Philos Locking plates in proximal humerus fractures –literature review.

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Citation

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Abstract

Objectives: The aim of this study was to evaluate the results of various studies conducted on patient's world wide so far and results of proximal humerus fractures treated with the PHILOS locking plate. Results: Radio graphically union, Plate fixation was associated with minimal deformity Implant failure, Reflex sympathetic dystrophy and a vascular necrosis were observed in very few.Conclusion: Fixation with the PHILOS plate is a near ideal technique with a high union rate in the treatment of proximal humeral fractures.

INTRODUCTION

Proximal humeral fractures (PHF) are a frequent health problem for people of various ages. They can affect quality of life, not only in acute phases, but also permanently, due to sequels. Proximal humeral fractures are common (approximately 4–5% of all fractures) and increasing in frequency, probably due to their association with osteoporosis in our increasingly aged population.[1] They represent over 70% of humeral fractures occurring over the age 40. Various treatment options of undisplaced fractures are known but are still associated with high complication rates. Over the past several decades, a wide variety of fixation devices have been developed to treat displaced and unstable proximal humerus fractures; however, there has been a lack of consensus for the optimal treatment of these complex fractures.[2,3] Treatment options include use of proximal humeral nails, plates, tension band wiring, and percutaneous or minimally invasive techniques such as pinning or screw osteosynthesis.[4-8] Moreover, the incidence of complications from operative treatment has been reported to vary between 11% and 50%.[7, 9] Open reduction and internal fixation (ORIF) of proximal humerus fractures with conventional plates has been associated with loss of reduction, screw loosening, and osteonecrosis.[10-19] Consequently, angular stable plates [20-31] have been developed in recent years to preserve anatomic reduction with stronger anchorage, especially in osteoporotic bone. Among them, the 3-dimensional anatomically adjusted Philos plate (Synthes, Oberdorf, Switzerland) provides a locking system for its proximal part contacting the humeral head. To our knowledge, limited scientific evidence from only few case series studies has been published on fracture and patient outcomes after the use of this implant.[32-45] many different implants have been tested and investigated, thus demonstrating lack of sufficient results. Over the last years the development of angle stable, locking implants started and clinical studies demonstrated encouraging results. The locking proximal humerus plate and the PHILOS plate advanced to the implant of choice now for treatment of displaced proximal humerus fractures. There are still cases of implant failure and humerus head necrosis, but most of these complications were caused by the fracture type and not an implant specific problem. However the overall results with these new implants are encouraging. The PHILOS plate that consists of new generation of locked plates can be applied with a minimal invasive method and it is a fixating device that permits early mobility and lowers the risk of complications. And screws, has been associated with loss of reduction, screw loosening, and osteonecrosis.

MATERIALS AND METHODS

All of the studies were followed by standard history taking and examination of the patient with a possible shoulder injury, including neurovascular assessment, full radiological examination is required. The complete shoulder trauma radiological series consists of an anteroposterior view, scapula lateral view and an axillary view (a Velpeau view may be required if the shoulder cannot be abducted sufficiently for the axillary view).Without these 3 views the fractured proximal humerus cannot be completely assessed.

The axillary view is particularly important to assess head splitting fractures, visualize posterior displacement of the greater tuberosity and to assess the relationship between the articular surfaces. Unfortunately this view is often considered articular surfaces in impression, head splitting and glenoid rim fractures. It is also useful in assessing bone stock in cases of nonunion and anatomy in malunion. Patients underwent ORIF with a Philos plate and were prospectively followed according to a predefined protocol. Exclusion criteria included pseudarthrosis, pathologic fractures and refractures open fractures, or concomitant fractures of the ipsilateral elbow or distal radius. In addition, patients with existing disorders having an effect on the healing process and function such as multiple sclerosis, paraplegia, or other relevant neurologic disorders, patients with polytrauma with an Injury Severity Score greater than 16, and patients with posttraumatic brachial plexus injury or peripheral nerve palsy were excluded. Surgery was performed in a beach chair position or prone on a radiolucent table, with side placement of an image intensifier to allow viewing of the humeral head in 2 planes. Depending on the particular need for exposure, an anterior deltopectoral or transdeltoid lateral approach was chosen. The latter approach was only appropriate for limited operations with exposure of the greater tuberosity or the most proximal part of the humeral head. After reduction, mostly with the aid of sutures, the plates were positioned using a mounted aiming device. Plates with 3 or 5 holes at shaft level were chosen based on fracture extension. Plates were placed at least 5-8 mm inferior to the upper end of the greater tuberosity to avoid subacromial impingement and 2-4 mm lateral to the bicipital groove, ensuring that a sufficient gap was maintained between the plate and the tendon of the long head of the biceps muscle. The achieved reduction was temporarily fixed with 1.6-mm K-wires through the proximal holes and checked with an image intensifier. When reduction was satisfactory, the K-wires were replaced by locked screws. Locked or standard cortical screws were inserted into the remaining holes of the humeral shaft at the discretion of the treating surgeon. During hospitalization, patient demographics (ie, sex, age, dexterity, smoking, concomitant diseases, and medication) and baseline characteristics (ie, accident type, energy level of trauma, concomitant injuries, fracture classification, delay between accident and surgery, operation time, C-arm time, use of plates with 3 or 5 holes at shaft level, distribution of used standard and locking screws, additional implants and sutures, additional medication, type and duration of immobilization, and beginning of active assisted and unrestricted mobilization) were documented. Fractures were classified according to the AO/OTA and Neer classification [46,47] by the treating surgeons. Intraoperative complications such as bleeding, hematoma, and nerve injury were documented. The radiographs were repeated postoperatively. Computed tomography evaluation was undertaken at the discretion of the treating surgeon. Follow-up Examinations After surgery, all patients were treated with a similar postoperative protocol. Isometric deltoid, bicep, and triceps strengthening were begun immediately on the first postoperative day. Patients were placed in a sling and were encouraged to start early passive range of motion exercises. Patients allowed passive range of motion exercises for the first 4 to 6 weeks postoperatively until radiographic evidence of fracture healing, and then patients began active range of motion exercises in a formal physiotherapy program. Patients were examined immediately postoperatively and after 12 weeks and 6 and 12 months, 24 and some followed it to52 months. At each follow-up, patients received shoulder radiographs in 2 planes (anterior-posterior and Neer view) to survey fracture healing. Anticipated postoperative complications included loss of reduction, fragment displacement, major varus or valgus deformation, head necrosis or implant-related problems ("screw perforation," screw loosening or backing out, plate pullout, or breakage), and surgical and other general complications such as wound infection or soft-tissue problems (rotator cuff lesions, adhesions, frozen shoulders, impingement, and nerve lesions). Complications and radiographic findings were reviewed to define if complications were implant or nonimplant related; A complication was considered as implant related if screws perforated secondary to angular stability or if implant breakage, secondary loss of reduction, or screw pullout due to insufficient purchase occurred. Patients were further interviewed concerning pain and shoulder mobility and underwent shoulder examination using a spring balance (Isobex; Curson AG, Bern, Switzerland) at 90-degree abduction. The average of these power measurements was used to assess individual Constant scores[48] 47 of injured and contralateral shoulders. Additionally, DASH and Neer scores were determined at the 1-year follow-up in some studies. Humeral head-to-shaft angle was measured in all anterior-posterior postoperative x-ray projections, and those specifically taken at the last follow-up were measured using the viewing software, IcoView Light (Icoserve Information Technologies, Innsbruck, Austria). The angle between shaft axis and head

axis was measured and approximated to the next 5 degrees, whereby head axis was taken as perpendicular to a line between the nearest lateral and medial visible points of the anatomic neck through the apex of the head. Head-to-shaft angle measurements were further categorized as major varus (<115 degrees), minor varus (115-124 degrees), normal (125-145 degrees), minor valgus (146-155 degrees), and major valgus (>155 degrees) and compared between the postoperative and latest follow-up examination. Data Management and Analysis-Study monitoring, database management, and statistics were performed by a central monitoring organization. Complication were recorded as Plate breakage, medial varus deviation, loosening of screw and greater tuberosity displacement of greater tuberosity again; Secondary loss of reduction, with secondary impaction, secondary screw perforation, proximal screw backing out, or proximal plate pullout, complete and partial osteonecrosis, wound infection, hematoma , Soft-tissue complications mainly of impingement, adhesions leading to a frozen shoulder, after the wounds were also operatively revised. Soft-tissue complications consisted mainly of impingement, neurologic complications adhesions leading to a frozen shoulder, rotator cuff lesions and neurologic complications. 1-2 year follow-up examinations were done. Anatomic Restoration and Functional Outcomes were tabulated.

DISCUSSION

Methods like closed reduction and percutaneous screwing, pressure band application, intramedullary rod placement with circlage augmentation, T-buttress plate, double tubular plate, fixation with a plate having fixed angulation and primary arthroplasty are

Used in the surgical treatment of displaced proximal humerus fractures. Painful and frozen shoulder, malunion and AVN are among the serious results of this clinical entity.

The PHILOS plate is one of the top of the line locked compression plate used with a minimally invasive technique. It permits indirect fracture reduction thus lowering the possibility of AVN and by reducing the need of immobilization time helps diminishing

the possibility of frozen shoulder. Furthermore, it is a low profile plate with the proximal screws having the capability of being applied in different directions thus making it a fixating device with a high stability in osteoporotic bones. Bulent KILIC, [32] in 2008 studied13 males and 9 females; mean age: 57; age distribution35-83, all underwent surgical therapy for proximal humerus fractures and PHILOS plate was used in all for fixation. According to Neer classification 7 patients had two piece fractures (5 were surgical collum and 2 were anatomic collum), 4 patients had valgus impaction injuries, 2 patients had fracture dislocation, 5 patients had 3 piece fracture, 1 patient had 4 piece fracture and 3 patients had 1/3 proximal fracture of the corpus. While in 8 patients a transdeltoid approach and minimal invasive method was preferred for an indirect reduction, in 14 patients open reduction with anterior deltopectoral approach was the method of treatment. Attention was given to that this guiding Kirschner wire did not pass the peak point of the greater tubercule hence the height of the plate was adjusted and impingement was prevented. Before final screwing, the height and the position of the plate were controlled under the scope and a temporary K-wire fixation was performed. The patients received antibiotic for two days for prophylaxis. All patients began passive exercises after the postoperative second day and active exercises after 4-6 weeks of surgery. All cases were invited for a control by the ends of the 2nd, 4th, 6th and 10th weeks. Cases fulfilling a 12 months of follow up (mean 14 months; distribution 12-19 months) were evaluated with Constant - Murley Shoulder Scoring System [46](0-55 points: poor, 56-70 points: mean, 71-85 points: good and 86-100 points: very good) [5] in terms of shoulder movement clearness in every direction, pain and efficiency in performing daily activity. The Constant - Murley scores of the cases in whom open reduction was performed with deltopectoral approach and the results of the cases done with indirect reduction using the transdeltoid. In 10 of the cases both radiological and clinical union of the bones were achieved. In one case it took 16 weeks to achieve union. In another case non union was observed by the end of the 16th week and therefore it was grafted with an autologous graft. The average Constant - Murley score was 75.5 (distribution 51-93). In 8 (36.4%) of the cases the results were very good, in 7 (31.8%) of the cases the results were found to be good, in 6 (27.3%) of the cases the results were found to be mean and in 1 case (4.6%) the result was found to be poor. We were unable to put forward a significant difference between the scores of the cases in whom open reduction was performed with deltopectoral approach and the cases in whom indirect reduction was applied by using the transdeltoid lateral approach (p=0.669). Postoperative x-rays of two patients revealed a fixation in a minor varus position while in one patient the plate was placed in such a way that it would give rise to subacromial impingement (figure 1). Implant insufficiency was not

observed in any of the cases. Reflex sympathetic distrofy in one case and a vascular necrosis in another one respectively. Brunner F, [33] in 2009 operated on157 patients with 158 fractures. Occurrence of postoperative complications up to 1 year and active follow-up for 1 year with radiologic assessment to observe fracture healing, alignment, reduction, a vascular necrosis, and functional outcome measurements including Constant, Disabilities of the Arm, Shoulder, and Hand, and Neer scores. One-year follow-up rate was 84%. The incidence of experiencing any implant-related complication was 9% and 35% for nonimplant-related complications. Primary screw perforation was the most frequent problem (14%) followed by secondary screw perforation (8%) and a vascular necrosis (8%). After 1 year, a mean Constant score of 72 points (87% of the contra lateral noninjured side), a mean Neer score of 76 points, and mean Disabilities of the Arm, Shoulder, and Hand score of 16 points were achieved. Zhang H [34] in 2009 studied 35 cases with the proximal humerus and humeral shaft fractures were treated with long PHILOS locking compression plate, including 16 males and 19 females aged 29-68 years old (average 54.5 years old). There were 34 cases of fresh and close fracture, and the time from injury to operation was 3-9 days. One case had delayed union of fracture 5 months after receiving T-plates and internal fixation with steel plate. For the proximal humerus fracture, 7 cases had 2 parts of fracture, 19 had 3 parts of fracture, and 9 had 4 parts of fracture according to Neer classification; while for the humeral shaft fracture, 3 cases were classified as A1, 5 as A2, 10 as B1, 3 as B2, 6 as B3, 7 as C1 and 1 as C3 according to AO classification. Postoperatively, Neer scoring system was employed to evaluate the function of shoulder joint and HSS scoring system was adopted to evaluate the function of elbow joint. All incisions healed by first intension, and 30 cases were followed up for 12-33 months (average 18.2 months). Postoperatively, 2 cases had symptoms of radial nerve paralysis, which disappeared within 3 weeks; 1 case suffered from humeral head necrosis and received the secondary operation of humeral head replacement; humeral head was reduced evenly in 1 case, and 2 cases felt chronic slight pain in shoulder joints and received no further treatment. X-ray films showed 29 cases had fracture healing 6 months after operation, and all the patients had bone union 12 months after operation except 1 case receiving humeral head replacement. No such complications as screw loosening and internal fixation loosening occurred. By Neer scoring system, 6 cases were graded as excellent, 19 as good, 3 as fair, 2 as poor, and the excellent and good rate was 83.3%. By HSS scoring system, 16 cases were graded as excellent, 14 as good, and the excellent and good rate was 100%.Fazal MA[35] in 2009 conducted study on 6 men and 21 women aged 22 to 85 (mean, 56) years underwent Philos plate fixation for displaced proximal humeral fractures. 11 patients were aged 60 years or younger and 16 older than 60 years. All fractures were closed with no associated injuries and classified as 2-part (n=13), 3-part (n=12), and 4-part (n=2), according to the Neer classification. Patients were assessed radiologically and functionally using the Constant shoulder score Patients were followed up for 6 to 24 (mean, 13) months. All the fractures united except in a 76- year-old woman with a 3-part fracture in whom there was fracture collapse and screw penetration of the humeral head at 6 weeks. She subsequently developed non-union and a vascular necrosis. The mean Constant shoulder score was 70 (range, 28-88). 11 patients had a score exceeding 75, 13 were scored between 50 and 75, and 3 were below 50. Martinez AA[36] in 2009 Functional outcomes of 31 men and 27 women aged 36 to 73 (mean, 61) years who underwent Philos plate fixation for proximal humeral fractures were retrospectively reviewed. Indications for surgery were 3-part (n=33) or 4-part (n=25) closed proximal humeral fractures with angulation of more than 45 degrees or displacement of more than 1 cm. Functional outcomes and shoulder range of movement were assessed based on the Constant scoring system. Patients were followed up for 12 to 18 (mean, 15) months. All fractures healed satisfactorily, except in one patient with a valgus 4-part fracture who had malunion. No wound infections, vascular injuries, a vascular necrosis, or loss of fixation ensued. Two patients with axillary nerve palsy recovered spontaneously within 3 months. Functional outcome was excellent in 13 patients, good in 36, moderate in 8, and poor in 1. The mean Constant score was 80 (range, 40-100) Helwig P[37] in 2009 Fractures of the proximal humerus were stabilized surgically in 87 patients (mean age 64 (16-93) years) by application of a fixed-angle plate (65 PHILOS, 22 T-LCP). There were 34 2-segment fractures, 42 3-segment fractures, and 11 4-segment fractures, including 7 dislocation fractures. Follow-up assessment after a minimum of 12 months was based on the Constant, UCLA, and DASH scores and on radiographs. Postoperative complications included soft tissue problems (n = 9), humeral head necrosis (n = 9), screw perforation (n = 11), secondary displacements (n = 14), and delayed fracture healing (n = 4). Treatment outcomes recorded on the various scores were very good in 60-82% of the cases. Shahid R[38]prospectively reviewed 50 patients who had a proximal

humeral fracture treated with the PHILOS plate .Clinical outcome was measured using the patient-based Oxford shoulder and DASH scoring systems. Five patients died and four were lost to follow-up. Eleven patients had 2-part, eleven 3-part and eighteen 4-part fractures. Mean follow-up time was 21.7 months (range: 6-44 months). Radiological union was achieved within 8 weeks in 40/41 fractures; complications were noted in four cases. Better results were achieved in younger than in older patients and in male than in female patients. The number of fracture fragments did not appear to affect the results, but associated dislocation of the humeral head was a pejorative factor. Their study has shown that the PHILOS plate is a reliable implant. A direct correlation was observed between Oxford shoulder and DASH scores. Kiliç B [39] study included 22 patients (13 males, 9 females; mean age 57 years; range 35 to 83 years) were treated with the PHILOS locking plate. According to the Neer classification, 13 patients had comminuted fractures, four patients had valgus impact injuries, two patients had fracture-dislocations, and three patients had fractures involving the proximal 1/3 of the humerus. The fractures were reduced by the transdeltoid lateral approach (n=8) using minimally invasive surgery, and by the anterior deltopectoral approach (n=14) using open surgery. Passive and active exercises were initiated on the second postoperative day and after 4 to 6 weeks, respectively. The results were assessed using the Constant-Murley shoulder scoring system. The mean follow up was 14 months (range 12 to 19 months). Radio graphically, union was observed in 20 patients at the end of 10 weeks. In one patient, time to union was 16 weeks. One patient underwent autogenous bone grafting because of nonunion after 16 weeks. The mean Constant-Murley score was 75.5 (range 51 to 93). There was no significant difference between Constant-Murley scores of patients undergoing the transdeltoid lateral and anterior deltopectoral approaches ($p>0.05$). Plate fixation was associated with minimal varus deformity in two patients, and subacromial impingement in one patient. Implant failure did not occur. Reflex sympathetic dystrophy and a vascular necrosis were observed in two patients, respectively. Krivohlávek M [40] study comprised 97 patients. The proximal humeral internal locking system (PHILOS) plate was used in 49 patients (31 women and 18 men); with age average 57.4 years (women, 64.5 and men, 45.3 years). By the AO classification, 12 patients with type A, 15 with type B, and 22 with type C fractures. The Targon PH nail was used in 48 patients (32 women and 16 men) at an average age of 65.3 years (women, 72.2 and men, 51.4 years). Type A fractures were in 18, type B in 18 and type C in 12 patients The patients were prospectively evaluated and placed into the two groups. The post-operative range of motion was assessed by the Constant-Murley (CM) score at 6 weeks, and at 3, 6 and 12 months. The CM value was related to the healthy collateral limb and recorded as a relative CM score. In the PHILOS group, the average values were: operative time, 76.2 min; X-ray exposure, 4.2 min; and relative CM score, 74.5 points. The Targon PH group showed the average operative time of 50.2 min., X-ray exposure for 4 min. and the relative CM score 78.3 points. There were no significant differences between the groups, with the exception of shorter operative time in intramedullary nailing. Korkmaz MF [4] , 41 patients who were treated with the PHILOS plate for proximal humeral fractures were evaluated in two age groups. Group A included 24 patients (12 males, 12 females; mean age 47 years; range 24 to 64 years) younger than 65 years, and group B involved 17 patients (4 males, 13 females; mean age 78 years; range 67 to 90 years) at or above 65 years. Radio graphically; all fractures were classified according to the AO/ASIF system. Surgery was performed with the deltopectoral approach in 10 and two patients, and with a deltoid split in 14 and 15 patients in group A and B, respectively. Functional and radiographic results were evaluated after a mean follow-up of 15 months (range 6 to 28 months).The mean Constant scores were 95.0 (range 74 to 100) and 92.8 (range 72 to 100) in group A and B, respectively ($p>0.05$). After six months of surgery, Constant scores and functional outcomes were similar in patients operated on with the deltopectoral approach or deltoid split. There was neither nonunion nor implant failure. Complications included intra-articular screw penetration (n=1), displacement of the greater tuberculum (n=1) with oblique placement of the plate (n=1), insufficient reduction (n=4), and varus displacement of the humeral head (n=3). No a vascular necrosis was seen. Egol KA [42] -51 patients were available for minimum 6-month follow-up (mean, 16 months; range, 6 to 45 months). Radiographically, 92% of the cases united at 3 months after surgery, and 2 fractures had signs of osteonecrosis at latest follow-up. Sixteen complications were seen in 12 patients (24%). Eight shoulders in eight patients (16%) had screws that penetrated the humeral head. Two patients developed osteonecrosis at latest follow-up. One acute fracture and one nonunion failed to unite after index surgery. Significant heterotopic bone developed in 1 patient. Early implant failure occurred in 2 patients; one was revised to a longer plate, and one underwent resection arthroplasty. There was one acute

postoperative infection The major complication reported in this study was screw penetration, suggesting that exceptional vigilance must be taken in estimating the appropriate number and length of screws used to prevent articular penetration .Handschin AE [43] studied 20 female, 11 male, mean age: 62+/-16 years with two-, three- and four-part proximal humerus fractures (Neer classification) were operated using the proximal humeral internal locking system (PHILOS). The mean follow-up time was 19+/-3 postoperative months (range: 340-720 days). Functional results (Constant score, UCLA-score) were analyzed and compared to an equivalent historic control group of 60 patients operated for the same fracture types using two one-third tubular plates. Additionally, total implant costs for each technique were compared. Complications in the PHILOS group included one implant failure with refractures, one secondary dislocation, two cases of subacromial impingement, and two cases of partial a vascular necrosis of the humeral head. The mean Constant score (age- and sex-matched) was 80+/-11% for the affected side and 104+/-13% for the healthy side. The UCLA scores were excellent in 10%, good in 67%, and fair in 23% of the patients. Complication rate and functional results did not differ significantly from the control group treated with one-third tubular plates. Implant costs were significantly higher for the PHILOS group (684+/-40 Euro vs. 158+/-20 Euro, $p<0.05$). Strohm PC[7 7]cases of implant failure and humerus head necrosis, but most of these complications were caused by the fracture type and not an implant specific problem. Moonot P,[30] 32 patients with acutely displaced three- or four-part proximal fractures of the humerus were treated by open reduction and internal fixation using the proximal humeral internal locking system (PHILOS) plate. There were 23 women and nine men with a mean age of 59.9 years (18 to 87). Data were collected prospectively and the outcomes were assessed using the Constant score. The mean follow-up was for 11 months (3 to 24). In 31 patients (97%) the fracture united clinically and radiologically at a mean of 10 weeks (8 to 24). The mean Constant score at final review was 66.5 (30 to 92). There was no significant difference in outcome when comparing patients aged more than 60 years (18 patients) with those aged less than 60 years (14 patients) (t-test, $p = 0.8443$). There was one case each of nonunion, malunion and a broken screw in the elderly population. Füchtmeier B in 2007, three randomized groups were formed (n = 4 pairs) from 12 matched pairs of human cadaver humeri. The intramedullary load carriers were biomechanically superior when compared to the plating systems in the fracture model presented. Charalambous CP [44] - A chart and radiographic review of 25 cases that had proximal humeral internal locking system (PHILOS) plate for the treatment of proximal humeral fractures was performed : Of the 25 cases, 20 went to union with a mean neck/shaft angle of 127.2 degrees . Five cases required or were considered for revision surgery for non-union or implant failure. Of the 25 implants, 4 had screw protrusion into the gleno-humeral joint, 4 had screw loosening and backing out, and 1 plate broke without further trauma. Füchtmeier B in 2006[45] - Biomechanical comparison of this implant with established systems. 12 matched pairs of human humeri were employed for testing. Three randomized groups were formed (n = 4 pairs). A bending moment of 7.5 Nm and a torsional moment of 8.3 Nm were applied in a test of five loading cycles to all intact bones. Loading was consistently initiated at the distal epiphysis. The consequent deformation at the distal epiphysis was continuously recorded. Then an osteotomy with a defect of 5 mm was created to simulate an unstable subcapital humerus fracture. For paired comparison, one of each pair was stabilized with the Sirus proximal humerus nail. The other side was fixed with a reference implant. The following groups were created.: Group I: Sirus versus Proximal humerus nail (PHN) with spiral blade. Group II: Sirus versus PHILOS plate. Group III: Sirus versus 4.5 mm AO T-plate. The proximal humerus nail (Sirus) demonstrated significantly higher stiffness values than the reference implants for both bending and torsional load. The following values were recorded at a bending moment of 7.5 Nm: Sirus 14.2 mm, PHN 20.7 mm, PHILOS plate 28.1 mm, 4.5 AO T-plate 29.3 mm $p < 0.0012$). The values at 8.3 Nm torsional moment were: Sirus 8.5 degrees , PHN 12.3 degrees , PHILOS plate 16.4 degrees , 4.5 AO T-Platte 15.6 degrees ($p < 0.002$). The intramedullary load carriers were biomechanically superior when compared to the plating systems in the fracture model presented here. Supplementary, the Sirus Nail showed higher stiffness values than the PHN.

CONCLUSION

The Philos plate is effective in maintaining fracture reduction in proximal humerus fractures. Due to stable restoration, early functional aftercare is possible and allows the patient to regain good shoulder function and return to work earlier. Loss of reduction was rarely seen compared with other implants. Complication incidence proportions increased in older patients due to higher rates of secondary impaction, screw perforations, and humeral head necrosis, Patients older than 60 years had a 2-fold higher incidence of developing any type of complication, and those older than 70

years had a 3-fold greater incidence of experiencing plate-related complications. Osteonecrosis was mostly seen in severe fracture types. Fixation with the PHILOS plate is a near ideal technique with a high union rate in the treatment of proximal humeral fractures.

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