of slender, easy wired and low contact LC-DCP plate using SolidWorks CAD software.
3. Conducting heat transfer and stress analysis on the DCP plate using 3-point bending technique with Algor FEA simulation.

1.4 Problem Statement

1. Patient will suffer from pain after the plate had been assembled especially when they was in an air conditioned room. The uncomforting feeling happens because of the high surfaces contact between the plates and the bone itself.
2. Traditional design of DCP broad bone plate does not have any wire hole to tie the plate onto the bone prior drilling. This phenomenon causes difficulties to the surgeon to place the plate and drill screw holes with a bit accurate.

1.5 Project Background

Bone is the main constituent of the skeletal system and it differs from the connective tissue primarily due to its rigidity and strength. A strong and stiff bone enables the skeleton to maintain body shape, to protect the internal organs, and to transmit force of the muscular contraction from one part of the body to another during movement. Fatigue and impact loads are the most common reasons for bone fracture. Fractured bones need to be fixed surgically for it's healing and proper functioning as early as possible. Fracture fixation by bone plate provides rigid immobilization at the fracture site and reduces the fracture gap thus allowing primary bone healing by new formation. The role of bone plate and screws is to hold the fragments of the bone in position till the bone heals. In this study, the main research is to improve the previous design of DCP broad type bone plates that was used in bone fracture fixation.

Today's DCP broad type bone plate looks like a plain holed square 4mm thick stainless steel plat. When the plate had been assembled, the patient will suffer from the pain especially when they were in an air conditioned room. The plate's metal will contract and shrink when cold. The uncomforting feeling happens because of the high surfaces contact between the plates and the bone itself. When the plates metal shrink, the deformation in compression resulting a change in stress shielding on the bone surfaces. Another complications associated is effects on vascularity of the cortex beneath the plate, blocking the normal blood flow. (Ischemia – deficiency of blood in a part, usually due to functional constriction or actual obstruction of blood vessel).

During surgery, the surgeon place the plate and drill screw holes on the fragment part where the bone fracture. The traditional design of DCP broad type bone plate does not have any wire hole to tie the plate onto the bone prior drilling. This phenomenon causes difficulties to the surgeon to place the plate and drill screw holes with a bit accurate.

Therefore in this project, a new concept and design of LC-DCP broad type bone plate will be introduced to give benefit on orthopedics field.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, focus will be to find out the related information from internet, books and journals. These information can use as a guide and procedure to conduct the project. Areas of studies are human bone system, the bone fracture, the bone fracture fixation, the DCP broad type bone plate, the new concept of Low Contact – DCP broad type bone and others. The understanding of the literature review will helps to achieve the project objective.

2.2 Human Bone System

The human skeleton contains 206 bones. Each of them has a different size and length. **Figure 2.1** show that the human skeleton. The human skeleton has six main functions:

1. The skeleton provides the framework to support our body allow us to maintain the body shape.
2. The bones of the skeleton provide the attachment surface for muscle, tendons and ligaments.
3. Our movement is dependent on the skeletal muscle. Without the skeleton to give the leverage, movement would be greatly restricted.

4. The skeleton protects many vital organs.
5. The skeleton is the site of haematopoiesis – the generation of blood cell.
6. Bone also serves as a mineral storage deposit in which nutrients can be stored and retrieved. Calcium, especially, can be released by dissolution of bone tissue under the control of 1,25-dihydroxyvitamin D3 during periods of low calcium intake.[1]

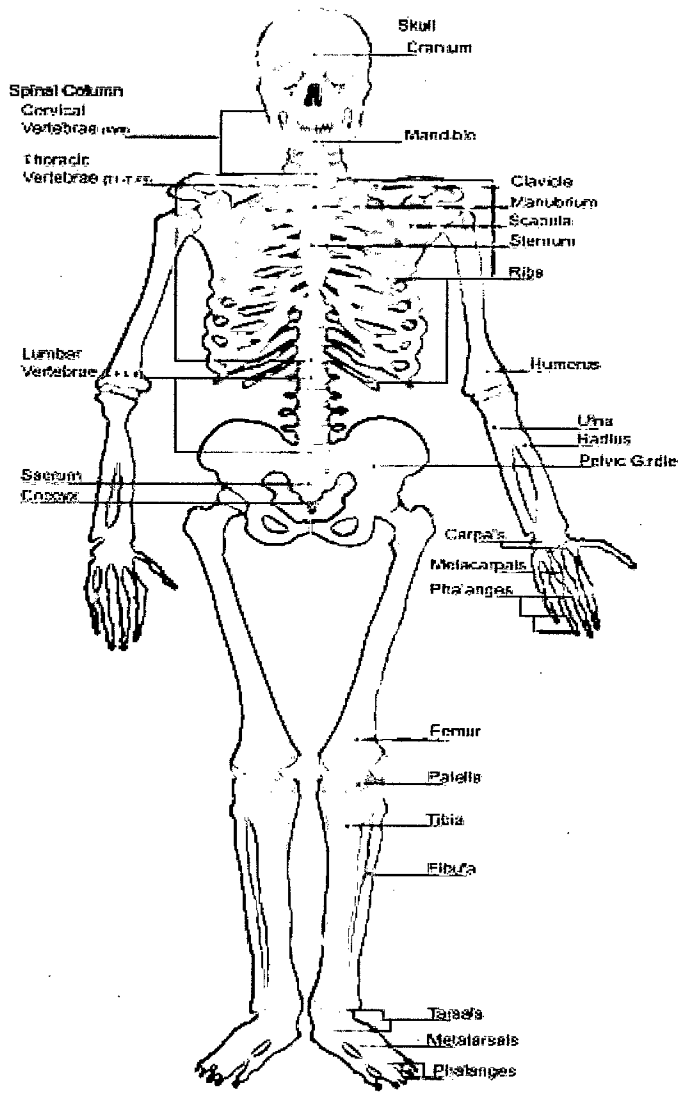

Figure 2.1: Human Skeleton [1]

2.3 Bone Characteristic

Bones is the one of the hardest structures of the human body. Bones come in a variety of shapes and have a complex internal and external structure, allowing them to be lightweight yet strong and hard, while fulfilling their many other functions. Bone have they special characteristic.

Bone is anisotropic. Its modulus is dependent upon the direction of loading.Mechanical properties dependent upon direction of loading. Bone is weakest in shear, then tension, then compression.

Bone is viscoelastic. Its force deformation characteristics are dependent upon the rate of loading. Stress-Strain character dependent upon rate of applied strain (time dependent) [2] **Figure 2.2** show the bending, compression and torsion occur on the bone.

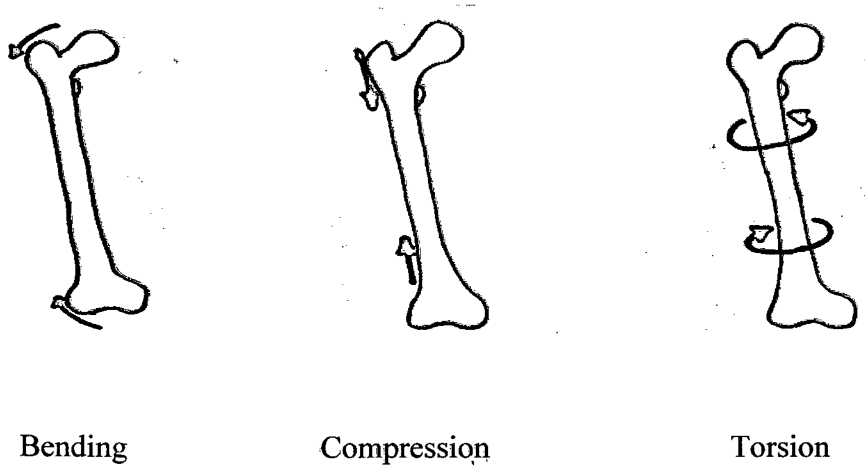

Figure 2.2: Bending, Compression and Torsion occur on the bone [2]

2.4 Mechanical Properties of Bone

Compact bone has a porosity of 5-30% and cancellous bone of approximately 30-90%, which is the proportion of the volume occupied by nonmineralized tissue [3].

A key requirement in bone is compressive strength, and the most important factor in compressive strength is the degree of mineralization. Loss of mineralization results in increased risk of fracture [4].

The compressive strength of cortical bone varies, being in humans around 200 MPa (megapascals) for the femur; the elastic compressive modulus is around 17 GPa [5, 6].Cancellous bone is much weaker and the results obtained have varied, depending on the location of the bone. [7] Compressive strengths of 0.15-27 MPa and elastic modulus from 50 to 350 MPa have been reported for cancellous bone. [8] **Table 2.1** and **Table 2.2** show that the mechanical properties of human bone.

Table 2.1: Young's Modulus, Compressive strength, Tensile strength, Density and Fracture Toughness of human bone [9]

	Young's Modulus GPa	Compressive Strength MPa	Tensile Strength MPa	Density g/cm^3	Fracture Toughness $MPam^{1/2}$
Cortical Bone	3.8-11.7	88-164	82-114	1.7-2.0	2-12
Cancellous Bone	0.2-0.5	23	10-20	-	-

Table 2.2: Mechanical Properties of Human Bone [10]

Cortical Bone	Compressive strength, MPa	131-224 longitudinal 106-133 transverse
	Tensile strength, MPa	80-172 longitudinal 51-56 transverse
	Shear strength, MPa	53-70
	Elastic Modulus, GPa	11-20 longitudinal
Cancellous bone	Tissue compressive strength, MPa	0.5-50
	Tissue elastic modulus, MPa	5-150
	Material elastic modulus, GPa	1-11

2.5 Bone Fracture

A bone fracture is a medical condition in which a bone becomes cracked, splintered, or bisected as a result of physical trauma. A bone fracture can also occur as a result of certain medical conditions that weaken the bones, such as osteoporosis or certain types of cancer. A broken bone is not always defined as a fracture, much as a fracture is not always defined as a broken bone. A broken bone is defined as a complete severing of the bone, as in opposition to a fracture covering any type of crack or break in the bone. Fatigue and impact loads are the most common reasons for bone fracture. [2] **Figure 2.3** show the types of bone fracture.

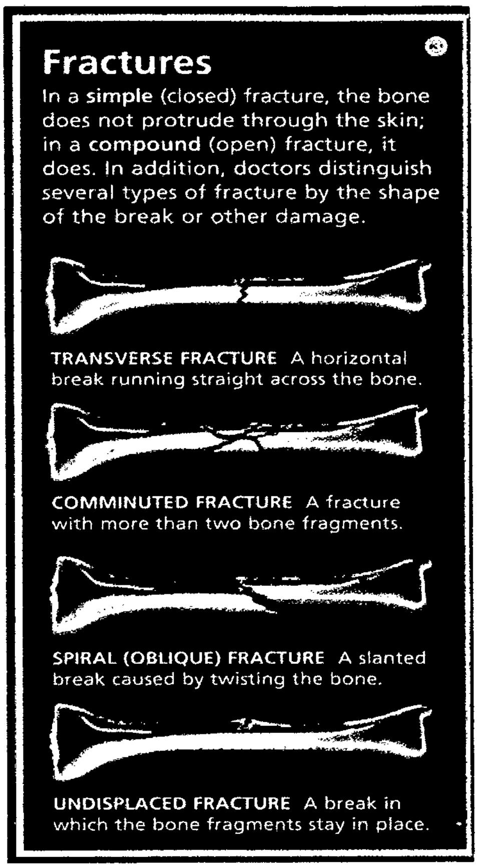

Figure 2.3: Types of Bone Fracture [2]

2.6 Fracture Fixation

Fractured bones need to be fixed surgically for it's healing and proper functioning as early as possible. Fracture fixation by bone plate provides rigid immobilization at the fracture site and reduces the fracture gap thus allowing primary bone healing by new formation. The role of bone plate and screws is to hold the fragments of the bone in position till the bone heals. DCP broad bone plate is used when the actual bone is fracture or broken. The plate fixation is according to the place. DCP broad bone plate is submerge at broad bone like at humerus, tibia and femur bone. The function of the plate is as an internal splint an compress the bone. The bone protects the plate. [11, 12] **Figure 2.4** till **Figure 2.7** show various fracture internal fixation using bone plates.

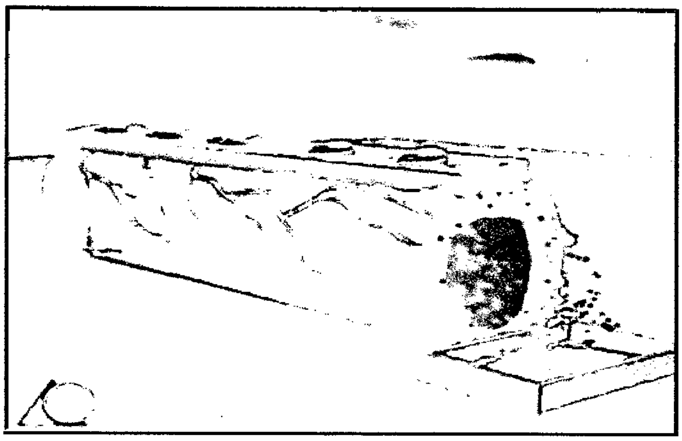

Figure 2.4: Simulation of internal fixation using bone plates [13]

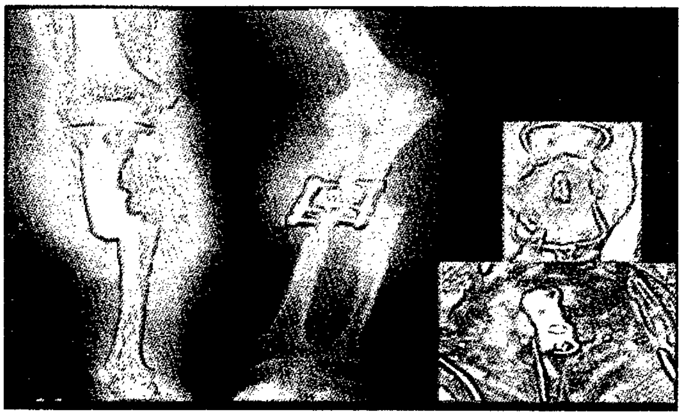

Figure 2.5: Internal fixation at humerus bone[13]

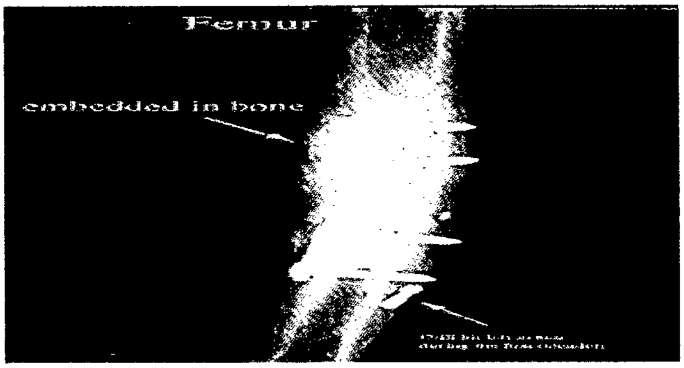

Figure 2.6: Internal fixation at human femur bone [13]

Figure 2.7: Internal fixation using bone plate [13]

2.7 Bone Plate (The Dynamic Compression Plate – DCP Plate)

There are many types of bone fractures depending on the crack size, orientation, morphology, and location - which have to be treated in different ways. In general, medical devices are necessary to fix the fractured bone for proper healing. The most commonly used of such devices are the bone plate.

Bone plates, also known as osteosynthesis plates, are conventionally made of stainless steel, Cr-Co, and Ti alloys. The rigid fixation is designed to provide high axial pressures (also known as Dynamic Compression) in the fragments of the bone, in order to facilitate primary bone healing without the formation of external callus. A secondary operation is generally required to remove the plate once the bone healing is completed - which may take one to two years. However, the high rigidity of the metal plate fixation can result in bone atrophy. The bone underneath the plate adapts to the low stress and becomes less dense and weak. Due to bone atrophy, there is a possibility of bone refracture after the plate is removed. This is recognized as the "stress shielding" effect. It may be noted that the modulus of stainless steel (210-230 GPa) is much higher than the 10-18 GPa modulus of the bone. In the plate and the fractured bone system, the amount of stress carried by each of them is directly related to its stiffness. [9]

Thus bone is insufficiently loaded compared to the implanted plate, resulting in "stress-shielding" or stress protection. Many investigators have shown that the degree of stress protection is proportional to the degree of stiffness mismatch. This suggests that `less rigid fixation plates' diminish the stress-shielding problem, and that it is desirable to use plates whose stiffness is close to that of the bone. However, low stiffness should not be accompanied with low fatigue strength, since the plate/bone system will have to sustain severe cyclic loading while the bone is healing. Polymer composite materials offer the desired high strength and bone-like elastic properties, and hence have been proposed for bone plate applications. They may be grouped into non-resorbable, partially resorbable, and fully resorbable bone plates. [14] **Figure 2.8** show the DCP Broad Type Bone Plating System Interface profile.

DCP plate in a direct comparison with the DCP. [13] **Figure 2.9** show the LC-DCP Plating System Interface profile.

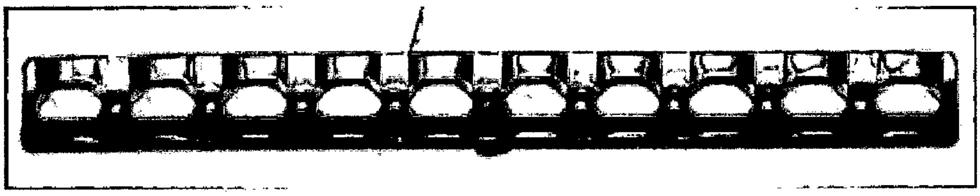

Figure 2.9: The LC-DCP Plating System Interface Profile. [15]

2.9 Common Metals Used In Bone Plate Applications

In surgical implants, metals that were used for surgical implants rely on the development of a passive oxide film to reduce their corrosion rates to acceptable levels. The actual specifications of modern surgical implant alloys, including chemical compositions and heat treatments, are now covered by the international standard ISO 5832.[9]

2.10 Stainless Steel

Stainless steels are in fact a family of ferrous alloys that contain more than 12% chromium. In the 1930s, stainless steels were the main implant materials. With respect to surgical implants, usually the more ductile austenitic stainless steels containing at least 8% nickel are used - the most important one being grade 316L.

316L stainless steel has a nominal composition of 17Cr, 8Ni, 2Mo, balanced Fe, and an extremely low carbon content to prevent chromium depletion, hence the suffix `L'. Occasionally nitrogen is added at about one-quarter percent level to improve the corrosion resistance of the alloy. The relative corrosion resistance of stainless steels can be estimated from their pitting resistance number (PREN):

$$\mathbf{PREN = \%Cr + 3.3x\%Mo + 16x\%N}$$

However, 316L stainless steel can corrode within the body - especially in regions where there is insufficient oxygen to maintain the passive film or where crevices are formed (e.g., under the heads of screws). In addition, stainless steel femoral components can fracture. Therefore stainless steel is more suitable for temporary implant devices. Nevertheless, there are cases where 316L fracture plates have been removed from patients after more than 20 years of service, yet show no evidences of corrosion. One final word of caution on stainless steels is that different grades should not be mixed as this can result in galvanic corrosion. Since it is not possible to visually distinguish one grade of stainless steel from another, careful quality control must be exercised. Thebecause one out of a group of was fabricated using the lower 304L grade. [9] **Figure 2.10** show The DCP bone plates and screw removed from a patient after nearly 50 years of service.