LOAD TO FAILURE ANALYSIS OF SHORT SEGMENT PEDICLE SCREW INSTRUMENTATION WITH SCREW AT THE FRACTURE LEVEL IN UNSTABLE THORACOLUMBAR BURST FRACTURE ; AN ANIMAL BIOMECHANICAL STUDY

By

DR OTHMAN BIN ABDUL HAMID

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

Of

MASTERS OF MEDICINE

(ORTHOPAEDIC SURGERY)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AO	Arbeitsgemeinschaft für Osteosynthesefragen
CT	Computed Tomography
OTA	Orthopaedic Trauma Association
PLC	Posterior Ligamentous Complex
RCT	Randomised Control Trial
ROM	Range of Motion
SSPI	Short Segment Pedicle Screw Instrumentation
TL	Thoracolumbar
TLICS	Thoracolumbar Injury Classification and Scoring System

ABSTRAK

PENGENALAN

Kepatahan tulang belakang pada aras torakolambar adalah kepatahan spinal yang paling kerap di seluruh dunia. Walaupun begitu, petunjuk dan cara pembedahan untuk penstabilan kepatahan masih lagi di peringkat kontroversi. Instrumentasi pedikel segmen pendek ditambah dengan skrew pedikel pada aras kepatahan telah berjaya memberi keputusan yang menggalakkan di dalam kajian biomekanik dan klinikal. Kajian ini adalah yang pertama yang melihat aspek biomekanik untuk konstruk diatas bila dibeban dengan maksima di dalam bentuk kompressi dan dibandingkan dengan konstruk segmen panjang.

METODOLOGI

Kajian eksperimen biomekanik ini menggunakan lapan tulang belakang lembu, kepatahan burst yang tidak stabil diadakan dan tulang-tulang belakang lembu tersebut dibahagikan kepada dua bahagian. Kumpulan pertama diinstrumentasikan dengan instrumentasi segmen pendek ditambah dengan skrew pada aras kepatahan dan kumpulan kedua diinstrumentasi menggunakan instrumentasi skrew pedikel konstruk panjang. Kedua-dua konstruk kemudian dibeban di dalam bentuk kompressi menggunakan mesin ujian bahan Instron 8874 dan nilai kekuatan dan lod maksima dicatatkan. Cara kegagalan juga dianalisa. Data di analisis menggunakan SPSS versi 20.

KEPUTUSAN

Keputusan median untuk kekuatan kompressi adalah 4248.6 N didalam kumpulan segmen pendek manakala segmen panjng adalah 4085.4N. Beban kompressi adalah 0.7550MPa untuk kumpulan segmen pendek dan 1.060 MPa untuk kumpulan segmen panjang. Tiada hubungkait yang signifikan diantara nilai-nilai untuk segmen kumpulan pendek dengan tambahan skrew pada peringkat kepatahan bila dibandingkan dengan segmen panjang dengan p=0.686 untuk kekuatan kompressi dan p=0.486 untuk beban kompressi.

KESIMPULAN

Instrumentasi pedikel dengan tambahan skrew pada peringkat kepatahan mempunyai nilai yang hampir sama dengan konstruk pedikel skrew yang panjang bila dibeban dengan tahap yang maksima. Didalam kedua-dua kumpulan, konstruk gagal didalam bentuk skrew yang tertarik keluar.

ABSTRACT

INTRODUCTION

Thoracolumbar fracture is the most common spinal fractures worldwide. Despite this, the indications and the methods of treatments remain controversial. The short segment pedicle screw instrumentation with the addition of screw at the fracture level has been shown in biomechanical and clinical studies to have promising results with its performance and outcome. This study looks at the biomechanical properties of this construct when being loaded maximally in compression comparing it to the conventional long segment fixation.

METHODOLOGY

This experimental biomechanical study is performed using 8 cow spines. Unstable burst fracture is firstly induced and the spines are randomly divided into two groups. First group is instrumented with the short segment pedicle screw with the addition of intermediate screw and the second group is the long segment construct. The constructs are loaded in compression using the Instron 8874 material testing machine and the values of strength and maximum load obtained are recorded. The mechanism of failures are also analyzed. Data was analyzed using SPSS version 20.

RESULTS

The means of the strength was 4248.6 N in the short segment group whilst the long segment recorded a means of 4085.4N. The compressive load was 0.7550 MPa and 1.060 MPa for the short and long segment respectively. However no significant difference between these two groups were found with p=0.686 and p=0.486 for strength and compression respectively.

The method of failure was screw pullout for both groups.

CONCLUSION

The short segment pedicle screw instrumentation with the addition of intermediate screw have similar load to failure compared to the long segment fixation. In both groups the construct fail by screw pullout.

CHAPTER 1

INTRODUCTION

The thoracolumbar (TL) region is defined as an area from the T11 cranially to the L2 caudally. Despite its short region compared to the length of the spine, thoracolumbar fractures accounts for almost 90% of all spinal fractures (Smith et al., 2010). It is an area of high energy concentration as result from the transition from kyphotic thoracic spine to the lordotic lumbar spine (Smith et al., 2010). Anatomically as well, the orientation of the facet joints and the discrepancy of movement between the two segments further aggravate the mismatch of the two regions (White et al., 1978).

The classification systems for thoracolumbar (TL) fractures have evolved from being purely descriptive for examples the Denis and AO classifications to the recently devised Thoracolumbar Injury Classification and Scoring System (TLICS) . The latter system of classification is based on three main factors , which are the fracture morphology, the integrity of the posterior ligamentous complex (PLC) and the neurologic status of the patient. This classification tries to incorporate all the relevant important factors to guide the options between surgical and non-operative management and to aid which approaches is appropriate based on the scoring system.

Operative treatment is required in about 20-30% of the spine injured patient based on a number of strict indications which are progressive neurological deficits, fracture dislocations or progressive symptomatic kyphosis (Shimer et al., 2010). Other relative indications are > 50% canal compromise, >50% loss of vertebral body height and > 30^0 kyphosis.

The advantages of operative management in TL fractures are many. Firstly, the immediate stabilization of the injured spine that will benefitted the multiply injured patients and the patients that are unable to tolerate prolonged bed rest (McLain RF., 2006). These operated patients can be sat upright, eases nursing care and can be started on early rehabilitation. Secondly, operative treatment reliably restores alignment in the sagittal plane, deformity correction and canal dimension than the non-operative measures. The rationale for operative measures is that with decompression there will be no progressive compression hence no risks of further progression in neurology. When the acute kyphosis is corrected, the risk of pain will also be minimized.

However, a number of studies comparing operative and non-operative intervention in the neurologically intact TL burst fractures patients have shown that despite the initial improvements in kyphotic angle and pain score in the operated patients, the functional outcomes of these two groups of patients are similar at 2 years (Shen et al., 2001 ; Thomas et al., 2006 : Yi et al., 2006). There is no relationship between kyphotic angle and pain and the canal dimension also improves with time despite being left alone. The non-operated patients also have no risk of developing complications associated surgery for example infections as compared to the surgically treated patients.

To date, despite the high incidence of TL fractures, the indications and the treatments are still controversial. The approaches and types of instrumentations are also controversial with systematic reviews showing no difference in the Frankel grade improvements between anterior, posterior or combine approaches (Oner et al., 2010)

In surgically treating TL fractures, the posterior approach has multiple advantages for being more extensile, the access to multiple segments fixation and the ability to perform reduction maneuvers (Radcliff et al., 2012). Posterior instrumentation has the ability to restore the vertebral body height by application of distraction force. In addition to this, the kyphosis is corrected when the spine assumes the contour of the rods (Ahmed et al., 2011). This is achievable due to the three-column fixation obtained by the pedicle screws. The segmental pedicle instrumentation has been shown biomechanically to provide the most rigid restrain to spinal motion in flexion, extension and torsion (Yahiro MA., 1994)

Traditionally, the long segment posterior instrumentation constructs are chosen because the long moment arms of the construct are postulated to better counteract the development of kyphosis during fracture healing (McLain RF., 2006). The long segment typically spans 2 or 3 levels above the fracture and 2 levels below. However, by rigidly immobilizing the spine especially the mobile lumbar spine segment predispose the level above and below the construct to develop the segment disease. This is the alteration of the biomechanics of the spine cranial and caudad to the rigidly fixed segment that caused higher compression and shear force at the junction with subsequent increased in disc pressure and the facet joints that accelerate degeneration of those segments (Nagata et al., 1993 ; Cunningham et al., 1997 ; Shono et al., 1998).

The short segment pedicle screw instrumentation (SSPI) is advantageous as it preserves more segments hence the ability to minimize the segment disease. Short segment instrumentation spans only one segment above and below the fracture. However because of the shorter moment arm, it is less efficient in counteracting against the development of kyphosis in the unstable fracture and associated with high rate of fixation failures (McLain et al., 1990 ; McLain RF., 2006 ; Ahmed et al., 2011).

To improve on the biomechanical properties, a number of additions or augmentations to the SSPI construct has been described in the literatures. They are crosslinks (Wahba et al.,2010 ; Lazaro et al., 2011), percutaneous vertebroplasty (Qing-Yi et al., 2009) and the addition of screws at the fracture levels.

There are a handful of biomechanical studies that looked at the effects of putting the screws at the fracture level (SSPI + intermediate screw) with results that showed an increased in the stiffness of the constructs compared to SSPI alone (Anekstein et al. 2007 ; Mahar et al., 2007 ; Bolestra et al., 2012). No studies have ever looked at the load to failure or the ultimate compressive strength between the SSPI + intermediate screw and the long segment fixation in an unstable TL facture.

The purpose of this study are two-fold. Firstly by obtaining the ultimate compressive strength of the SSPI with the addition of intermediate screw, we can add to the pool of evidence on the other aspect of its biomechanical properties . This will indirectly infer on the stability that this construct may offer in the setting of unstable thoracolumbar burst fracture.

Secondly, it will be interesting to know the mechanism by which these construct might fail when loaded maximally in compression.

CHAPTER 2

LITERATURE REVIEW

Chapter 2.1

Anatomy and Biomechanics of Thoracolumbar Spine

The thoracolumbar junction is an area formed by the level of T11 to L2 vertebrae. The thoracic spine is kyphotic which means in the sagittal plane its convexity is located posteriorly. Conversely, the lumbar spine on the other hand is lordotic which in the sagittal plane has its curve pointed anteriorly. It is a transition zone from a rigid and kyphotic thoracic spine to a mobile and lordotic lumbar spine. As a result of the transition, high energy forces are being transmitted at a relatively small area (Smith et al., 2010).

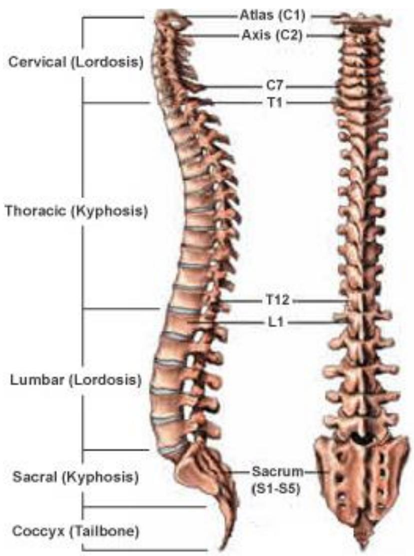

Figure 1 : Human vertebrae in the sagittal plane showing the lordotic and kyphotic curves. Adapted from www.neurospineinstitute.org

The thoracic spine as opposed to the lumbar spine is protected from injury due to the presence of the ribs and chest wall musculature that help dissipate forces. They also buttress against compressive forces.

White et al., 1978 point to the differences in the orientation of the facet joints in the thoracic compared to the lumbar regions. The thoracic spine's facet joints are coronally oriented and they resist flexion and extension. Conversely, in the lumbar region, the facet joints are oriented in the sagittal plane and this increases motion in flexion and extension. Hence the mismatch in the facet joints and the motion permitted in these two regions further add to the stresses experienced at this zone.

Stagnara et al., 1982 calculated that the kyphosis at the thoracic region ranges from 18^0 to 51^0 whereas the lordosis at the lumbar region ranges from 42^0 to 74^0. Biomechanically, the center of gravity in the thoracic spine is located anteriorly so is the forces that pass through it. Compressive forces are located at the bodies and tensile forces being borne by the posterior elements. Conversely in the lumbar spine, the center of gravity are passed more posteriorly, hence the posterior elements experienced the compressive forces. This study helps in understanding further on mismatch between the two regions in the biomechanics aspect as well as highlighting the role of posterior elements in the lumbar region to resist compressive instead of tensile stresses.

Chapter 2.2

Classifications of Thoracolumbar Fractures

Classification systems are typically formulated to provide guide in the formulation of treatment plan as well as to prognosticate the disease. The discussion below will try to incorporate the most common classification systems being used to date.

Denis Classification

Denis, F., 1983 in his anatomic classification system proposed that the spine stability is based on three columns, which are the anterior, middle and posterior columns. The anterior column is made of anterior half of the vertebral body , anterior annulus fibrosus and the anterior longitudinal ligament. The middle column is composed of posterior half of the vertebral body, posterior annulus fibrosus and the posterior longitudinal ligament. The posterior column is made up of the pedicles, facet joints and the posterior ligamentous complex (PLC). Based on the column theory, he divided the fractures into major and minor . Major injuries are essentially involvement of two or more columns and they are the burst fractures, flexion-distraction fractures and fracture-dislocations . These groups are further subdivided into 3-5 subgroups.

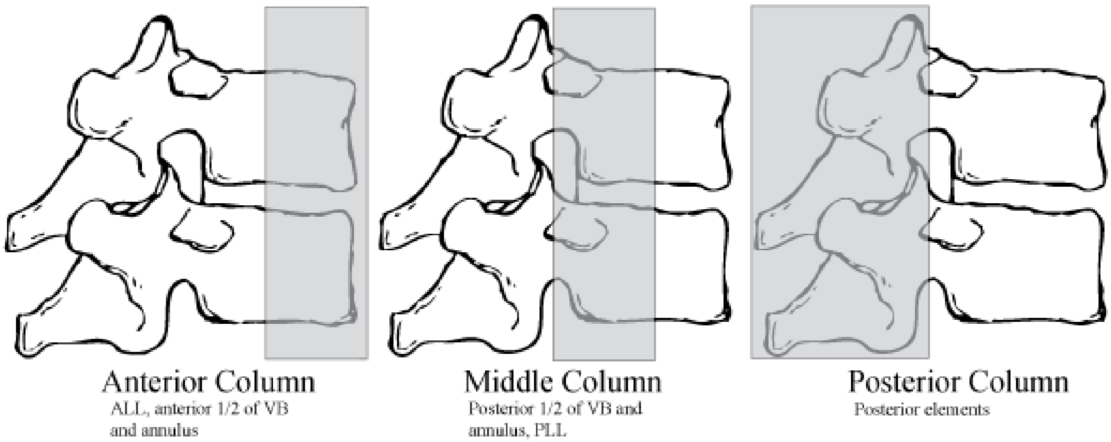

Figure 2: Denis 3 column model. Adapted from www.neurosurgerysurvivalguide.com

James et al., 1994 in his cadaveric biomechanical study looked at the 3 columns that contributed to spinal stability. The authors found that the posterior column was the main resistance to flexion and kyphosis and that the PLC is critical to the biomechanical stability. PLC is made up of interspinous ligament, supraspinous ligament and the ligamentum flavum.

McCormack and Gaines classification

This classification was derived after an association was found between fracture morphology of the fractured vertebra and the success or failure of the short segment pedicle screw instrumentation. This is also known as the load-sharing classification system and it take consideration of 3 factors. Firstly, the degree of vertebral body comminution. Secondly, the apposition of vertebral body fragments and lastly the degree of kyphotic deformity (Kepler et al., 2012). Points are given to each category and scores 6 and below will benefit from short segment posterior instrumentation whilst score of 7 and above will require an anterior instrumentation as posterior based fixation will generally will fail.

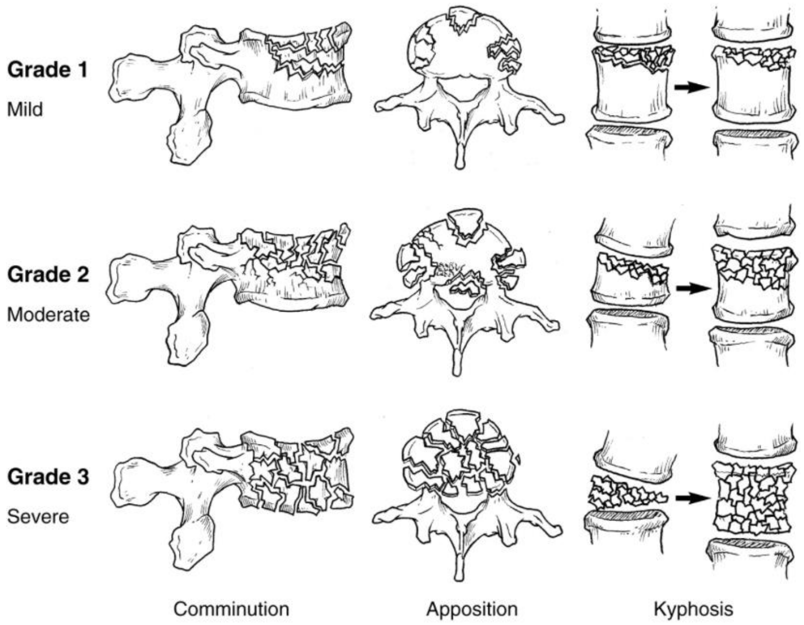

Figure 3 : McCormack and Gaines classification illustrating the 3 factors for scoring and their severity. Adapted from www.jaaos.org.

Table 1 : Point scoring allocation in McCormack and Gaines classification.

Score	1 point	2 points	3 points
Sagittal collapse	30%	>30%	60%
Shift	1mm	2mm	>2mm
Correction	3 degrees	9 degrees	10 degrees
Total	3 points	6 points	9 points

AO Classification

Magerl et al., 1994 classifies fractures of the spine based on the AO (Arbeitsgemeinschaft für Osteosynthesefragen) method of extremities fracture classification into three parts A (Compression fracture), B (distraction injury) and C (fracture-dislocations) . As with the AO classification, type A is less severe with type C being the most severe. Each group is further subdivided into three subgroups.

Both Denis and the AO Classifications were found to have fair to moderate validity and reliability but it becomes less reliable with increasing complexity of the fracture patterns. Oner et al., 2002 looked at the interobserver and intraobserver reliability for both Denis and AO classifications. Both were found to have fair reliability when X-ray and CT were used. With the addition of MRI, reliability of the AO system was enhanced to moderate reliability but not for the Denis Classification.

TLICS Classification

The Spine Trauma Study Group (STSG) in trying to incorporate important factors needed in the management for TL fracture, formulates The Thoracolumbar Injury Classification and Scoring System (TLICS) based on three main factors which are the fracture morphology, the integrity of the posterior ligamentous complex (PLC) and the neurologic status of the patient (Vaccaro et al, 2005). This classification and scoring system grades the severity of the injury as well as to aid in the treatment recommendations. Each of the subcomponents is given point score. The points in each category are tallied to yield an overall score that may range from minimum score of 1 to maximum of 10. They advocate injuries with severity score of 3 or less can be treated non-operatively whilst score of 5 or more will require surgical intervention. Score of 4 are "grey area" whereby operative or non-operative treatment may be appropriate based on the patients factors for example other co-morbidities and/or injuries as well as the surgeon's preference.

In addition this classification may also guide as to which approaches may be appropriate. For example, associated PLC injury will require a posterior approach and patient with neurological deficits will dictate that an anterior approach may be required for decompression. Based on the investigative findings, both approaches may be required if associated neurology and PLC injury are present.

Morphology	
Compression	(1 point)
Burst	(1 point)
Translation/rotation	(3 points)
Distraction	(4 points)
Posterior ligamentous complex	
Intact	(0 points)
Suspected/indeterminate	(2 points)
Injured	(3 points)
Neurologic status	
Intact (ASIA-E)	(0 points)
Nerve root	(2 points)
Cord/conus	
Complete (ASIA-A)	(2 points)
Incomplete (ASIA-B,C,D)	(3 points)
Cauda equina	(3 points)

Table 2: TLICS classification scoring system.

Whang et al., 2007 found moderate to substantial interobserver reliability for TLICS classification. One disadvantage of the TLICS classification is that it requires an MRI to assess the PLC, which may not be available in some centers in Malaysia where the definitive management of thoracolumbar injured patient are performed .

Chapter 2.3

Epidemiology of thoracolumbar fracture, burden of the condition.

Thoracolumbar region is defined as a region that encompasses the level of T11 to L2. Despite its short segment compared to the total level of vertebrae from C1 to the sacrum, it accounts for up to 90% of all spinal fractures (Smith et al., 2010).

Zhang Y, 2012, has compiled the largest database on orthopaedic trauma epidemiology to date. He retrospectively reviewed radiographs of 65 267 fractures of 60 000 patients in the Republic of China and codes them based on AO/OTA classifications. This was done over a period of 5 years, which are from 2003 to 2007. Out of these, there were 4720 spinal column fractures, which accounts for 7.23% of all types of fractures. The thoracolumbar junction based on the AO coding segment are from region 52.11 – 53.02 and these accounts for 57.83% of all spinal column fractures. He also found that male accounts for 54.20% and female 25.80% of these fractures. The high-risk age group is the 31-40 year old for both males and females.

Wang et al., 2012 looked at 3142 patients with traumatic spinal injuries admitted to two major hospitals in China over a period of ten years and found 54.9% of these involved the thoracolumbar spine. The peak age were in the 31 to 40 year old group with accidental falls and motor vehicle accidents being the 2 most common mechanism of injuries (58.9% and 20.9% respectively). Younger patients were more commonly involved in motor vehicle accidents and older patient in accidental falls.

What could be gathered from these two studies on the demographics of thoracolumbar fractures is that it involved the 31-40 year old age group. Firstly, this age group is typically fairly active and it has to be an essential part in decision making in the management. Secondly, they are typically the breadwinners for most families and the financial impact of time off work to the families have to be taken into consideration as well. Lastly, there are also the direct impact to the nation workforce and economic burden to the health system that needs to be taken into consideration.

Chapter 2.4

Natural history of thoracolumbar fracture.

Shen et al., 2001 performed a prospective clinical trial involving 80 neurologically intact patients to look at the results of non-operative treatment versus operative treatment using short segment posterior instrumentation with pedicle screws. These patients were followed up for two years. 47 patients were included in the non-operative group whilst 33 patients were in the operative groups. The non-operative group was put on hyperextension brace and allowed early activity early and the operative group was instrumented with short segment fixation with pedicle screw at the fracture level. The author found that the operative group showed improvement in pain score up to 6 months post injury after which showed no difference between the two groups. In this group, the kyphotic angle also showed initial improvement by initial 17^0 which was subsequently lost. In addition, there were also one case of superficial infection and two cases of broken screws and this group has hospital charges 4 times compared to the non-operative group. There were no neurologic deficits in the non-operative group, the retropulsion was decreased from 34% to 15% but the kyphosis worsened by 4^0. The authors conclude that despite the initial improvement in pain score and kyphotic angle correction, the functional outcome was similar at 2 years.

A literature reviews on the operative versus non-operative treatment of thoracolumbar fractures in the neurologically intact was performed by (Thomas et al., 2006). There is no evidence to support the superiority of one treatment to the other when measured using specific quality of life scales. In addition, there is also no evidence that links posttraumatic kyphosis to the clinical outcomes.

Yi et al., 2006 performed a review of the literatures , which also looks at whether operative treatment in thoracolumbar fractures is more superior compared to the non-operative measures in the neurologically intact patients. The authors looked at multiple databases from 1978 to 2005 and found only one randomized controlled trial (RCT). They found no statistical difference in pain and function related outcomes. There are also no differences in the rates of return to work, radiographic findings or average length of hospitalization at final follow up. However, in the operative group, the rate of complication and the cost of treatment were higher. They also found that the degree of kyphosis or the percentage of correction lost did not correlate with the clinical symptoms. This was derived from one study even though randomized but with small sample size and the authors concluded the need for more RCT to be performed.

Chapter 2.5

Indications for treatment for thoracolumbar burst fracture

McLain RF., 2006 highlighted the principles in the treatment of TL burst fractures. These are to protect neural elements and to maintain neurologic function, to correct segmental collapse and deformity, to prevent spinal instability and subsequent pain, to permit early ambulation and return to function and lastly to restore normal spinal mechanics.

The absolute indication for surgical treatment in TL burst fracture is progressive neurological deficit in the setting of neural element compression, fracture dislocation or progressive kyphosis, which is symptomatic. Other indications are >50% canal compromise, 50% loss of vertebral body height and > 30^0 kyphosis (Shimer et al., 2010).

The main advantage of operative managements are provision of immediate spinal stability and this is beneficial for patients who are multiply injured or patients who are unable to tolerate prolonged bed rest or brace (McLain RF., 2006). Also in the setting of multiply injured patient, short posterior fixation will allow for shorter surgical time, immediate stabilization and achieve minimal blood loss. This is another measure of "damage control" orthopaedics in spine. The other advantage of operative management is that it can reliably correct the deformity, restore the sagittal alignment and canal dimension that non- operative measures (McLain RF., 2006)

Interestingly, a review of the literature to look at whether canal clearance obtained surgically is more superior compared to non-operative measures in regards to the neurological outcome was done by Boerger et al., 2000. The authors found that out of the 60 publications reviewed, there was no significant advantage of surgical over non-surgical treatment in terms of the neurological improvement. Additionally, the authors found that in 75% of the papers reported significant complications with surgical treatment, which include neurological deterioration.

To date, there are no evidence-based standards on the indications and management of thoracolumbar burst fractures as good quality trials are still sparse. In addition to this, the approaches and types of instrumentation are also controversial. (Oner et al.,2010) found in their systematic reviews that there is no difference in Frankel Grade improvement when anterior, posterior or combined approaches were used.

Radcliff K., 2012 lists the advantages of utilizing the posterior approach, which are its extensile nature, the ability to obtain multiple level fixations and ability to perform deformity reduction maneuvers. He also added that through posterior approach instrumentation, the spinal alignment can be controlled 3 dimensionally as well as correction of the kyphosis.

Chapter 2.6

Posterior Instrumentation history.

Historically, the initial posterior stabilization system was deviced by Dr Harrington in 1953. It was a posterior hook-rod device that was also known as the Harrington Rod system that utilize a screw at the facet that was augmented with hooks over the lamina connected by rods. The constructs were intended to provide distraction and help maintaining that with "ligamentotaxis". Unfortunately, kyphosis tends to recur. Luque introduced the modification of the Harrington Rod where he augmented the system with sub laminar wire (Singh et al., 2004)

Pedicle screw was first being introduced in the literature back in 1985 by Dick W and associates. Pedicle screw fixation offers stabilization in all three mechanical columns of the spine. Hence, it is able to provide more lordosing force from posteriorly. This is important as the aim of the posterior instrumentation in TL burst fracture is to reduce the spinal deformity through a combination of lordosis and distraction and also to maintain this correction until healing is achieve (Zdeblick et al., 2010).

As being mentioned earlier, in the cervical and lumbar region, because of the lordosis, the load bearing axes are located in the posterior aspect. Conversely in the thoracic region the axis are located anteriorly. As the screw-bone interface has greater strength compared to the hook-bone interface, a shorter construct is now possible (Cinotti et al., 1999)

Chapter 2.6.1

Pedicle Screw Anatomy

Pedicle screw like any bone screws is composed of a head, neck and body as being illustrated in figure 6. The body is the part being embedded in the vertebra and it has an inner and outer diameter also known as the major and minor diameter respectively. The difference between these two is called the thread depth. The two aspects that are critical with a pedicle screw body , firstly is its thread depth that will contribute to its pullout strength and secondly the inner diameter that will influence its strength.

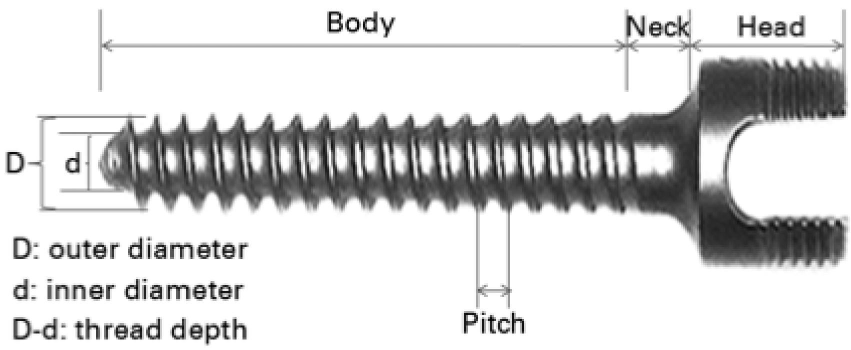

Figure 4 : Parts of a pedicle screw.

The head of the pedicle screw can be monoaxial which means the neck is fixed to the body and placement of the rod to the head has to be perfect as being illustrated in figure 6 and 7. The polyaxial head, has a mobile neck that allows multidirectional movement of the head in relation to the body as is less forgiving if the placement of the screw is not in exact alignment with the rod as being illustrated in figure 8. The rod is connected to the head by an inner screw that is threaded to the head.

Figure 5 : An example of a monoaxial pedicle screw. Adapted from www.orthopedicequipments.com.

Figure 6: An example of a polyaxial pedicle screw. Adapted from www.orthopedicequipments.com.

Pullout strength.

The bigger the thread depth the better the screw will be able to bite into the bone and resist it from being pulled backwards. To achieve this however the inner diameter will have to be smaller which unfortunately will affect the screw fatigue stiffness. The other factors that contribute to the pullout strength is the quality of the bone. Therefore in osteoporotic bone with thinner cortex and reduced density will reduce the screw pullout strength.

Fatigue strength

The inner diameter of the pedicle screw is the main factors contributing to its strength. Liu et al., 1990 have demonstrated in their study that by increasing the inner diameter by 27% will increase the fatgue strength by 104%. The weakest part of the screw is the neck. In polyaxial screw, the site of the coupling between the head and the screw is the weakest part (Fogel et al,. 2003) whereas in monoaxial screw, the neck is the weakest part (Liu et al., 1990). The downside of the increased in inner diameter is the thread depth will be reduced and so is the pullout strength. New generation screws are addressing this issue by increasing the inner diameter around the neck and increasing the thread number at the pedicle to increase its pullout strength.

Insertion and fixation in the vertebrae

The pedicle screw is inserted at the pedicle and spans to the vertebral body and by following the pedicle will miss the vertebral canal that house the spinal cord and its extension depending on the level. Approximately 60% of the pullout strength and 80% of longitudinal stiffness is depending on the pedicle and not the vertebral body (Hirano et al., 1997).

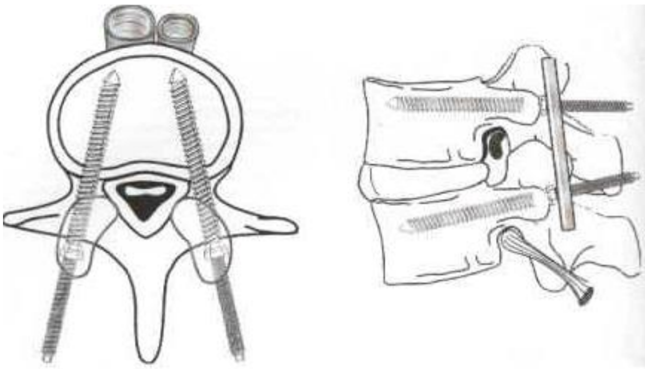

Figure 7 : Diagram to illustrate the placement of pedicle screws in a vertebra. Adapted from www.partmedical.com.

Figure 8 : The use of pedicle screw and contouring of the rod to correct deformity. Adapted from www.buffaloneuro.com.

Chapter 2.7

Short Segment Pedicle Screw Instrumentation (SSPI).

Short segment pedicle screw instrumentation is the use of pedicle screw one level above and one level below the level of fracture to obtain stabilization of the fracture. Conversely, a long segment fixation typically spans 3 levels above and 2 levels below the fracture (McLain RF., 2006). SSPI is a widely practiced method in the treatment of thoracolumbar fractures worldwide. It allows for stabilization of the fracture utilizing the least number of segment necessary and in doing so restoring the sagittal balance of the spine (McLain RF., 2006).

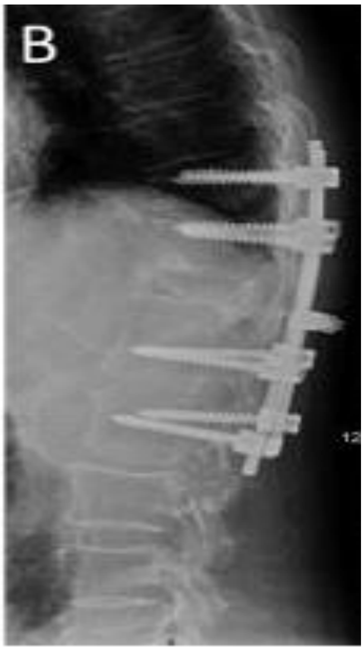

Figure 9 : Lateral radiograph of long segment posterior instrumentation. Adapted from Nouh M.R. 2012.

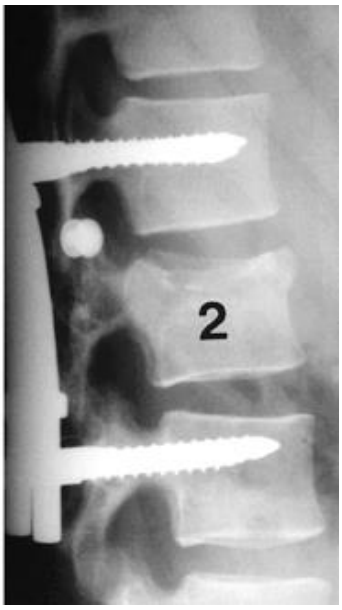

Figure 10 : Radiograph of short segment posterior instrumentation. Adapted from Nouh M.R. 2012.

Figure 11 : Radiograph of short segment posterior instrumentation with intermediate screw at the fracture level. Adapted from Nouh M.R. 2012.