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Use of locked plating in proximal humerus fractures

Abstract

The majority of proximal humeral fractures are undisplaced or minimally displaced and do not need surgery. For the remaining cases requiring surgery, there are numerous surgical techniques described in the literature to address them. Surgical indications include displaced, comminuted unstable fractures and fracture dislocations. The treatment of these fractures remains controversial. There are numerous reconstructive options available to the surgeon and some of these will be discussed. An emphasis will be placed on the use of locked plates in proximal humeral fractures requiring surgical intervention. Two case reports presented below will serve as a template for this discussion.

Keywords: Locked plating, Humerus, Proximal, Fracture, Hemiarthroplasty, Osteosynthesis

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Introduction

The overwhelming majority of proximal humeral fractures are either minimally displaced or undisplaced.[1] Approximately 20% of displaced proximal humeral fractures benefit from operative management.[1] Many surgical techniques are described in the literature, however none are considered to be the standard of care.[1] These range from transosseus suture fixation, closed reduction and percutaneous fixation, open reduction and internal fixation with conventional and locked-plate fixation to hemiarthroplasty.[1]

The following cases are presented to discuss surgical options in treating proximal humeral fractures with emphasis on locked plating.

Case presentations

Case one

A 56 year old male janitor presented to hospital having been involved in a motor vehicle accident that day. He complained of pain and swelling of the right arm. On examination, he had normal vital signs. The remainder of his examination was also normal except for the right shoulder and proximal arm which was grossly swollen and tender. There were no distal neurovascular deficits. X-rays of the proximal right humerus revealed a two-part simple fracture (Figure 1).

Figure 1 X-rays of the proximal right humerus revealed a two-part simple fracture.

He was managed in a sling, initially. At 11 days post injury, the swelling was significantly reduced and he was taken to the operating room. Via a standard deltopectoral approach, the fracture site was exposed. The soft tissue near the long head of biceps was preserved. Both fragments were reduced with the aid of the locking plate and Kirshner wires through the plate. Post reduction, locking screws were passed and engaged in subchondral bone. The plate was placed 1cm distal to greater tuberosity. Fluoroscopy was used to ensure appropriate placement of the screws (Figure 2). Non-locking screws were used in the diaphyseal bone. No clinical evidence of impingement was demonstrated on the table.

Figure 2 Fluoroscopy was used to ensure appropriate placement of the screws.

Passive range of motion (ROM) was commenced 15 days postoperatively and active ROM commenced when healing was demonstrated. At three months post operatively, there was no radiographic evidence of implant failure or loss of reduction or alignment. There was radiographic evidence of adequate healing. The patient had no complaints and had good shoulder ROM. By six months post operatively, he had grade 5 power in all directions with no limitations in overhead activity. He has been doing well on the job where he is functioning well on the job.

Case two

A 76 year old female presented to hospital complaining of right shoulder pain for four hours. She was walking on her veranda, slipped and fell on her outstretched right hand. On examination, she had swelling, tenderness and decreased ROM of her right shoulder. There were no distal neurovascular deficits. X-rays revealed osteopenic bone and a two-part proximal humeral fracture (Figure 3). Preoperatively, she was noted to be anaemic.

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Figure 3 X-rays revealed osteopenic bone and a two-part proximal humeral fracture.

After initial management in a sling she was taken to the operating theatre four days post injury, where via an anterolateral approach, an antegrade locked humeral nail was placed. Post operative x-rays showed the implant cutting out of the humeral head (Figure 4).

Figure 4 Post operative x-rays showed the implant cutting out of the humeral head.

Six days later, via the previous incisions the nail was removed, then via a deltopectoral approach, open reduction was achieved and a locking plate was placed 5mm distal to the greater tubercle. Locking screws were placed in the humeral head. A non-locking screw was placed inferomedially in the head and shaft. There was no impingement post fixation.

Two weeks post operation; she developed a stroke which resulted in residual weakness on the side of the fixation. The fracture healed 3 months afterwards. She was pain free and satisfied with her function despite grade 3 power throughout the upper limb.

Discussion

Fractures of the proximal humerus make up about 5% of all fractures.[2,3] They are a health problem for persons of various ages and may significantly affect their quality of life in the short and long term.[4,5] Highest rates are seen in individuals who are 75 to 80 years, female and white due to osteoporosis.[6] These fractures result primarily from falls.[7] Elderly patients usually have a low energy mechanism of injury, whilst young patients such as the first case, are usually affected by a high energy mechanism.[8] Other risk factors include medical conditions such as epilepsy, depression and diabetes.[7]

Undisplaced and minimally displaced fractures make up the majority of proximal humeral fractures, and may be managed nonoperatively with a sling and early physiotherapy.[8-14]

Cadaveric studies have demonstrated the role of the anterior circumflex humeral artery and the accessory role of the posterior circumflex artery. They form a vascular ring around the surgical neck, giving an abundant supply to the greater tuberosity.[15] An ascending anterolateral branch of the anterior circumflex follows the length of the biceps brachii and is the essential supply of the epiphysis .[15]

The posterior circumflex is only responsible for the posteroinferior part of the epiphysis and an acromial branch anastamosis with the anterolateral branch before its intraosseus entry.[15] Trauma, additional devascularisaton of the head during surgical exposure and implant placement all increase the risk of osteonecrosis.[9] During surgical exposure, one should try to preserve the anterior circumflex branch as was done in the index cases. Wijgman et al.[9] noted that anatomic or near anatomic reduction and stable fixation allows for the possibility of revascularisation. Low profile plates permit improved preservation of vascularity due to avoidance of periosteal compression.[16]

Although there is general agreement that complex proximal humeral fractures ought to be treated surgically, there is no consensus in the literature with respect to the ideal surgical option.[6, 17] and hence it remains a challenge.[18] Indications for surgery include displaced, comminuted unstable fractures and fracture dislocations.[16] however the treatment of displaced fractures remains controversial.[1,12,13,17] Currently there is an expanding range of reconstruction options each with advantages and disadvantages.[14]

Surgical options include closed reduction and percutaneous pinning.[19] tension band wiring.[20] intramedullary nailing.[21,22] conventional plating.[9,23] transosseous suture.[13] external fixation.[24] hemiarthroplasty.[10] and locked plating.[12,17,18,25-28] The above options range from surgical head preservation to joint replacement depending on the extent of displacement and fragmentation [29] The continued evolution of osteosynthesis and the large range of surgical options reflect the lack of clear superiority of one over the other.[5,12] Variations in clinical outcomes are partly due to the fracture type as determined by the available classification systems which have high intra and inter observer differences in reliability.[11,12]. This suboptimal reproducibility and reliability of the commonly used classification systems also adds to the dilemma of choosing the correct surgical option.[4,8] Another factor has been the paucity of literature containing randomised and controlled studies.[4]

Whichever treatment option is chosen, potential challenges include restoring humeral alignment, joint surface congruity and rotator cuff function while maintaining humeral vascularity.[13]. A successful therapeutic regimen requires careful patient selection and adherence to defined indications.[13]. There are more treatment options for patients with good bone quality and minimal comminution (index case one).[4]. Comminuted fractures may be treated with a special blade plate.[30]

After closed reduction is achieved, there are potential problems when Kirshner wires are used and poorly positioned, or if too few are used.[31] Percutaneous Kirshner wires often migrate in dangerous directions when inappropriately used.[31]

Martin et al.[24] stated that external fixation avoided several problems associated with percutaneous and open methods. The risk of iatrogenic devascularisation and subsequent osteonecrosis is minimised whilst providing primary stabilisation. This permitted immediate rehabilitation leading to eventual acceptable ROM. Their

80% satisfactory rate in terms of postoperative function is comparable to other authors using open techniques. This was a viable option for the first case.

Intramedullary stabilisation with an angular and stable locking nail represents a minimally invasive procedure allowing for a high degree of primary stability including use in osteoporotic bone.[22] Those characteristics were the reason why this option was initially used in case 2. The patient was mildly anaemic and so the surgeon opted for a stable construct which would avoid significant blood loss. Mittlmeier et al.[22] stated that intramedullary stabilisation was easy to perform and it allowed for early postoperative mobilisation. Zhu et al.[32] recommended this implant for two-part fractures only because of increased complication rates with more complex injuries. Despite postoperative complications being common, the majority of them are minor.[22] and easily treatable. Gradl et al.[33] prospectively compared intramedullary nails to lock plating in 152 patients from three level one centres. There was no difference in the functional outcome using the Constant-Murley scoring system or in the overall complication rates. Secondary fracture displacement without implant failure was only seen in the plating group.

Zhu et al.[32] prospectively randomised 51 patients to intramedullary nailing and locked plating in two-part fractures. They also found no differences in terms of functional outcome using the Constant-Murley score, visual analogue pain score and American Shoulder and Elbow Score.

Prior to locked plating, conventional plating was used in the majority of patients who had open reduction and internal fixation.[1] Early plate and screws designs required extensive soft tissue stripping which places the humeral head vascular supply at risk.[1] Moda et al.[23] achieved an 84% satisfactory rate with meticulous placement of a T shaped plate and screws. He had poor results on patients with intra-articular fractures or fracture dislocations, especially with concomitant rotator cuff injuries. Traditional plating has been associated with stability problems mainly in osteoporotic bone, because of inadequate anchorage of the screws on poor quality bone.[16] Patients with osteoporotic bone or comminuted fractures have unpredictable results when treated with traditional plating.[34] which explained why it was not used in the second index case. Conventional plating depends on contact between the plate and bone in addition to the anchorage of the screws in bone where the screws are compressing two surfaces together.[16,27,34] thus the effectiveness decreases as the bone quality decreases.[16,34]

Wijgman et al.[9] states that open reduction and internal fixation with a nonlocking plate and screws has been shown to provide the strongest fixation in nonosteoporotic bone. The average age in their study was 48 years. Conventional plate and screws may loosen quickly due to poor quality bone due to a lack of load sharing, especially with comminuted fractures, and a lack of a fixed angle between the plate and screws.[12,27,31]. Frequent complications seen with traditional plating are related to subacromial impingement as well as humeral head osteonecrosis due to the required extensive exposure.[16]

There is however, renewed interest in plate and screws with the development of better implants including the fixed angled blade plate and the locking anatomical proximal humeral plate.[5, 30]. The introduction of locking plate technology has coincided with the development of less invasive surgical techniques.[27] There is now a trend towards less invasive surgical exposures and osteosynthesis techniques involving sutures, wires, screws, and locking plates in an attempt to minimise soft tissue detachments, peri articular scarring and vascular insult to the humeral head.[5, 13] Traditionally, the deltopectoral

approach was utilised to expose the anterior and lateral surfaces for reduction and plating, as was done in both cases.[28]. The anterolateral approach allows for easier exposure of the plating zone while requiring less of soft tissue devascularisation however; there is an increased risk of axillary nerve injury.[28] Freiss et al..[17] stated that although there were numerous studies claiming good success following the use of locked plating, but at the time, there were no head to head comparisons with other implants in the literature. When Freiss et al.[17] compared locked plating with closed reduction and percutaneous pinning as well as blade plating, decreased shoulder function was noted in all groups. The locked plating group had better alignment and there were no cases of malunion or non-union. Unfortunately the numbers in this study were too small to achieve statistical significance. Freiss et al.[17] noted an increased incidence (9%) of superficial infection with percutaneous pinning which was similar to the 7% pin site infection rate seen by Jaberg et al.[19] who achieved a 95% union rate.

With locked plating, the use of locking screws provides locking compression, which is especially useful in fractures prone to collapse.[12,18] The locking humeral plate was designed for proximal humeral fractures whereby it is contoured to the anatomy of the lateral aspect of the proximal humeral metaphysis and proximal diaphysis.[18,28,35] Fragments must be reduced before locking screws are placed.[5] The plate may be used to aid reduction and non-locked screws may be used to achieve interfragmentary compression.[16]

Locking screws are placed multidirectionally without drilling in well vascularised bone.[12,34]. One should obtain an axillary view under fluoroscopy to ensure the screws do not penetrate the humeral head and impinge on the glenoid.[12] The optimal number of screws is unknown, but it appears that the greater the number of screws placed, the better.[12] This is in contrast to the diaphysis where placement of unnecessary screws may disturb the normal bone biology since these screws must be drilled and placed in cortical bone which is less vascular than the cancellous bone in the head and neck.[12]

With locking plates, the load is transmitted through the implant screw interface and bypasses bone.[18] By working as an internal fixator, it maintains anatomic reduction and angular stability.[16,27] Supplemental wires or suture fixation may be passed through the smaller holes in the plate. Additional lag screws e.g. the inferomedial lag screw used in case two may be used to maintain reduction.[34] Bony sutures are widely used for isolated tuberosity fractures, but rarely used on its own as it is rarely solid enough, especially during re-education which should be commenced early.[15] Transosseus suture neutralises the tension forces of the rotator cuff.[34] For the two part fracture such as the first index case, sole transosseus suture fixation is not recommended as rotational instability would persist plus the fixation between the large proximal fragment and the narrow diaphysis would be inadequate.[13,19,34] Maintenance of reduction is important because Helwig et al.[29] noted a significant relationship between poor subjective and objective treatment scores and a poor anatomical reconstruction. There was also a negative influence of secondary fracture displacement on the final score. Recent studies suggest that stabilising the medial column prevents varus malunion, plate failure, screw cut-out and impingement.[1, 34] Gaining inferomedial support with a locking screw in the proximal head fragment is the key to maintaining the reduction.[12,32] This inferomedial support was achieved in the second case with a non-locking lag screw. The locking plate used in the case did not allow for a locking screw to be angled in that direction.

Locking plates stabilise bone fragments via screw attachments to the plate in a rigid fixed angle coupling, usually accompanied with threads in the screw head, plate or both. The fixed angle results in

decreased risk of angular deformity via the ability to resist cantilever bending stresses.[27] This fixation makes the construct more resistant to failure from sequential screw loosening and pullout.[27] This is advantageous in osteoporotic bone with thin cortices. Nonlocking screws provided less plate to bone contact with the thinned cortex, therefore the functional forces are less.[27] These characteristics are why this was chosen to revise the elderly patient with this device. According to Bjorkenheim et al.[26] and Siwach et al[35] the main advantage of the locking plate was in elderly patients as they registered no failures in this group. Bjorkenheim et al. [26] Siwach et al.[35] and Aggarwal et al. [36] found that these patients were able to achieve an activity level which allowed them to do activities of daily living. Bjorkenheim et al.[26] saw no additional advantages in using this implant in younger patients. It can therefore be argued as to whether or not a locking plate was indicated in first case, in which he had a two-part fracture with good bone stock and no comminution.[36] Leanard et al.[18] found significantly worse outcome in patients older than 65 years when using a locked plate which he attributed to decrease strength and ROM, and a tenuous blood supply. After achieving a good functional result initially, they often aren't compliant with exercises.[34] Indications for its use should be considered in conjunction with the fracture pattern, bone quality, screw purchase, patient age, activity level and rotator cuff which is weighed against other forms of fixation.[1,12,30] Failure of the locking plate and humeral head necrosis occurs in the minority and is due to treatment of an inappropriate fracture type.[5] Varus deformity with subsequent impingement and screw cut-out may occur when using a locked plate for unstable fractures.[18]

Loss of fixation in the proximal humeral fragment is not an uncommon complication.[16,31,34] Fixation loss is due usually to loosening of the portion of the construct in the humeral head.[31] With osteoporotic bone, there is poor holding power in the cancellous bone in the humeral head and neck. The elderly patient poses a challenge because of the osteoporotic bone with potential comminution.[35,36] High stresses will exceed the holding power of the screws during arm motion thus elderly patients must not undergo aggressive physiotherapy in the early postoperative period.[31] Primary screw perforation was the most common complication noted in Sudkamp et al 2009 study. Subacromial impingement may occur due to the locking plate being placed too cranially.[34] Lupo et al.[16] and Bjorkenheim et al.[26] placed the locking plate at least 1cm distal to the greater tuberosity, similar to the first index case. In order to avoid impingement Sahu et al.[5] and Helwig et al.[29] placed the locking plate at least 5-8mm distal to the greater tuberosity, as in the second case. Therefore, Bjorkenheim et al.[26] and Helwig et al.[29] all avoided impingement by avoiding placement being too proximal.

A major consideration when using a locked plate is that they are significantly more costly, than non-locking plates.[12, 26] Bjorkenheim et al.[26] stated that the Philos locking plate was easy to use and felt that these advantages and a low reoperation rate justified its cost. Contrastingly, Helwig et al.[29] found that the use of the Philos plate was initially associated with a high revision rate because of early postoperative infection or haematoma which he attributed to an early learning curve. Aggarwal et al.[36] found that there is a steep learning curve when using locking plates in general as his results improved with experience and using appropriate surgical technique. Once he modified the surgical approach he had no cases of postoperative infection or haematoma. Leonard et al.[18] also cautioned surgeons with respect to a high revision rate, but they were mainly due to technical errors.

Hemiarthroplasty is the treatment of choice for fractures with vascular compromise, head splitting fractures, some fracture dislocations and fractures involving 40% or more of the articular surface.[1] Hemiarthroplasty consistently allows good pain relief however patients tend to have poor ROM and shoulder power.[8,10] Despite decreased ability to perform activities of daily living, satisfaction rates are high in the elderly because of decreased functional expectations.[10] Locking plate technology is now allowing surgeons the opportunity to attempt fixation in some of the more complex fractures previously listed, in younger patients, thus facilitating humeral head preservation, which is important due to the consistent decreased shoulder function post hemiarthroplasty.[1] There are currently no randomised, prospectively studies comparing locked plating and hemiarthroplasty.[6] With new technologies and techniques as well as an improved understanding of accurate reduction and patient expectations, there is an increase in the usage of open reduction and internal fixation and decrease utilisation of hemiarthroplasty.[6] This has also led to increase incidence of revision surgery.[6] Physiologically younger and active patients have increased treatment expectations.[14]

The ultimate goal of surgical intervention is for the patient to return to an acceptable level of productive shoulder function via anatomic reduction, stable fixation and early function rehabilitation.[13,14,33] Surgery is also intended on avoiding complications of nonoperative management including symptomatic non-union or malunion.[14]

The shoulder joint is particularly vulnerable to stiffness post surgery due to the formation of adhesions in the subacromial and subdeltoid spaces, and capsular contracture.[12,23] Enhanced stability of locked plate fixation allows for early ROM as early as day one post surgery in certain situations.[12] If only partial stability is achieved postoperatively, mobilisation must be delayed by at least 10 days and is preferably active assisted.[15,22] Early mobilisation prior to maturation of adhesions around the gliding surfaces is an essential step.[23] which accounts for the good functional result in the index case. Limited articular function is usually caused by delayed or incorrect rehabilitation.[16] Early mobilisation is thus the best preventative treatment for articular stiffness and equally for neuromuscular shoulder dysfunction and socio-professional withdrawal in the active subject.[15] Patients must be informed that compliance with rehabilitation will influence their outcome and that it is potentially long and arduous [14]

Conclusion

Internal fixation of proximal humeral fractures via the use of locked plating yields reliable results when utilised appropriately. The greatest number of complications is associated with incorrect surgical techniques. It is important that the treating surgeon ought to have the adequate surgical skill and assistance to decrease intra-operative errors. Treatment must be based upon an assessment of the personality of the fracture.

Acknowledgments

Conflicts of interest

None.

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