Predictive Value of Deltoid Tuberosity Index in Plate Osteosynthesis of Proximal Fractures: Is it Better than Age?

Valor Preditivo do Índice de Tuberosidade do Deltoide na Osteossíntese com Placa de Fraturas do Úmero Proximal: Será Superior ao da Idade?

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ABSTRACT

Introduction: Proximal humerus fractures (PHF) are considered fragility fractures, with increasing incidence in the elderly. Several risk factors negatively influence osteosynthesis outcomes, including age, bone density and medial hinge comminution. Age ≥65 is often considered a decision threshold in treatment algorithms. The deltoid tuberosity index (DTI) is a simple, reproducible method to evaluate local bone density. This study aimed to assess whether DTI is a better predictor than age for complications and re-interventions in PHF treated with locking plates.

Methods: This retrospective study included 40 patients with PHF treated with open reduction and internal fixation with locking plates between 2021 and 2024. DTI was measured on pre-operative AP Grashey views by two independent shoulder specialists. Calcar screw–calcar distance and calcar reduction were also evaluated. Early complications (<12 weeks), late complications (>12 weeks), and the type of re-intervention were recorded.

Results: Early complications occurred in 15% (n=6), late complications in 27.5% (n=11), and re-intervention was required in 25% (n=10). DTI had good accuracy for predicting complications (AUC=0.809), with an optimal cut-off of ≤1.64 (100% sensitivity, 92% specificity; Youden Index = 0.92). DTI was significantly lower in patients with late complications (1.34 *vs* 1.46; p=0.001) and re-intervention (1.31 *vs* 1.45; p=0.002), but not with early complications (p=0.309). Age was not associated with early (p=0.668), late complications (p=0.148), or re-intervention (p=0.889). There was no correlation between age and DTI (r=0.232, p=0.150). Calcar screw–calcar distance was significantly higher in early complications (11.23 *vs* 7.84 mm; p=0.018) and re-intervention (10.77 *vs* 7.92 mm; p=0.036). Calcar deviation had no significant associations.

Conclusion: DTI is a valuable tool in the management of PHF, predicting complications and re-intervention more reliably than patient age.

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Keywords: Bone Density; Bone Plates; Fracture Fixation, Internal; Fracture Healing; Humeral Fractures

RESUMO

Introdução: As fraturas do úmero proximal são consideradas fraturas por fragilidade, com incidência crescente em idosos. Diversos fatores de risco influenciam negativamente os resultados da osteossíntese, incluindo idade, densidade óssea e cominuição do calcar medial. A idade ≥65 anos é frequentemente considerada um ponto de corte nos algoritmos de tratamento. O índice da tuberosidade deltoide (ITD) é um método simples e reprodutível para avaliar a densidade óssea local. Este estudo teve como objetivo avaliar se o ITD é um melhor preditor do que a idade para complicações e reintervenções em fraturas do úmero proximal tratadas com placas bloqueadas.

Métodos: Este estudo retrospetivo incluiu 40 pacientes com fratura do úmero proximal tratados com redução aberta e fixação interna com placas bloqueadas entre 2021 e 2024. O ITD foi medido em radiografias pré-operatórias na incidência antero-posterior de Grashey por dois especialistas em ombro independentes. A distância parafuso do calcar–calcar e a redução do calcar também foram avaliadas. Complicações precoces (<12 semanas), complicações tardias (>12 semanas) e o tipo de reintervenção foram registados.

Resultados: Complicações precoces ocorreram em 15% (n=6), complicações tardias em 27,5% (n=11), e foi necessária reintervenção em 25% (n=10). O ITD apresentou boa predição de complicações (AUC=0,809), com um ponto de corte ideal de ≤1,64 (100% de sensibilidade, 92% de especificidade; Índice de Youden = 0,92). O ITD foi significativamente menor em pacientes com complicações tardias (1,34 *vs* 1,46; *p*=0,001) e em casos que exigiram reintervenção (1,31 *vs* 1,45; *p*=0,002), mas não em complicações precoces (*p*=0,309). A idade não teve associação com complicações precoces (*p*=0,668), complicações tardias (*p*=0,148) ou reintervenção (*p*=0,889). Não houve correlação entre idade e ITD (r=0,232; *p*=0,150). A distância parafuso do calcar–calcar foi significativamente menor nas complicações precoces (11,23 *vs* 7,84 mm; *p*=0,018) e reintervenções (10,77 *vs* 7,92 mm; *p*=0,036). O desvio do calcar não apresentou associações significativas.

Conclusão: O ITD é uma ferramenta valiosa na avaliação das fraturas do úmero proximal, prevendo complicações e necessidade de reintervenção de forma mais confiável do que a idade do paciente.

Palavras-chave: Consolidação da Fratura; Densidade Óssea; Fixação Interna de Fraturas; Fraturas do Úmero; Placas Ósseas

INTRODUCTION

Proximal humerus fractures (PHF) are considered fragility fractures.[1-4] Their incidence is continuing to increase, even more in the elderly, and optimal treatment remains in doubt, especially in elderly people.[1,5-10] With reverse shoulder arthroplasty (RSA) appearing as a solution in Neer's three- and four-part,[9,11] combined with high complication rates described in the literature following locking plate osteosynthesis or intramedullary nailit,[5,8] is even more important to understand which patients benefit from shoulder-preserving surgery. Even though the number of RSA for fractures is increasing, due to their predictable results,[9,11] many studies reported very good function and range of motion (ROM) with plate osteosynthesis.[5] Several risk factors can negatively impact the outcome of the osteosynthesis, including age, bone density, medial hinge comminution and fracture severity.[2,4,5,12] Even when conservative treatment is chosen, osteoporosis and medial hinge comminution are relevant predictors of secondary displacement.[13] Aditionally, we also know that surgical technique is very important to avoid complications (screws size, calcar screw position and restoring medial support).[3,6,7,14,15] Classically, some PHF treatment algorithms define 65 years old as a turning point in treatment choice. Nowadays, people live longer and stay active for many years, challenging the definition of elderly. Some studies found reliable parameters to predict bone quality.[1,16] Spross *et al*[17] described the Deltoid Tuberosity Index (DTI) as an easy and reproducible tool to assess humerus bone density, which plays a major role in predicting osteosynthesis success. Furthermore, it is an easy measurement with a high intra- and interobserver reliability.[1,17-20] In complex fractures, it is very important to reduce and support the calcar region to avoid avascular necrosis (AVN) and secondary varus displacement.[12,21,22] Calcar screw position has been proven as a useful technique to support the medial hinge and avoid those complications,[3,14,23,24] even in biomechanical studies.[3,25]

The aim was to evaluate if DTI is more reliable than patient age in predicting complications and re-interventions in the

treatment of PHF with locking plates. Additionally, we seek to identify factors that can influence those results, such as calcar screw position and calcar reduction.

MATERIAL AND METHODS

This transversal retrospective study included 49 patients with PHF treated with open reduction and internal fixation (ORIF) with locking plate (AxSOS 3 Proximal Humerus Stryker) at our institution (Unidade Local de Saúde Gaia/Espinho). All patients were operated by senior trauma surgeons with a deltopectoral approach. After applying exclusion criteria, our final population was 40 patients.

Inclusion criteria:

- PHF treated with ORIF with locking plate between 2021 and 2024;
- Minimum 6 months follow-up;
- Complete medical records, including preoperative and postoperative images;

Exclusion criteria:

- Age < than 50 years old (4);
- Loss of follow-up (2);
- Fracture-dislocation (1);
- Open fractures;
- Pre-existing shoulder mobility problems due to paralysis or dementia (2);

Age, gender, side of injury and time until surgery were obtained from patient records. We classified PHF according to Neer classification in the trauma series X-ray and according to Mayo FDJ classification using pre-operative computed tomography (CT) scan.

DTI was measured by two independet shoulder specialists in the pre-operative AP Grashey view and defined as the mean between their values. We used the method described by Spross *et al.*[18] Distance between calcar screw and calcar was measured in the AP Grashey view obtained between 4-6 weeks post-operatively. Using the same X-ray, calcar reduction was measured as the distance between the neck and shaft. Both measurements were adapted from Kimmeyer *et al.*[23] Early complications were defined as those with less than 12 weeks and late complications with more than 12 weeks, as we know that screw cut-out occurs mainly between 6 and 12 weeks.[17] Intra-articular screw, implant loosening or breakage, non-union, osteonecrosis and secondary displacement were evaluated. We defined loss of reduction as a difference greater than 20º in neck-shaft angle in 2 consecutive X-rays with the same incidence and troquiter loss of reduction as a difference greater than 5 mm compared to the post-operative X-ray or resorption. The type of secondary intervention was also recorded.

Statistical analysis was performed using IBM SPSS Statistics, version 30 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as means and standard deviations. Normality was assessed using the Shapiro–Wilk test. Depending on distribution, comparisons between groups were performed using independent samples t-tests or the non-parametric Mann–Whitney U test. Pearson's correlation coefficient was used to assess the relationship between continuous variables. Categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. ROC (receiver operating characteristic) curve analysis was conducted to evaluate the discriminatory ability of the deltoid tuberosity index (DTI) for predicting complications, and the optimal cut-off was determined using the Youden Index. Subgroup analyses were performed to account for potential confounding factors. A p-value <0.05 was considered statistically significant.

This specific study protocol was approved by the relevant ethics committee and all patients gave full informed consent regarding their participation in this study.

RESULTS

Between 2021 and 2024, 49 proximal humerus fractures (PHF) were treated with plate osteosynthesis at our institution. Nine cases were excluded, resulting in a final cohort of 40 patients. The mean age was 61.8 ± 7.3 years, with a female predominance (75%; female-to-male ratio of 3:1) and equal right-left distribution (50%) (Table 1).

Tabela 1. Population demographics, fracture classification and general data

Variable	Mean ± SD or n (%)
Age (years)	61.8 ± 7.3
Sex (female)	30 patients (75%)
Side (right/left)	20 (50%) / 20 (50%)
Neer classification	2-part: 15 (37.5%), 3-part: 23 (57.5%), 4-part: 2 (5%)
Mayo JFD classification	SN: 4 (10%), SN+GT: 3 (7.5%), VPM: 13 (32.5%), Valgus: 15 (37.5%)
Time to surgery (days)	8.7 ± 3.6
DTI (Deltoid Tuberosity Index)	1.41 mm ± 0,11
Early complications / late complications / reinterventon	6/40 (15%) ; 11/40 (27,5%); 10/40 (25%)

According to the Neer classification, 15 fractures were 2-part, 23 were 3-part, and 2 were 4-part. Based on the Mayo Joint Fracture Dislocation (JFD) classification, 4 were surgical neck (SN), 3 SN + greater tuberosity (SN+GT), 13 varus posteromedial (VPM), and 15 valgus-impacted. CT imaging was unavailable in 5 patients. The mean time to surgery was 8.7 ± 3.6 days. DTI <1.4, was present in 42.5% of cases (Table 1).

Early complications occurred in 6 patients (15%), late complications in 11 (27.5%), and revision surgery was required in 10 cases (25%) (Table 1).

Predictors of Complications and Reintervention

DTI values were significantly lower in patients with late complications (1.34 *vs* 1.46; *p*=0.001) and in those requiring revision surgery (1.31 *vs* 1.45; *p*=0.002) (Table 2). No significant difference in DTI was found for early complications (1.38 *vs* 1.42; *p*=0.309) (Table 2). Bringing together complications, both early and late, patients who experienced any complication had significantly lower DTI scores compared to those without complications (mean DTI 1.34 *vs* 1.46; *p*=0.001).

Tabela 2. Outcomes related to DTI and age

Comparison	Statistical analysis	Statistical Result	*p*-value	Interpretation
DTI in patients with *vs* without early complications	Independent samples t- test	1.38 ± 0.13 *vs* 1.42 ± 0.11	0.309	Not statistically significant;
DTI in patients with *vs* without late complications	Independent samples t- test	1.34 ± 0.10 *vs* 1.46 ± 0.11	0.001	Significant difference; Lower DTI is associated with higher risk of late complications
DTI in patients with *vs* without revision surgery	Independent samples t- test	1.31 ± 0.09 *vs* 1.45 ± 0.11	0.002	Significant difference; Lower DTI is associated with higher risk of surgical reintervention.
DTI & Age	Pearson correlation	0.232	0.150	Not statistically significant; DTI and age are not correlated.
DTI in patients ≥65 *vs* <65 years	Independent samples t- test	1.40 ± 0.09 *vs* 1.44 ± 0.12	0.303	Not statistically significant; There is no difference in DTI between groups.
Age and early complications (years)	Independent samples t- test	65.0 *vs* 61.21	0.668	Not statistically significant;
Age and late complications (years)	Independent samples t- test	63.17 *vs* 58.09	0.148	Not statistically significant;
Age and revision surgery (years)	Independent samples t- test	62.10 *vs* 61.67	0.889	Not statistically significant;

Age was not associated with early or late complications (61.21 *vs* 65 years; *p*=0.668 and 63.17 *vs* 58.09 years; *p*= 0.148, respectively) nor with reintervention rate (61.67 *vs* 62.10 years; *p*=0.889) (Table 2) and there was no difference between patients aged ≥65 years and <65 years regarding DTI (1.40 *vs* 1.44; *p*=0.303) (Table 2). No significant correlation was observed between age and DTI (r=0.232, *p*=0.150) (Table 2).

Calcar deviation was not significantly associated with early complications (mean rank 20.19 *vs* 22.25; *p*=0.688), late complications (mean rank 19.05 *vs* 24.32; *p*=0.200), or revision surgery (mean rank 20.22 *vs* 21.35; *p*=0.789) (Table 3).

Tabela 3. Outcomes related to calcar screw distance and calcar reduction

Comparison	Statistical analysis	Statistical Result	*p*-value	Interpretation
Screw-to-calcar distance and early complications (mm)	Independent samples t- test	11.23 ± 3.93 vs 7.84 ± 2.97	0.018	Significant difference; Longer distance is associated with higher risk of early complications
Screw-to-calcar distance and late complications (mm)	Independent samples t- test	8.33 ± 3.81 mm vs 8.39 ± 3.99 mm	0.968	Not statistically significant.
Screw-to-calcar distance and revision surgery (mm)	Independent samples t- test	10.77 ± 4.29 mm vs 7.92 ± 3.34 mm	0.036	Significant difference; Longer distance is associated with higher risk of surgical reintervention.
Calcar deviation and early complications (mean - mm)	Mann–Whitney U test	Mean ranks: 20.19 vs 22.25	0.688	Not statistically significant.
Calcar deviation and late complications (mean - mm)	Mann–Whitney U test	Mean ranks: 24.32 vs 19.05	0.200	Not statistically significant. Trend toward higher deviation associated with higher risk of late complications.
Calcar deviation and revision surgery (mean - mm)	Mann–Whitney U test	Mean ranks: 21.35 vs 20.22	0.789	Not statistically significant.

Calcar screw distance to calcar significantly differed in patients with early complications (7.84 *vs* 11.23 mm; p=0.018) and revision surgery (7.92 *vs* 10.77 mm; p=0.036) (Table 3). However, it did not significantly differ in patients with late complications (8.33 *vs* 8.39 mm; p=0.968) (Table 3). When the distance was categorized as <12 mm or ≥12 mm, no significant differences were found in early complications (p=0.115), late complications (p=0.687), or revision rates (p=0.827).

Subgroup Analyses

After excluding cases of AVN and pseudoarthrosis (deemed unrelated to bone quality), DTI remained significantly lower in patients with late complications (1.32 *vs* 1.45; p=0.002). Excluding revision cases due solely to symptomatic osteosynthesis implant, DTI values remained significantly lower in the revision surgery group (1.31 *vs* 1.45; p=0.002).

ROC Curve Analysis

DTI demonstrated good accuracy in predicting complications, with an area under the curve (AUC) of 0.809. A commonly cited threshold of 1.4 yielded a sensitivity of 80% and specificity of 76%. In our cohort, the optimal cut-off was ≤1.64, providing 100% sensitivity and 92% specificity (Youden Index = 0.92).

Fracture Classification and Outcomes

Neer classification did not correlate with early (p=0.160) or late complications (p=0.412), but was significantly associated with the need for revision surgery (p=0.022); Mayo JFD classification showed no significant association with early complications (p=0.622), late complications (p=0.508), or revision rate (p=0.934).

DISCUSSION

Our population was comparable to previous studies in proximal humerus fractures regarding mean age (61.8 years) and female ratio (3:1).[1,5,7,12,16,26] As for Neer classification, many studies included only 3 and 4-part,[5,16] but in those where 2-part fracture where included, we had a similar distribution to Brunner *et al*[7] but different to Spross *et al*[17] or Padegimas *et al*[12] with the majority of our fractures being 3-part versus 2-part in their study.

Some studies found a high variability in complications and re-interventions. Thy Le *et al*[5] had only 10% complications, all related to plate osteosynthesis but there are studies with up to 42%-49% complications, such as Taskesen *et al*[26] and Sproul *et al*,[27] respectively. Brunner *et al*[7] reported 9% plate-related complications *vs* 35% non-plate related within one year postoperatively. In our study, bringing together both early and late complications, 14 patients had at least one type and that means an overall of 35%, in line with previous studies. We decided to divide between early and late complications because screw cut-out and almost all mechanical failures occur mainly between 6 and 12 weeks.[4,12,17] In our study, early complications occurred in 15% of patients (all of them plate-related). Late complications occurred in 27.5% (2 of them non-plate related – avascular necrosis and pseudarthrosis, which means 22.5% due solely to bone quality). For early complications, we had the same percentage as Padegimas *et al*, 15%.[12] This was less than previously reported by Spross *et al*[17] with 33% cut-out as an early complication in their series or Kralinger *et al*[4] with 26% early loss of reduction and 23% screw cut-out, with 35% overall risk of early mechanical failure.

Secondary surgical intervention was required in 10 patients (25%), but 2 of them were due to material intolerance and not directly related to failure, which means 20%

re-intervention due to bone-quality-related events. Brorson *et al*[28] made a review of 4-part fractures, including prospective, retrospective and case series with a complication rate between 16% and 64% and re-intervention 11%-27%, which means our results meet previous literature.

Bone quality has been studied and there are studies concluding that it can be a reliable predictor of plate osteosynthesis failure.[6,17,18,29] On the other hand it is quite accepted that age has to be taken into account when deciding the type of treatment. First of all we found no association between age and DTI (p=0.150), while Spross *et al*[18] found moderate association and other studies found a statistically significant association.[1,6,26] For age we found no association with early, late or re-intervention rate, which was in line with Thy[5] *et al* ou Schnetzke *et al.*[15] There was also no statistically significant difference in DTI score between patients aged ≥65 years and those younger than 65 years (p=0.303), reinforcing that may be age is not related with bone quality. This is important because it shows that may be in the future we should include bone quality instead of age in treatment decision, despite some authors found age as a risk factor for complications.[7,17] In our study, there was a statistically significant difference regarding DTI for both late complications and re-intervention. Even when including only bone-quality-related complications or re-interventions DTI remained significantly lower (p=0.02 for both variables). Interestingly, we did not find this association for early complications. We believe that bone quality has greater influence in avoiding loss of reduction over time and that early complications can rely more on surgical technique. Furthermore not all patients had an appointment at 12 weeks and because of that, some late complications could be in fact, early complications if patients had been seen earlier.

Regarding complications, Spross *et al* determined a cut-off DTI < 1.44 with a sensivity of 0.88 and specificity of 0.80.[18] In a more recent study, the same author found that DTI < 1.4 and age > 65 years old were significantly related to screw cut-out as an early complication.[17] In our study, the optimal cut-off was ≤1.64, providing 100% sensitivity and 92% specificity. For <1.44 sensivity was 81% and specificity 77%. Nevertheless, some studies does not find that relation between bone density and locking plate osteosynthesis outcomes.[4,5]

Regarding osteoporosis, Handa *et al*[1] concluded that osteoporosis, determined at the distal radius, can be defined with a DTI less than 1.38 (sensivity 60%, specificity 91%). More recently, a 2025 study from Xiang *et al*[19] concluded that a cut-off of 1.6 had the highest sensitivity and specificity with a very strong association with osteoporosis, same result and cut-off as Jain *et al*.[30] Interestingly, this is the same cut-off value we found to predict complications.

Surgical technique is of utmost importance for a good outcome after plate osteosynthesis.[6,15] The calcar screw to avoid secondary displacement and fracture reduction is essential, as demonstrated in many previous studies.[3,23-25] Kimmeyer *et al*[23] found that calcar screw less than 12 mm from calcar has significantly lower complications and better outcomes, the same distance defined by Padegimas *et al.*[12] We found a statistically significant relationship with calcar screw distance for early complications (p=0.018) and re-intervention (p=0.036). On the other hand, we found no association for late complications (p=0.968). Categorizing for less or more than 12 mm we found no difference in all variables. We can argue that the calcar screw can help to prevent secondary displacement in early phases, as the major challenge is to maintain reduction until bone healing occurs.[6] Furthermore, screw cut-out and almost all mechanical failures occur mainly between 6 and 12 weeks,[4,12,17] justifying why early complications and re-interventions were significantly different, opposing to late complications. Our study is in line with the literature reinforcing the importance of calcar screw position but contrary to studies previously mentioned we found no difference with the 12 mm cut-off.

As for fracture reduction we found no significative association between calcar deviation and the outcomes, same result as Padegimas *et al*[12] but contrary to other studies[6,12,15] There was a trend to a bigger distance in those with late complications but without a statistically difference (p=0.20). Calcar reduction is important not only to achieve union and prevent secondary displacement but also to prevent AVN.[2,6,17,21,22] In our study, we only had 1 case of AVN (2.5%), which is far less than those reported in previous studies.[2,5,23] That can occur due to a shorter follow-up, as there were different surgeons protocols with early discharge, but also because we included 2-part fractures and we know that 3 and 4-part have an higher AVN incidence.[2] To have such a difference in AVN incidence can explain why calcar deviation was not statistically different between groups as it plays a major role preventing not only varus displacement but also this complication that can occur many time after surgery.

Regarding fracture classification, our results were in line with literature, with Neer 4-part being significantly associated with a higher revision rate (p=0.022), which shows that this classification can still be useful as one more tool to decide the best treatment.[5,7] That can be due to a more complex pattern with medial hinge comminution but also

because a 4-part fracture ca be associated with a lower DTI as suggested by Koczy-Baron *et al*[31] although other studies did not find that relation.[16,26] Interestingly, our results found no association with early or late complications.

This study has several limitations. It is a retrospective study and so we were not able to request different X-rays if needed. It also included all types of fractures, with 37.5% being 2-part fractures according to Neer in contrast to many other studies that only included type 3 and 4-part. Surgeries were performed by many surgeons, which means there were differences in surgical technique and postoperative protocol. The number of complications or secondary interventions could be higher if we had a longer follow-up.

CONCLUSION

DTI appears to be an important tool to consider when choosing the treatment for PHF, predicting both complication and re-intervention rate. It is not correlated with age, which showed no association with outcomes, despite being widely accepted as a variable to take into account.

Responsabilidades Éticas

Conflitos de Interesse: Os autores declaram a inexistência de conflitos de interesse na realização do presente trabalho.

Fontes de Financiamento: Não existiram fontes externas de financiamento para a realização deste artigo.

Confidencialidade dos Dados: Os autores declaram ter seguido os protocolos da sua instituição acerca da publicação dos dados de doentes.

Proteção de Pessoas e Animais: Os autores declaram que os procedimentos seguidos estavam de acordo com os regulamentos estabelecidos pela Comissão de Ética responsável e de acordo com a Declaração de Helsínquia revista em 2024 e da Associação Médica Mundial.

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Protection of Human and Animal Subjects: The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and those of the Code of Ethics of the World Medical Association (Declaration of Helsinki as revised in 2024).

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Declaração de Contribuição

DG: Análise estatística, conhecimento científico e escrita do artigo.

MP, PL, MF e AS: Conhecimento científico, revisão do artigo.

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Contributorship Statement

DG: Statistical analysis, scientific knowledge, and article writing.

MP, PL, MF, and AS: Scientific knowledge, article review.

All authors approved the version to be published.

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