FUNCTIONAL OUTCOMES OF INTRA-ARTICULAR CALCANEAL FRACTURED PATIENTS WHO HAD BEEN TREATED OPERATIVELY AND NON-OPERATIVELY IN QUEEN ELIZABETH HOSPITAL, KOTA KINABALU, SABAH FROM JUNE 2009 TO MAY 2013

By

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LIST OF ABBREVIATIONS AND SYMBOLS

IACF	Intra-articular calcaneal fractures
ORIF	Open reduction and internal fixation
SF-36v2	Short Form-36 (international version)
PCS	Physical component summary
MCS	Mental component summary
RTW	Return to work
ADLs	Activities of daily living
POP	Plaster of Paris
CT	Computed Tomography
%	Percentage
°	Degree
IQR	Inter Quartile Range

KEPUTUSAN HASIL BERFUNGSI DI ANTARA PESAKIT PATAH TULANG INTRA-ARTIKULAR KALKANEAL YANG MENERIMA RAWATAN PEMBEDAHAN BERBANDING DENGAN PESAKIT YANG TANPA MEMERLUKAN RAWATAN PEMBEDAHAN DARI BULAN JUN 2009 HINGGA BULAN MEI 2013 DI HOSPITAL QUEEN ELIZABETH, KOTA KINABALU, SABAH

ABSTRAK

PENGENALAN: Patah tulang kalkaneal adalah disebabkan oleh trauma yang bertenaga tinggi dan kebanyakan keretakan adalah melibatkan sendi, iaitu intra-artikular. Patah tulang intra-artikular kalkaneal yang tidak berpecah-belah boleh dirawat secara am tanpa pembedahan. Patah tulang intra-artikular kalkaneal yang berpecah-belah memerlukan rawatan pembedahan. Ini adalah bertujuan untuk mengembalikan kedudukan dan bentuk asal anatomi-nya supaya mendapat pemulihan fungsi awal pergelangan kaki dan meminimumkan kerosakan sendi. Kajian ini bertujuan untuk mengetahui keputusan hasil berfungsi pada pesakit patah tulang intra-artikular kalkaneal yang telah menjalani rawatan pembedahan berbanding dengan pesakit yang tanpa memerlukan rawatan pembedahan.

KAEDAH: Kajian ini merupakan satu kajian keratan rentas di mana hanya satu intervensi dilakukan terhadap 62 orang pesakit yang telah mengalami kecederaan patah tulang intra-artikular kalkaneal. Pesakit-pesakit berkenaan hanya terpilih selepas memenuhi kriteria-kriteria inklusi and exklusi. Dua kumpulan pesakit akan terpilih melalui kaedah pengsampilan ini, iaitu kumpulan pesakit yang telah menjalani rawatan pembedahan dan kumpulan pesakit yang menerima rawatan tanpa pembedahan. Untuk perbandingan sudut Bohler ketika melaksanakan kajian ini, kedua-dua belah kaki pesakit akan diambilkan sinaran x-ray atau radiograf. Selain daripada kajian soal selidik kesihatan SF-36v2, kedua-dua kumpulan pesakit akan dinilai berdasarkan keupayaan pesakit melakukan aktiviti kerja seharian atau kembali ke pekerjaan asal.

KEPUTUSAN: Kumpulan pesakit yang menerima rawatan pembedahan tidak mencapai keputusan yang berbeza atau lebih baik dari segi PCS dan MCS pada SF-36v2, jika berbanding dengan kumpulan pesakit yang tanpa memerlukan rawatan pembedahan. Sudut Bohler pada kaki pesakit adalah terbukti penting terhadap keputan hasil berfungsi pada seseorang pesakit yang mengalami patah tulang intra-artikular kalkaneal. Kumpulan pesakit yang menerima rawatan pembedahan juga tidak mampu melakukan aktiviti kerja seharian atau kembali ke pekerjaan asal mereka lebih awal, jika berbanding dengan kumpulan pesakit yang tanpa memerlukan rawatan pembedahan.

KESIMPULAN: Rawatan pembedahan untuk mengembalikan struktur anatomi tulang kalkaneal pada seseorang pesakit patah tulang intra-artikular kalkaneal tidak menghasilkan keputusan klinikal yang berbeza jika berbanding dengan kumpulan pesakit yang tanpa memerlukan rawatan pembedahan. Kemampuan seseorang pesakit melakukan aktiviti kerja seharian atau kembali ke pekerjaan asal lebih awal juga diketahui tidak berbeza di antara kedua-dua kumpulan pesakit.

Kunci perkataan: Intra-articular calcaneal fracture, SF-36v2 health survey.

FUNCTIONAL OUTCOME OF INTRA-ARTICULAR CALCANEAL FRACTURED PATIENTS WHO HAD BEEN TREATED OPERATIVELY AND NON-OPERATIVELY IN QUEEN ELIZABETH HOSPITAL, KOTA KINABALU, SABAH FROM JUNE 2009 TO MAY 2013

ABSTRACT

INTRODUCTION: Calcaneal fractures are caused by high energy trauma and mostly are intra-articular fractures. Non-displaced intra-articular calcaneal fracture (IACF) can be treated non-operatively. Displaced intra-articular need to be reduced and fixed anatomically to facilitate early ankle rehabilitation and minimize functional impairment. This study intends to find out the functional outcome of the IACF patients who were underwent operative treatment compared with patients who treated non-operatively.

METHODS: This study was a cross-sectional, single-intervention and retrospectively assessed the selected 62 patients with IACF, who had fulfilled inclusion and exclusion criterias. All patients recruited in this study were from June 2009 to May 2013 and sampled into two groups; the operative treatment and non-operative treatment groups. The patient's bilateral foot lateral view plain radiographs will be taken for comparison of the Bohler's angle. Both groups of patients were assessed by the SF-36v2 health survey questionnaire and their ability to perform ADLs or RTW was being assessed as well.

RESULTS: achieved no significantly better result in the PCS and MCS scores if compared with the non-operative treatment group. The Bohler's angle was found to have direct correlation with the functional outcome. In addition, the operative treatment group of displaced IACF patients not achieved significant earlier RTW or performs ADLs when compared with the non-operative treatment group.

CONCLUSIONS: If compared with the undisplaced IACF patients which had treated non-operatively, the operative anatomical restoration and fixation of the displaced IACF is essential to provide as similar as, but not significant better functional outcome as well as early RTW and performs ADLs.

Key words: Intra-articular calcaneal fracture, SF-36v2 health survey.

CHAPTER 1 - Introduction

1.1 Background of the study

Calcaneal fractures are caused by high energy trauma. They usually occur by axial load on the patient's heel. Most calcaneal fractures are intra-articular fractures. The calcaneum being a weight bearing bone, any intra-articular fractures and disruptions can cause bad consequences if the fracture displacement was not reduced and fixed anatomically.

Various treatment options for intra-articular calcaneal fractures (IACF) are available which could either be the non-operative treatment or surgical treatments. Patients who had small or non-displaced fractures had good results with closed treatment (Crosby and Fitzgibbons, 1990). The selection of operative intervention usually was influenced by the severity of fractures, fracture patterns, the soft tissue conditions, and also the patient's underlying pre-morbid illnesses (Buckley *et al*., 1992).

Many authors suggest that an anatomical reduction of the displaced IACF cannot be accomplished using non-operative methods and instead recommend surgery (Bezes *et al*., 1993; Letournel, 1993; Thermann *et al*., 1998). Restoration of the calcaneal length, height and width is equally important to minimize functional impairment (Flemister *et al*., 2000). Advancement in surgical treatments allows stable fixation of the fractures and facilitate early rehabilitation of the affected ankle.

CHAPTER 2 – Literature Review

2.1 Epidemiology

Calcaneus is a weight bearing bone and basically subcutaneous. Its bony anatomy is complex and has three joints namely subtalar, calcaneocuboid and calcaneo-navicular joints. Calcaneal fractures account for 60% of all tarsal fractures but only 2% of all fractures (Kitaoka *et al.*, 1994; Benson *et al.*, 2007; HY Wong *et al.*, 2008). It is usually caused by a sudden, high-velocity impact on the heel (Kenwright, 1993). The most common mechanism of injury are motor-vehicle-accidents and falls from heights (Schatzker and Tscherne, 1992).

The annual incidence of the fracture was 11.5 per 100,000, and occurred 2.4 times more frequently in males than females (Mitchell *et al.*, 2009). Men are more commonly sustained this type of injury if compared with the women because this form of injury commonly happened as occupational injuries (Sanders, 2000). In males, the incidence was 16.5/100,000/year, with a peak incidence in the age range of 20 to 29. In females, the overall incidence was 6.26/100,000/year and evenly spread throughout the age with slight increase in incidence towards the postmenopausal years (Mitchell *et al.*, 2009).

Calcaneal fractures can be classified into extra-articular or intra-articular type with the articular surface of the subtalar joint commonly involved approximately 75% of the time (Hecman, 1996; Ebraheim *et al.*, 2000; Sanders, 2000). Most of the intra-articular injuries were result from a direct axial load, whereas those extra-articular injuries often resulted from more of a twisting or avulsive force (Connolly, 1981; Crenshaw, 1971). Bilateral fractures can occur in 10% to 15% of patients. Most calcaneal injuries occurred in isolation; however among the concomitant injuries which were commonly seen are the lower limb (13.2%) or spinal injuries (6.3%) (Mitchell *et al.,* 2009).

Calcaneal fractures also have a significant impact on the economy as they not only involve the costs of treating the fracture but also the outcome and disability from the patients' perspective (Essex-Lopresti, 1952). As the world population increases in age both in the developed and also developing countries, the calcaneal fractures becomes an important and increasing economic problem (Mitchell *et al.,* 2009).

2.2 Classification of Intra-articular Calcaneal Fractures (IACF)

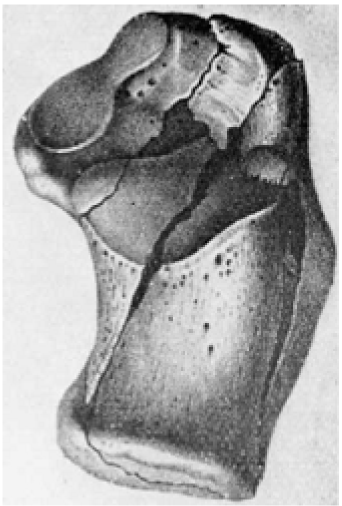

Figure 2-1: Intra-articular calcanel fracture (IACF) with typical fragmentation seen from the superior aspect (redrawn from Malgaigne's atlas).

Most classifications were focused on being descriptive and assistive in managing IACF, they represent 75% of the fractures seen in the calcaeum, and the vast majority will require operative intervention (Tornetta, 1998).

There are several classifications systems of the calcaneal fracture patterns which have been described by various authors such as Palmer in 1948, Essex-Lopresti in 1952, Rowe in 1963, McReynolds in 1976, Letournel in 1984, Carr in 1989 and Burdeaux in 1993 before modern imaging techniques were widely available. These classifications were based on morphological patterns, intra-articular extension, degrees of comminution and mechanism of injury.

The original Essex-Lopresti classification has been persistently used over the years to classify calcaneal fracture lines of the subtalar joint according to the direction of the “secondary fracture line”. In this classification, there are two types (Essex-Lopresti, 1952), which are the Tongue-type fracture and the Joint-depression fracture. Although the Essex-Lopresti classification has been used for many years and is useful in describing the location of the secondary fracture line, it does not describe the overall energy absorbed by the posterior facet, by comminution or by the displaced fragments (Burdeaux, 1983). In addition, when this classification is used, approximately 50% of calcaneal fractures were considered Joint depressive, 35% were tongue type, and 10% to 15% were unclassified.

Subsequently, there are two classification systems which respectively developed by the AO-OTA (Arbeitsgemeinschaft fur Osteosynthesefragen-Orthopaedic Trauma Association) and the AOFAS (American Orthopaedic Foot and Ankle Society), but both had been shown to have limited inter-observer reliability and reproducibility (Bhattachary *et al.*, 2005; Sayed-Noor *et al.*, 2011).

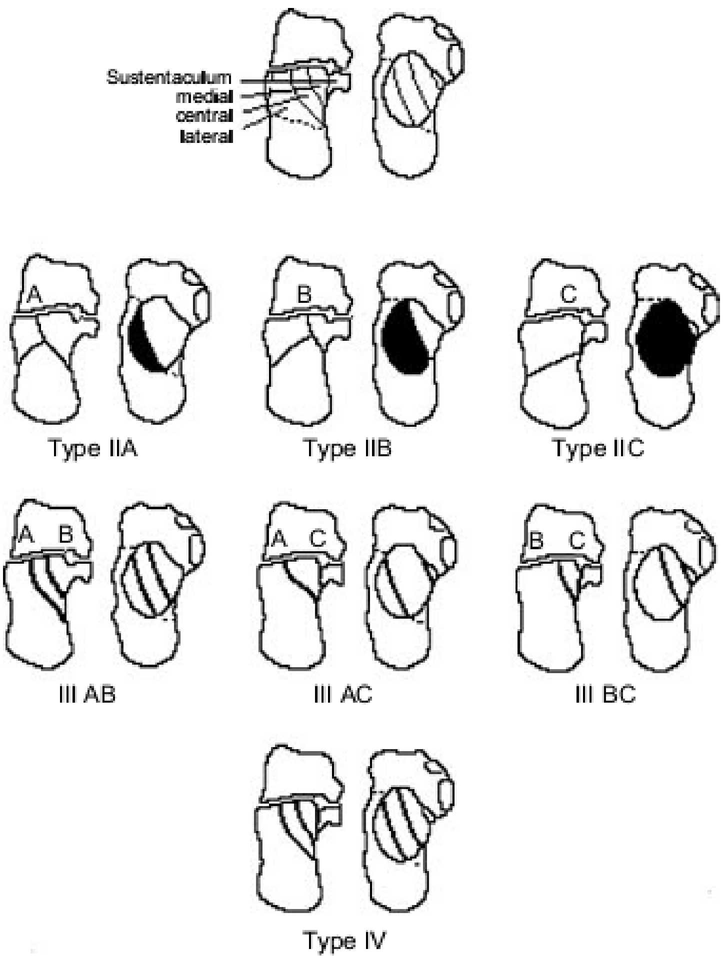

Figure 2-2: Sanders Classfication of Intraarticular Calcaneal Fractures (taken from Sanders et al., 1993)

A displaced IACF is strongly recommended for operative intervention, hence, Computed Tomography (CT) scan has became the most vital radiological investigation for the diagnosis, pre-operative planning and management of calcaneal fractures (Zwipp *et al.*, 1993). Sanders Classification has become most widely accepted in the evaluation of intra-articular fractures based on CT scans (Schepers *et al.*, 2009). It describes the comminution and displacement of the posterior facet. All non-displaced articular fractures, irrespective of the number of fracture lines, are classified as Type I. Type II fractures are two part fractures of the posterior facet. Type III articular fractures are three part fractures that feature a centrally depressed fragment. Type IV fractures are highly comminuted and often more than four articular fragments exist (Sanders *et al.*, 1993).

The Sanders classification was chosen in this current study because it has the ease of description for the fracture patterns and with the CT reconstruction. It gives precisely the location and number of fracture lines through the posterior facet for planning the operative intervention (Sanders *et al.*, 1993). In addition, the Sanders classification also correlates better with the prognosis and outcomes (Rubino *et al.*, 2009; Schepers *et al.*, 2009). However, the Sanders classification have limitations in descriptions of other important aspects of the fractures including heel height and width, varus-valgus alignment and calcaneocuboid involvement (Crosby and Fizgibbons, 1996) and does not consider the osteochondral and soft tissue displacement or tendon entrapment (Guerado *et al.*, 2012).

2.3 Treatment of Intra-articular Calcaneal Fractures (IACF)

There are generally more than 15 types and combinations of treatment methods for IACF (Poeze *et al.*, 2008; Gougoulias *et al.*, 2009; Dhillon *et al.*, 2011; Schepers, 2011), which can be broadly divided to non-operative and operative treatments. There were few operative techniques such as external fixation (Magman *et al.*, 2006; Dayton *et al.*, 2014), closed reduction and percutaneous treatment (Essex-Lopresti, 1993; Tornetta, 2000; Rammelt *et al.*, 2010), mini-open reduction or less-invasive surgery (LIS) described by Carr (2005) and Weber *et al.* (2008), minimally invasive sinus tarsi approach (Schepers, 2011; Meraj *et al.*, 2012), minimally invasive with endobutton (Kesemenli *et al.*, 2013) and arthroscopic assisted surgery (Gavlik *et al.*, 2002; Schuberth *et al.*, 2009). All these operative methods are not being discussed in this current study.

2.3.1 Non-operative Treatment for non-displaced fractures

Figure 2-3: A posterior, removable, well-padded splint in a non-displaced IACF who treated non-operatively (taken from San Luis Podiatry Group, 2005).

Sanders *et al.* (1993) stated that all non-displaced articular fractures, irrespective of the number of fracture lines, are considered Sanders Type I and should treated non-operative. Later on, Macey *et al.* (1994) supported it by mentioned those fractures with a simple fracture pattern (two fragment) and 2mm or less of intra-articular displacement should be treated non-operatively by a simple posterior, removable, well-padded splint in a plantigrade position to avoid equinus contracture and potential skin complications (Barei *et al.*, 2002). Heel widening can be corrected by applying lateral and medial compression (Guerado *et al.*, 2012).

Buckley *et al.* (2002) carried out non-operative treatments mainly with rest, cooling packs, compressive bandage and elevation. Non-steroidal anti-inflammatories are also recommended by Ibrahim *et al.* (2007) for pain relief and aims for early subtalar motion. The swelling will become better and the injuries become comfortable within a week or two, then early physiotherapy for full range of motion of all joints is started afterwards to prevent stiffness (Bucholz *et al.*, 1994).

Non-weight bearing must be maintained until evidence of healing, which occurs after some 8 to 12 weeks (Kitaoka *et al.*, 1994; Basile, 2010). Beyond that, weight bearing is progressively applied (Barei *et al.*, 2002). Lopez and Forriol (2011) suggested that shoe insoles are usually required for better distribution of load. Besides that, custom-orthoses can improve patients standing and walking tolerance (Kitaoka *et al.*, 1994).

Studies had shown that cast immobilization before swelling subsided carry risk of cutaneous necrosis and acute compartment syndrome (Lopez and Forriol, 2011). In addition, Veltman *et al.* (2013) had shown scientific evidence that early cast immobilization will leads to worse results in mid-term duration.

In this study, the non-displaced IACF Sanders Type I patients had been treated by a protective below knee backslab. Patient's ankle was elevated with Bohler-Braun Frame with cryotherapy applied on. Patients had been given adequate non-opioid analgesia and NSAIDs and protected-passive range of motion exercises were instituted as soon as the swelling and pain were under control. Upon discharge home, patients were adviced for strict non-weight bearing ambulation for at least 6 weeks before adequate callus were seen on the plain radiographs (which are about 12 weeks). Thereafter, the patients were allowed progressive weight bearing on their affected limb.

2.3.2 Open Reduction & Internal Fixation (ORIF) for displaced fractures

The main principles of operative treatment for a displaced IACF are for accurate reduction of the subtalar joint with early subtalar motion exercises (Hetsroni *et al.*, 2011), the restoration of the three-dimensional calcaneus anatomy (height, width and alignment) as stated clearly by Mitchell *et al.* (2009) and Basile (2010), accurate repositioning of the midfoot in relation to the forefoot, subfibular decompression and implementation of measures to minimize swelling. The final goals of treatment are restoration of subtalar and ankle function, painless heel-to-toe gait, avoidance of deformity to allow normal shoe-wear, early post-treatment rehabilitation program and early return to work (Buckley and Meek, 1992; Sanders, 2000).

ORIF is the most commonly used technique for calcaneal fracture fixation, mainly with a lateral approach (Tennent *et al.*, 2001; Potter and Nunley, 2009; Makki *et al.*, 2010). Guerado *et al.* (2012) stated that ORIF is the best method of achieving anatomic joint reduction and calcaneus morphology restoration but the soft tissue complications are proportionally direct with the aggression magnitude of soft tissue. In addition, ORIF is usually performed when soft tissue has recovered from fracture trauma (Guerado *et al.*, 2012).

Newer methods of management, treatment algorithms, fracture classifications, instrumentation, imaging procedures, and education on handling of the surrounding soft tissues have resulted in better surgical outcomes than with non-operative management of intra-articular injuries (Rowe *et al.*, 1963; O'Connell *et al.*, 1972; Tanke, 1982). In addition, the current management are turned toward operative intervention as the recent literatures have reported better radiographic and functional results with open reduction and restoration of calcaneal anatomy (Bezes *et al.*, 1993; Loucks and Buckley, 1999).

2.4 Timing of Operative Intervention

The accuracy of reduction and the timing of operation directly affect the functional outcome of the patients (Lopez and Forriol, 2011). Surgery is not usually possible immediately after injury because of the soft tissue edema caused by the trauma and the additional surgical procedures. Until swelling subsides, it is hard to know how severe the injury is and whether the patient can withstand additional surgical trauma. Harding and Waddell (1985) mentioned that a mistake in judgment with premature surgery can result in disastrous soft tissue problems, such as necrosis or infections or both, that may be salvaged only with free soft tissue transfer or amputation.

Gardner *et al.* (1990) suggested that while awaiting surgery, the patient's foot should be well-padded and splinted in neutral position, elevated and cooled. Intrinsic exercises of the deep plantar flexors of the foot are helpful in controlling edema. An intermittent pneumatic foot pump has shown to be effective in accelerating resolution of edema before surgery (Thordarson *et al.*, 1999).

Fracture blisters can be filled with either clear fluid or blood and it is regarded as an isolated entity but not an absolute contraindication to surgery. Varela *et al.* (1993), and Giordano and Koval (1995) reported that incision through the blister can lead to complications related to wound-healing. Microbacterial colonization by the skin pathogens occurs soon after rupture of the blister until re-epithelialization completed. If fracture blisters develop, it should be treated until completely re-epithelialized. All blisters will eventually heal and delay of surgery is unavoidable.

The optimal time for patients to undergo surgery is when consistent and persistent skin wrinkling occurs around the entire foot (Sanders *et al.*, 1993), which indicates that the venous and lymphatic drainage is returning. This usually occurs between 10 and 21 days after injury, if appropriate splinting and elevation have been carried out. Sanders (2000) mentioned operative treatment should be performed within the first three weeks after injury before early consolidation of the fracture. Once the fracture has consolidated, which usually occurs 3 to 4 weeks after injury, it is difficult to separate the fracture fragments to obtain an adequate reduction (Mehmet and Cengiz, 2002).

2.5 Contraindications for Operative Interventions

With calcaneal fractures, the decision for operative intervention depends on various factors besides the type of fracture. The patient's age and inter-current illnesses, the associated multiple traumas or local foot injuries and patient's compliance are all important aspects to considered because they will have a major influence on the outcome (Lopez and Forriol, 2011).

Those patients who have peripheral vascular disease, insensate limb caused by peripheral neuropathy and poorly-controlled diabetes mellitus are contraindicated (Guerado *et al.*, 2012) for operative intervention. In these patients, the prominent displaced fracture fragments may jeopardize the adjacent soft tissue healing post-operatively. In addition, those immunocompromised patients such as patients on prolonged steroid treatment and intravenous drug abuser; patients with significant smoking history, and alcoholism have a significant impact in the wound healing and higher wound complication rate (Guerado *et al*., 2012). For this reasons, these patients usually are not recommended for operative management.

For those patients who are elderly patients, low demands or sedentary lifestyle, there is a relative contraindication for operative intervention (Barei *et al.*, 2002). In addition, the concurrent osteoporosis will complicate the surgical management. Patients who are poor compliant to treatment or are unable to collaborate for treatment collaboration also were not recommended for operative intervention (Lopez and Forriol, 2011). Besides that, Ibrahim *et* *al.* (2007) also stated that those fractures which presented late are not feasible for primary fixation treatment.

Aktuglu and Aydogan (2002) pointed out that the course and prognosis of a calcaneal fracture in multiple trauma patients is worse than in cases of isolated fracture. In the presence of associated life threatening injuries, operative interventions are not advisable for the displaced IACF.

Sanders (2000) recommended that in certain fractures which are deemed impossible for adequate reconstruction, such as Sanders Type IV or highly comminuted IACF are indicated for primary arthrodesis. Gurkan *et al.* (2011) stated that the non-operative approach of Sander type IV fractures may be simpler, less expensive and with fewer complications than surgical treatment.

In severe open displaced IACF, the principles of emergent surgical wound management are still applied but primary osteosynthesis fixations are contraindicated. For this type of injuries, subsequent ORIF or reconstructive procedures performed after the open wound has healed (Harvey *et al.*, 2001). However, Thornton *et al.* (2006) reported that most of the open fractures wounds are at the medial aspect (87%) and the lateral wounds are rare. Medial wounds of less than 4cm can be treated with standard ORIF if the wound can be closed and remain stabilized using antibiotic therapy. Larger wounds more than 4cm or unstable wounds should not be treated with ORIF, but can be reduced and held in alignment using percutaneous wire fixation.

Acute calcaneal fractures almost always are accompanied by considerable soft tissue swelling and foot compartment syndrome are common. Immediate fasciotomy decompression of the compartment is indicated but will cause inadequate soft tissue envelope. However, Myerson and Manoli (1993) recommended that ORIF of a calcaneal fracture is performed on a delayed basis, after the fasciotomy wounds had closed.

2.6 Surgical Approaches

The surgical approaches have been used for ORIF are the lateral approach, medial approach and combined lateral and medial approach. In this study, all the Sanders Type II and III; and few selected Sanders Type IV fractures were underwent operation via the lateral extended approach.

2.6.1 The Extended Lateral Approach

This approach is the most frequently used (Gallino *et al.*, 2009; Potter and Nunley, 2009; Basile, 2010; Makki *et al.*, 2010) and the L-shaped incision either short or extended allows full reduction of the anterolateral and posterolateral fragments, the entire subtalar joint, the calcaneocuboid joint, and the greater tuberosity. In addition, the risk of neurovascular damage is minimal and adequate space available for the placement of implant.

During the surgical procedure, the foot is positioned in lateral decubitus with a soft support under the heel to correct its natural tendency toward varus and to prevent reconstructions in varus (Lopez and Forriol, 2011).

Figure 2-4: Clinical photograph showing standard extended lateral approach (taken from Rak et al., 2009).

To prevent incidence of wound problem, the vertical incision must start just lateral to the Achilles tendon and the horizontal incision must parallels with the plantar surface of the foot (Rammelt *et al.,* 2003). The horizontal incision can be extended distally across the calcaneocuboid joint. The peroneal tendons, sural nerve and calcaneofibular ligament are left undisturbed and are reflected en mass in the flap (Harvey *et al.*, 2001). By preventing dissection of the flap, the skin incision should go all the way down to the bone and lift the skin directly off from the periosteum. The flap is then flipped-up by inserted few Kirschner wires into the malleolus, talus, and anterior tuberosity (Lopez and Forriol, 2011). This incision provides excellent visualization of the calcaneum and eliminates the need for a medial incision in most cases.

Once the fracture is exposed, the depressed or displaced fragments are accessed and elevated under direct vision (Barei *et al.*, 2002). After the subtalar joint is restored and varus or valgus malalignment are corrected; the lateral surface of calcaneus is supported with a plate, temporary wires and loose screws when necessary. Sanders *et al.* (1993) and Lopez and Forriol (2011) recommended that intra-operative Broden views to assure joint congruity. With modern imaging facilities, Schmidt *et al.* (2003) suggest intra-operative C-Arm fluoroscopes to assess precisely the subtalar joint congruity.

After implant fixation, a small closed-suction drain is placed deep to the flap and brought out anteriorly to prevent hematoma formation post-operatively. Closure of the incision is performed in 2 layers to decrease the incidence of wound dehiscence (Barei *et al.*, 2002). The initial deep interrupted absorbable suture should grasp periosteal tissue, giving a secure closure when tied. Interrupted sutures are places beginning at the ends of the wound and working toward the apex, advancing the flap slightly with each stitch. Ultimately, this technique minimizes tension at the apex of the wound and distributes the tension in the flap along the vertical and transverse limbs of the incision. Then the skin is closed with a non-absorbable suture for flap stitch.

Gould (1984) reported a very low incidence of complications through this lateral approach. But Harvey *et al.* (2001) reported that 89% wounds achieved primary healing uneventful, and the remaining 11% required local wound care. Postoperative sural nerve symptoms were reported as 2.8% but all had resolution over 6 months. The overall complication rate related to internal fixation was 16.5% but only 3.2% had wound infection (Harvey *et al.*, 2001).

2.6.2 The Medial Approach

This surgical approach was popularized by McReynolds (1976) and the most historical supported by Burdeaux (1997), but needed an additional lateral incision to obtain joint reduction in one fifth of cases.

The medial sustentacular fragment cannot be well reduced through a lateral approach because of the interosseous ligament act as a barrier for the medial structures access (Letournel, 1993; Benirschke and Sangeorzan, 1993). This medial approach has been used predominantly for simple two-part or extra-articular fractures, and in cases of medial wall blow out (Zwipp *et al.*, 2001). Della *et al.* (2009) recommended that this approach can also directly access to the tibialis posterior neurovascular bundle, flexor digitorum longus and flexor hallucis longus is very easy.

The incision is made horizontally, or as a lazy S-cut about 8-10cm exactly halfway between the tip of the medial malleolus and the sole (Burdeaux, 1993). The neurovascular bundles and tendinous structures are identified and carefully retracted. After achieved anatomical reduction, definitive fixation by a small plate using anti-glide fashion were recommended (Burdeaux, 1983).

However, with this approach the posterior facets are not able to be reduced directly. There was also be difficulty to assess the rest of the subtalar joint, address any lateral pathology and apply appropriate fixation or rigid implants along its surface. In addition, Paley and Hall (1993) observed that the neurovascular bundles remains at significant risk and 25% incidence of damage to the calcaneal branch of the posterior tibial nerve.

2.6.3 The Combined Lateral and Medial Approach

The combined lateral and medial approaches are indicated whenever lateral and medial fragments need accurate reduction (Guerado *et al.*, 2012). Stephenson (1987 and 1993) had reported that the combined extensile approach have 27% incidence of wound breakdown. Subsequently, Johnson and Gebhardt (1993) and Carr (2005) advocated small incisions in this combined approaches to address better the soft tissues with a less complication rate.

2.7 Osteosynthesis Perspectives

As with any other displaced intra-articular fracture; reconstruction with stable osteosynthesis is the most desirable of the surgical solutions (Lopez and Forriol, 2011). Swanson *et al.* (2008) showed that an imperfect osteosynthesis is far worse than non-operative treatment, with the added higher incidence of complications.

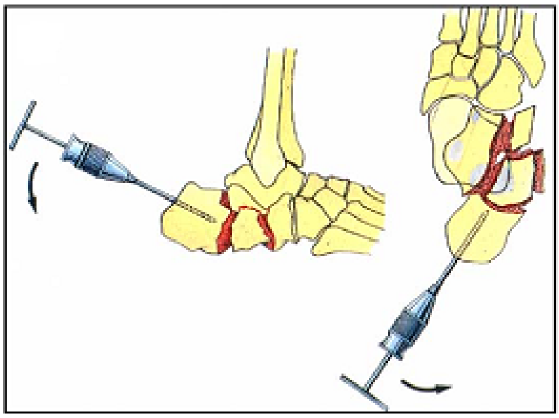

Figure 2-5: Using a Schanz screw introduced into the tuberosity to disimpact the fragments and to correct the height and varus/valgus malalignment. (taken from Rammelt and Zwipp, 2004).

Through the lateral extended approach, the subtalar joint is exposed to identify the primary line at the Gissane’s angle and reduce the tuberosity fragment by an axially placed 6.5mm Schanz screw (modified Westhue manoeuvre) or alternatively by placing placed 4.5mm to 5.5mm Schanz screw laterally (Benirschke and Sangeorzan, 1993; Zwipp *et al.*, 2001). The downward displacement of the tuberosity as well as its varus or valgus malalignment will then be corrected. The fractured posterior facet is reduced in a sequential fashion from medial to lateral. Then, the whole reconstructed posterior facet is brought into alignment with the tuberosity and the anterior process fragment; and provisionally stabilized by Kirschner wires. Satisfactory reduction is ensured under direct vision; by palpation using a semicurved surgical instrument; and axial and lateral x-ray or Broden’s projections will confirm the adequacy of all elements of reduction (Barei *et al.*, 2002; Rammelt and Zwipp, 2004; Lopez and Forriol, 2011).

Once the three-dimensional anatomy of the calcaneus have been reconstructed, any bony defect zone is identified and filled with either autologous ipsilateral iliac crest cancellous bone graft or bone substitutes. Although the indications for using bone graft or bone substitutes are controversial (Geel and Flemister, 2001), bone grafting is only for those fractures which have large defects or extensive collapse after provisional reduction (Rammelt *et al.*, 2003). In a prospective randomized study done by Longino and Buckley (2001) reported no evidence of superior results of using bone grafts. Because of the morbidity of autograft harvest from the iliac crest or Gerdy’s tubercle, the current trends are to use bone substitutes (Guerado *et al.*, 2012).

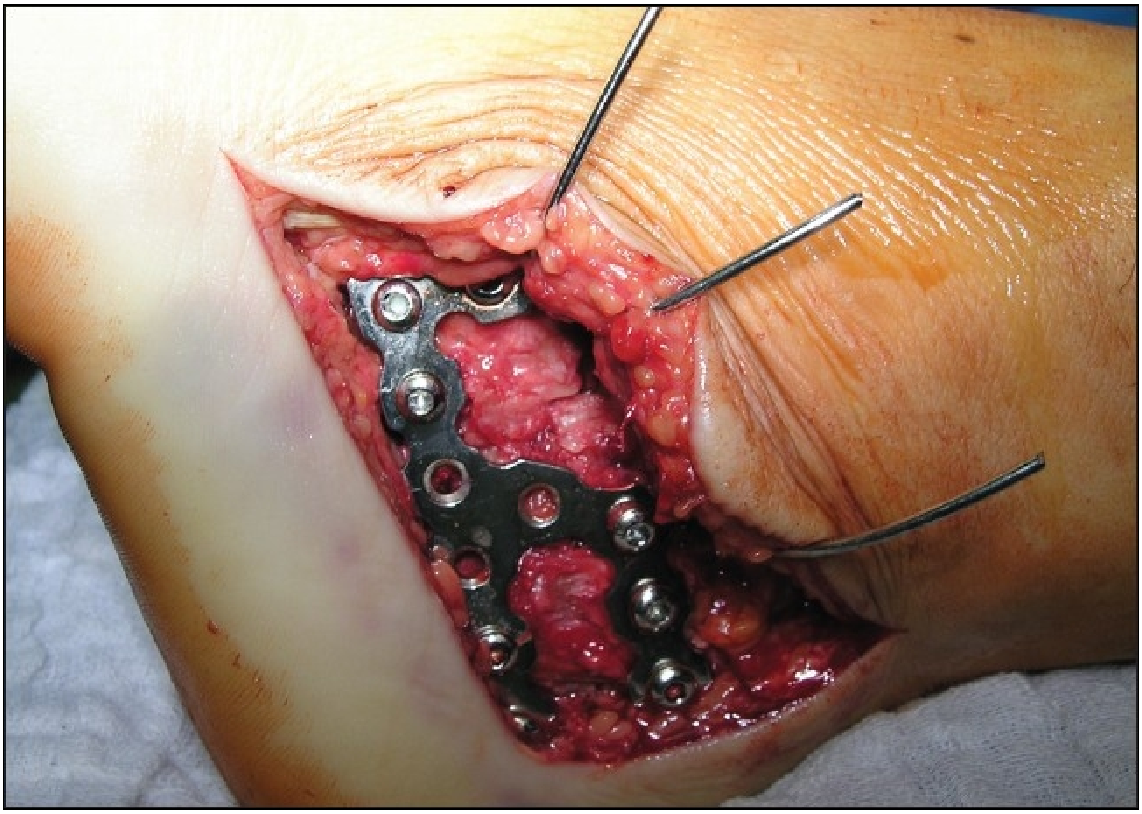

Figure 2-6: Intra-operative photograph showing non-locking calcaneal plate (taken from Rak et al., 2009).

Internal fixation is carried out with the use of an anatomically shaped plate fixed to the restored lateral wall of the calcaneus. There are several plates advocated, such as 3.5mm reconstruction plates, H-shaped plates, Y-shaped plates, T-shaped plates, a “low contact” plate and AO calcaneal plates. More recently, an interlocking anatomical (Synthes) plate has been developed by the AO Foot and Ankle Expert Group that obviate the need for bone grafting even in highly unstable fractures (Rammelt and Zwipp, 2004). The low profile locking plates were used with the intention of increasing osteosynthesis stability while interfering little with soft tissues.

It is important to fix the subtalar joint beforehand with 3.5mm screw in subchondral position directed from lateral to sustentaculum tali. However, it will be difficult to be carried out if an angular-stable screw-plate system such as interlocking anatomical (Synthes) plate is used. Lopez and Forriol, (2011) preferred using the screw-plate system without locking-angular stability, for it has a much lower profile, more versatile, allows applying compression or lag-screw effects against the plate, and enables the screws to be oriented by the surgeon's discretion. Until recently, the biomechanical stability and outcome between locking and non-locking plates are still controversial (Blake *et al.*, 2011; Illert *et al.*, 2011).

2.8 Rehabilitation following IACF

The duration of treatment for IACF is related to the associated soft tissue involvement and type of fracture. The main focus of rehabilitation should emphasize on restoring full range of motion, strength, proprioception and endurance while maintaining independence in all activities of daily living (Bucholz *et al.*, 1994). Resumption of pre-injury status is the goal with consideration of any residual deficit. Protocol for rehabilitation must be tailored with the stability of the fracture and fracture management, either non-operative or operative.

The goal of rehabilitation with an IACF is to return full function with a painless mobile ankle. Edema is a common problem and can be controlled by using modalities such as cold packs and compressive wrapping (Sanders, 2000). Non-steroidal anti-inflammatories are recommended by Ibrahim *et al.* (2007) to reduce the inflammation, the swelling and the pain. The patient should be encouraged to continue functional activities to prevent complications of inactivity and bed rest.

Gait training using appropriate assistive devices is indicated based on the ability and weight bearing status. Barei *et al.* (2002) supported that the ranges of motion of the adjacent joints, proprioceptive and strengthening exercises are beneficial for the patient and should continue until full function is regained. This rehabilitation regime requires a reliable patient who is willing to perform these exercises on a consistent basis for a specified number of times a day. If patients are compliant and actively participated in the rehabilitation, restoration of full ankle motion is expected with ability to regain the subtalar joint motion.

2.8.1 Rehabilitation following Non-operative Treatment

In this non-displaced IACF, the clotted fracture hematoma is slowly organized, resorbed and replaced by woven bone on the subperiosteal surfaces. Between 2 to 3 weeks, the immature woven bone in this cancellous calcaneum becomes more densely mineralized. Consolidation usually occurs between 3 to 4 weeks after injury (Mehmet and Cengiz, 2002). However, intra-articular fracture causes haemarthrosis and articular cartilage damaged. Chondrocyes are released and the repair mechanism is by forming fibrocartilage to fill and cover the defects. This fibrocartilage is made to resist tension forces but not to resist compression forces, which is mainly the property of hyaline cartilage (Mankin and Buckwalter, 1998). In addition, Rubak *et al.* (1982) concluded that the articular defects will be filled up with fibro-cartilaginous tissue if the joint is immobilized. Therefore, the articular cartilage can heal by forming hyaline cartilage with continuous passive joint motion. In 2013, Veltman *et al.* also had shown the scientific evidence that early cast immobilization will leads to worse results.

In this non-operated group of patients, the injured foot was immobilized by a simple posterior, removable, well-padded splint in a plantigrade position to avoid equinus contracture (Barei *et al.*, 2002). During the acute inflammatory stage of the fracture, which persists for 24 to 72 hours, cooling packs are applied, compressive bandaging, resting and elevation of the injured foot and ankle above the heart level. Adequate pain relief is important and aids for early protective passive subtalar motion. After the swelling becomes better and the injuries become comfortable within a week or two, graduated active range of motion of all joints should be started to prevent stiffness (Bucholz *et al.*, 1994). Early motion gives better functional recovery and outcomes if compared with prolonged immobilization (Essex-Lopresti, 1952; Lindsay and Dewar, 1958).

After 3 to 4 weeks, hard callus replaces soft callus, non-weight bearing must be maintained until evidence of healing, which usually occur after about 8 to 12 weeks (Kitaoka *et al.*, 1994; Basile, 2010). Ambulatory assistive devices are needed to facilitate the patients return to their daily functional activities. Graduated stretching and strengthening exercises are continued as well as active range of motions of the joints. After 12 weeks, weight bearing is progressively applied (Barei *et al.*, 2002). Shoe insoles are usually required for better distribution of the load (Lopez and Farriol, 2011) and the custom-orthoses can improve patients standing and walking tolerance (Kitaoka *et al.*, 1994).

2.8.2 Rehabilitation following ORIF

Post-operatively, a soft compressive Jones-type dressing is applied under a posterior, removable splint to hold the foot in neutral position. The foot and ankle is elevated slightly above cardiac level for 72 hours. Patients were given adequate analgesics and passive range of motion of the toes was begun immediately to prevent foot intrinsic contracture. The drain was removed on post-operative Day 2. Once the incision wound dries, which usually takes 3 to 5 days, active range of motion of the ankle and subtalar joints is commenced (Sanders, 2000; Harvey *et al.*, 2001; Barei *et al.*, 2002) according to patient tolerance.

Before discharge from the hospital, the patient initially is supplied with a removable, well-padded backslab to minimize gastrocnemius-soleus contracture and for comfort. This heavy-splint can changed to a well-padded lightweight thermoplastic splint upon discharged. Patients can continue their active ankle range of motion exercises out of the splint at the daytime but they should wear the splint at night to prevent the development of an equinus contracture (Sanders, 2000). The incision wound should cover with dry sterile dressing until the sutures are removed. Heier *et al.* (2003) and Clare *et al.* (2005) also recommended that progressively increased active range of motion physical therapy can be started as soon as the wound healed. In general, analgesics are discontinued 3 to 4 weeks after surgery.

The period of post-operative non-weight bearing varies by different authors. Ambulatory devices were needed and premature weight bearing is prohibited until signs of early healing are seen, usually occuring in 6 to 12 weeks, depending on the fracture pattern, degree of comminution and rigidity of fixation (Barei *et al.*, 2002). Most authors suggested post-operative non-weight bearing for 6 weeks (Asik and Sen, 2002; Buckley *et al.*, 2002; Ibrahim *et al.*, 2007; Potter and Nunley, 2009; Makki *et al.*, 2010), after which the patient was allowed partial weight bearing. However, Sanders (2000) recommended that the patient may begin progressive weight bearing after 9 weeks post-operatively. If the patient does not experience pain with the level of weight bearing used, the weight is then sequentially increased at regular intervals. In addition, patients were instructed to bear weight on the forefoot initially, with gradual resumption of heel-to-toe ambulation (Mehmet and Cengiz, 2002).

After 4 months, ambulatory aids are discontinued and the patient should be able to return to a reasonably active job. Patients can be fitted with support stockings as needed to control foot and ankle edema and encouraged to wear it for at least 6 months. After healing, patients are encouraged to wear shoes with cushioned or shock-absorbing sole. Some authors suggested that a prolonged period of rehabilitation may takes up to two years for a patient to gradually return to ordinary activities, work, sports, and others recreations activities (Crosby and Fizgibbons, 1996; Buckley *et al*., 2002; Guerado *et al.*, 2012).

2.9 Complications of IACF

A satisfactory functional outcome of IACF depends primarily on the occurrence of complications. These complications surrounding treatment options represent most of the causes of poor outcomes. Buckley and Meek (1992) reported that the complications following operative treatment have been as high as 53%. This high complication rate is the reason for the controversy about treating calcaneal fractures non-operatively or operatively (Veltman *et al.*, 2013).

2.9.1 Immediate Complications

(a) Fracture blisters or eschars

Blisters may appear when substantial swelling is present and more commonly occur laterally (Varela *et al.*, 1993). The vesicles can be filled with either clear fluid or blood. The blister is the result of a cleavage at the dermal-epidermal junction, and the fluid represents sterile transudate. If the dermis retains some epidermal cells, then the fluid remains clear. If the dermis is completely devoid of epidermal cells, then the transudate becomes bloody (Giordano and Koval, 1995).

(b) Compartment Syndrome

Swelling can occurs in all type of fractures. Approximately 10% of patients with calcaneal fractures can develop compartment syndrome of the foot (Myerson and Manoli, 1993). Prompt diagnosis and surgical release of the quadrates plantae compartment are important to minimize the sequelae of clawed toes and painful nerve dysfunction.

(c) Open fracture

Open fractures commonly occur as a direct trauma and typically on the medial aspect of the foot (Thornton *et al.*, 2006). This was invariably caused by penetration from the sustentacular fragment. Wound debridement and irrigation followed by provisional closed or percutaneous reduction is done to restore general alignment and to remove soft tissue tension on the injured medial aspect. Once the overall swelling has decreased, the definitive fixation can proceed (Barei *et al.*, 2002).

2.9.2 Early Complications (less than 6 months)

(a) Non-operative Treatment

i) Fracture displacement

For non-displaced IACF which had been treated non-operatively with the posterior splint, there is always a risk of fracture re-displacement once the soft tissue swelling reduces. Meraj *et al.* (2012) stated that the major causes of poor result from non-operative treatment are difficulty in maintaining reduction and loss of position, which can occur if weight bearing is initiated too early.

ii) Nerve entrapment