ORIGINAL ARTICLE

An alternative treatment for aseptic humeral shaft nonunion: intramedullary nailing without grafting

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ABSTRACT

BACKGROUND: This study evaluates the clinical and functional outcomes of intramedullary nailing without grafting for the treatment of aseptic humeral shaft nonunion.

METHODS: Between January 2017 and January 2024, 14 patients treated at a single center for humeral shaft fractures diagnosed with nonunion and managed with intramedullary nailing without grafting were retrospectively analyzed. Demographic and clinical characteristics, union status, and preoperative and postoperative range of motion, Visual Analog Scale (VAS), QuickDASH (Quick Disabilities of the Arm, Shoulder and Hand), and Constant-Murley scores were recorded.

RESULTS: The study included 14 patients (nine women, five men) with a mean age of 49.2±17.5 years (range: 26–80). Nonunion types were oligotrophic in 64.3% (n=9), atrophic in 28.6% (n=4), and hypertrophic in 7.1% (n=1) of cases. The union rate after intramedullary nailing without grafting was 78.5% (11/14). Two patients who did not achieve union underwent nail exchange with iliac autografting, resulting in a total union rate of 92.9% (13/14). The mean time to union was 4.3±2.8 months (range: 2–12). The mean preoperative and postoperative QuickDASH scores were 89.4±6.2 and 17.5±13.3, respectively, while the Visual Analog Scale scores were 7.7±1.1 and 1.7±1.1, respectively ($p<0.001$). Of the three patients who failed to achieve union after initial treatment, two had atrophic nonunion and one had oligotrophic nonunion. A statistically significant association was observed between nonunion type and the need for revision surgery ($p<0.01$), with atrophic nonunions being significantly more frequent in patients requiring revision. One patient developed adhesive capsulitis, and another patient who underwent revision experienced transient radial nerve palsy with complete functional recovery. Proximal screw loosening was observed in two patients and was recorded as a minor complication.

CONCLUSION: Intramedullary nailing without grafting is an effective and safe treatment option for aseptic humeral shaft nonunion in selected patients, particularly those previously treated conservatively. However, omission of grafting in cases of atrophic nonunion or during nail exchange procedures may negatively affect healing.

Keywords: Humerus fracture; intramedullary nailing; nonunion; pseudoarthrosis; graft.

INTRODUCTION

Humerus fractures account for approximately 3–5% of all fractures.[1] Conservative treatment is often successful; however, surgical intervention is preferred for specific indications. [2,3] Nonunion occurs in 8–13% of cases, leading to pain, functional loss, and the need for additional surgical intervention.[4,5]

Plate fixation with autograft is considered the standard treatment for humeral nonunion, with reported union rates ranging from 83% to 100%. Alternative treatment options include

Cite this article as: Tütüncü MN, Dilek M, Özyaman O, Onay T, Akpınar F. An alternative treatment for aseptic humeral shaft nonunion: intramedullary nailing without grafting. Ulus Travma Acil Cerrahi Derg 2026;32:197-203.

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Ulus Travma Acil Cerrahi Derg 2026;32(2):197-203 DOI: 10.14744/tjtes.2025.42888

Submitted: 08.10.2025 Revised: 15.10.2025 Accepted: 03.12.2025 Published: 09.02.2026

intramedullary nailing (IMN), external fixators, and fibular strut grafts.[4-7] Complications associated with plate fixation include wound issues, transient radial nerve palsy, and infection.[4,6,8] Although less commonly used, circular external fixators have demonstrated union rates of 93–100%; however, they are associated with patient non-compliance, pin-site infections, and prolonged treatment duration.[9,10]

Grafting, particularly iliac autografting, is commonly used in atrophic and oligotrophic nonunions.[4,11] Nevertheless, donor-site pain and prolonged operative time are notable disadvantages. Bone morphogenetic protein (BMP) offers the advantage of shorter operative times but is associated with high costs.[12,13]

Intramedullary nailing, with or without grafting, minimizes dissection and reduces the risks of infection and neurovascular injury.[14] However, shoulder pain, joint stiffness, and lower union rates have been reported as potential limitations.[14-16] This study investigates the efficacy of intramedullary nailing without grafting for aseptic humeral shaft nonunion in the absence of significant bone loss.

MATERIALS AND METHODS

After obtaining local ethics committee approval, 22 patients who underwent surgery for humeral nonunion at a single center between 2017 and 2024 were retrospectively analyzed. Of these patients, 15 were treated with IMN without graft, five with IMN plus autograft, and four with plate fixation plus autograft. Fourteen patients older than 18 years, with a follow-up period longer than 12 months, who were treated for traumatic humeral shaft fracture nonunion with intramedullary nailing without graft were included in the study. One patient was excluded due to the lack of follow-up. Patients with infected nonunion, pediatric patients, patients with nerve damage from previous surgery, fractures within 5 cm of the joint line, and pathologic fractures were excluded. Nonunion was defined as fractures showing no signs of union on X-ray imaging at least six months after trauma, accompanied by clinical pain or pathologic motion at the fracture site. The type of nonunion was evaluated according to the Weber and Cech classification.[17]

Demographic and clinical data, including age, sex, fracture side, dominant arm, prior treatment, time to nonunion surgery, and follow-up duration, were collected from medical records. Radiographic data included fracture type (AO/OTA classification [Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association]), fracture location, and nonunion type.

All surgeries were performed by a single surgeon (F.A.) with 30 years of experience in trauma and nonunion surgery, using the InSafeLOCK® Humerus Nail (TST Rakor Tıbbi Aletler, Istanbul, Türkiye). This cannulated, round nail allows distal locking with an internal Endopin without the need for an additional incision. It features a 3-cm distal segment angled 5° anteriorly and a 4-mm Ti6Al7Nb Endopin that anchors to the posterior cortex, allowing up to 6 mm of compression via a proximal set screw.

Surgical Technique

Surgeries were performed under general anesthesia in the beach-chair position using an antegrade approach. For closed reduction, the fracture ends were reamed until a hemorrhagic surface was observed. If closed reduction was not feasible, the fracture site was exposed using a deltopectoral (proximal), anterolateral (middle), or posterior (distal) approach. Scar tissue was debrided, the fracture was reduced, and reaming was initiated. After insertion of a nail of appropriate diameter and length, the nail was locked distally using an Endopin. Following adequate compression, the proximal nail was fixed with two or three screws. Identification and protection of the radial or ulnar nerve were performed when these structures were at risk.

Postoperative Rehabilitation and Follow-up

Early active and passive motion was initiated postoperatively. A sling was recommended for two weeks, except during exercises. Physical therapy was initiated at six weeks in patients with limited shoulder or elbow range of motion. Follow-up evaluations were performed monthly for the first six months, every three months during the first year, every six months during the second year, and annually thereafter.

Union rate, shoulder and elbow range of motion, and functional scores were evaluated at follow-up visits. Anteroposterior (AP) and lateral radiographs of the humerus were obtained at each visit. Radiographic union was defined as union of the fracture in at least three cortices, with callus or trabecular formation, obliteration of the fracture line, and/or cortical continuity. Clinically, union was defined as the absence of motion and pain at the fracture site.[17] Shoulder and elbow motion were measured using a goniometer. The Visual Analog Score (VAS), the shortened version of the Disabilities of the Arm, Shoulder, and Hand (QuickDASH) questionnaire, and the Constant-Murley Score were administered to evaluate the patients' subjective functional status preoperatively and at the last follow-up visit.[18-20] Based on Constant-Murley shoulder scores, outcomes were categorized as excellent (80-100), good (60-80), moderate (40-60), poor (20-40), and very poor (0-20).[21]

All functional and radiologic assessments were performed by an independent observer (M.D.). Complications, including nerve palsy, nonunion, malunion, infection, and hardware loosening, were recorded.

Statistical Analysis

For evaluation of the findings obtained in the study, statistical analyses were performed using NCSS (Number Cruncher Statistical System) 2020 Statistical Software (NCSS LLC, Kaysville, Utah, USA). Descriptive statistical methods were used to evaluate the study data: quantitative variables were

expressed as mean, standard deviation, median, minimum, and maximum values, while qualitative variables were presented as frequencies and percentages. The Shapiro-Wilks test and box plot graphs were used to assess the normality of data distribution.

For within-group comparisons of non-normally distributed variables in two related samples, the Wilcoxon signed-rank test was used. For comparison of qualitative data, Fisher's exact test and the Fisher-Freeman-Halton test were applied. Results were evaluated at a 95% confidence interval, with statistical significance set at $p<0.05$.

Written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethics approval was granted by the local institutional ethics committee (Date: 25.09.2025, No: 2025/0177).

RESULTS

This study included 14 patients (nine women, five men) with a mean age of 49.2±17.5 years (range: 26–80) and a mean follow-up of 37.5±23.8 months (range: 12–85). The mean time from the initial fracture to nonunion surgery was 13.5±9.8 months (range: 6–40). Eleven patients had received prior conservative treatment, and three had undergone intramedullary nailing. Nonunion types were oligotrophic in 64.3% (n=9), atrophic in 28.6% (n=4), and hypertrophic in 7.1% (n=1) of cases.

Intramedullary nailing without grafting achieved union in 78.5% (11/14) of cases after the initial surgery. Of the 11 patients with prior conservative treatment, 90.9% (10/11) achieved union, while one patient declined revision due to age and comorbidities (Fig. 1). Of the three patients requiring nail exchange without grafting, two (66.7%) did not achieve union (Fig. 2) and subsequently underwent revision with iliac

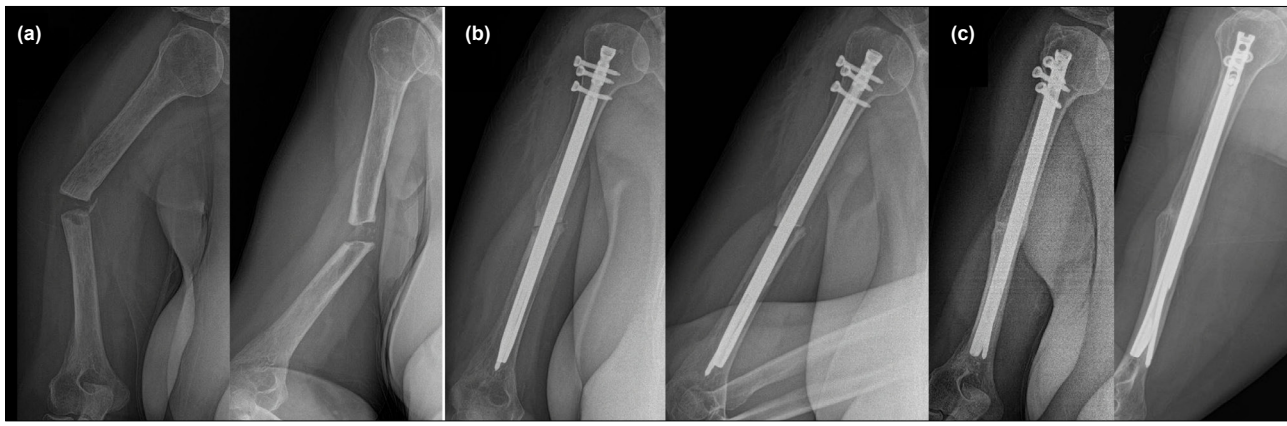

Figure 1. Closed reduction and compressive nailing were performed in a patient who underwent intramedullary nailing without grafting for nonunion 24 months after the initial fracture. Complete union was achieved. **(a)** Preoperative radiographs. **(b)** Early postoperative radiographs. **(c)** Radiographs at the second postoperative year.

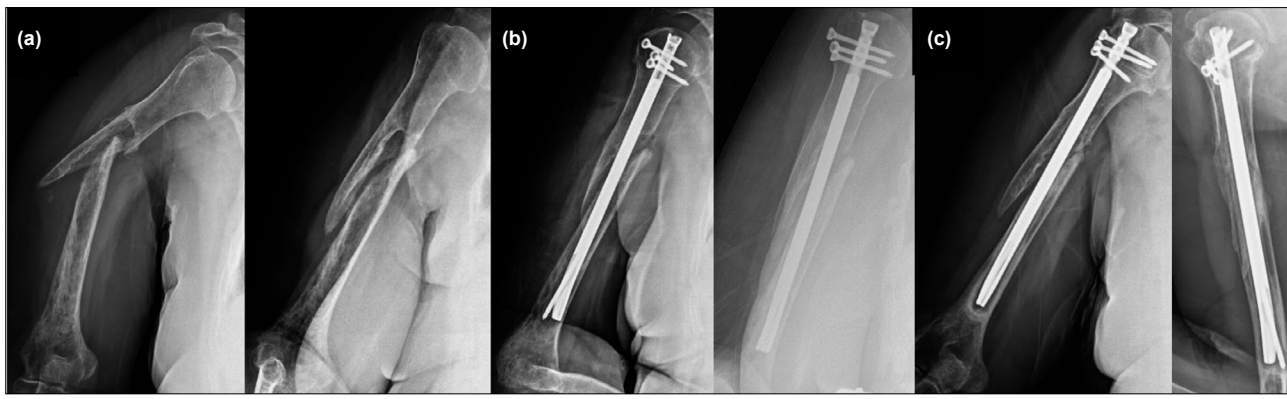

Figure 2. Open reduction and compressive nailing were performed in a patient who underwent intramedullary nailing without grafting for nonunion 12 months after the initial fracture. Postoperative union was not achieved, and the patient declined reoperation. **(a)** Preoperative radiographs. **(b)** Early postoperative radiographs. **(c)** Radiographs at the second postoperative year showing lysis around the nail and screw, supporting the diagnosis of nonunion.

Table 1. Patient demographics, treatment, and outcomes

Age/ Sex	Side	First-Line Treatment	Prior Surgery (n)	Nonunion Type	Graft	Total Surgeries (n)	Follow-up (mo)	Union Time (mo)	Complications/ Further Treatment	Final VAS	Final QuickDASH	Final Shoulder ROM (Flex/Ext/Abd, °)	Final Elbow ROM (Flex/Ext, °)	Constant-Murley Score
28/M	R	IMN	1	Atrophic	Iliac	3	73	4	Revision with grafting and exchange nailing	2	5.0	180/50/180	135/0	95
26/M	R	Conservative	0	Oligotrophic	-	1	71	3	None	0	0.0	180/40/180	140/0	99
61/F	R	Conservative	0	Hypertrophic	-	1	64	2	One proximal screw loosening	3	27.5	170/15/140	135/0	80
46/F	R	IMN	1	Atrophic	Iliac	3	64	5	Transient radial nerve palsy (fully recovered); revision with grafting and exchange nailing	2	2.3	170/40/170	135/0	95
28/F	L	Conservative	0	Oligotrophic	-	1	60	2	None	2	17.5	170/45/170	130/0	95
58/F	R	Conservative	0	Oligotrophic	-	1	38	5	None	0	9.1	175/45/95	130/0	95
39/F	L	Conservative	0	Oligotrophic	-	1	32	2	None	4	42.5	100/15/80	135/0	77
35/M	R	Conservative	0	Oligotrophic	-	1	31	8	Two proximal screws loosened	2	17.5	170/30/100	135/0	98
80/F	R	Conservative	0	Oligotrophic	-	1	24	-	Nonunion; declined further surgery	3	31.8	100/30/90	135/0	64
42/F	R	IMN	1	Atrophic	-	2	17	2	None	2	17.5	170/30/170	135/0	85
66/F	L	Conservative	0	Oligotrophic	-	1	14	12	None	2	20.0	170/45/100	120/0	82
74/F	R	Conservative	0	Oligotrophic	-	1	13	4	None	2	27.5	100/30/80	135/-10	73
60/M	R	Conservative	0	Atrophic	-	1	12	3	None	1	0.0	170/45/170	135/0	95
46/M	R	Conservative	0	Oligotrophic	-	1	12	4	Adhesive capsulitis	0	29.5	100/30/80	135/-10	60

M: Male; F: Female; R: Right; L: Left; IMN: Intramedullary nailing; VAS: Visual Analog Scale; QuickDASH: Quick Disabilities of the Arm, Shoulder, and Hand; ROM: Range of motion; Flex: Flexion; Ext: Extension; Abd: Abduction; mo: Months.

autograft, achieving union. The total union rate was 92.9% (13/14). The mean union time was 4.3±2.8 months (range: 2–12).

The mean preoperative and postoperative QuickDASH scores were 89.4±6.2 and 17.5±13.3, respectively, while the VAS scores were 7.7±1.1 and 1.7±1.1, respectively. These differences were statistically significant (p<0.001). The mean Constant-Murley score at the last follow-up visit was 85.2±12.9 (range: 60-99).

Shoulder flexion measured with a goniometer was 152.5±34.6° (range: 100-180), shoulder abduction was 134.6±43.0° (range: 80-180), and shoulder extension was 35.3±11.3° (range: 15-50). Elbow flexion was 133.9±4.8° (range: 120-140), and elbow extension was -1.4±3.6° (range: 0 to -10).

Complications

Nonunion persisted in three patients after the initial surgery; two achieved union after nail exchange with grafting. One patient developed adhesive capsulitis, and two experienced proximal screw loosening. One revision patient had transient radial nerve palsy with full recovery (Table 1).

The nonunion type of the two patients who underwent revision was atrophic, while the nonunion type of the other patient with persistent nonunion who declined revision surgery was oligotrophic. There was a statistically significant difference in nonunion types according to revision status (p=0.009; p<0.01). The success of IMN without grafting was statistically lower in atrophic-type nonunions.

DISCUSSION

In the present study, the results of intramedullary nailing without grafting in the treatment of aseptic humeral nonunion without significant bone loss were evaluated. The union rate after the first nonunion surgery was 78.5% (11/14). In other studies in which humeral nonunions were treated with IMN without grafting, the union rates after the first nonunion surgery ranged from 29% to 62%.[6,22] In this study, the total union rate after revision with grafting was 92.9%, while union rates in studies in which IMN with grafting was performed for nonunion ranged from 56% to 100% (mean: 88%).[6,8,14,15] These results appear to be consistent with the literature.

In 10 (90.9%) of 11 patients with previous conservative treatment resulting in nonunion, union was achieved with IMN without grafting. In a study by Verbuggen et al.,[23] union was achieved with IMN without grafting in seven (41.1%) of 17 patients who had previously been treated conservatively and subsequently developed nonunion. There are very few studies on IMN without grafting for the treatment of nonunion, and in general, reported union rates have been low. Dujardin et al.[22] reported an overall union rate of 62% after IMN without grafting in a group previously treated conservatively or with nails. Accordingly, the union rates in patients with prior conservative treatment in this study appear satisfactory compared to the literature.[6,22,23]

In a study by Fininkila et al.,[24] the union rate of exchange nailing without grafting in nonunions was 38% (5/13), and in a study by McKee et al.,[25] the union rate of exchange nailing without grafting in nonunions was 40% (4/10). Lin et al.[26] reported a union rate of 95.65% (22/23) after the first attempt at exchange nailing with grafting in patients previously treated with nails who developed nonunion, and Li et al.[15] reported a 100% union rate after exchange nailing with grafting in a 12-patient case series with a similar patient group. Including the present study, union rates of exchange nailing without grafting are considerably lower than those achieved with grafting. Grafting combined with exchange nailing may increase the likelihood of success in nonunion surgery.[6,8,15,26]

The mean union time was 4.3±2.8 months (range: 2-12). In the literature, union time after interventions for nonunion is generally reported as 3-5 months, and the findings of the present study are consistent with previous studies.[27]

Among patients undergoing surgery for nonunion, nine were classified as oligotrophic, one as hypertrophic, and four as atrophic. Of the three patients who experienced persistent nonunion after the initial surgery, two had atrophic nonunion and one had oligotrophic nonunion. The union rate for atrophic nonunions after the first surgery was 50% (2/4). Subsequent union in these cases was achieved with exchange nailing and grafting. In the current study, the success rate of intramedullary nailing without grafting was statistically lower for atrophic nonunions (p=0.009).

There are many biological and mechanical factors that need to be addressed in the treatment of nonunion. In hypertrophic nonunions, mechanical factors are primarily implicated, whereas in atrophic nonunions, disruption of local biology is considered the main cause. Factors leading to deterioration of local biology include excessive soft tissue dissection from previous surgeries, impaired blood supply, decreased local growth factors, and infection.[14,23,27] Giannoudis et al.[28] stated that both local biological factors should be corrected and mechanically stable fixation should be provided in nonunion surgery, emphasizing that grafts may be required to improve local biology after adequate fixation. In the present study, the low union rates observed in patients with atrophic nonunion treated with fixation without grafting, along with successful union after revision with grafting, suggest that grafting may be more appropriate in atrophic nonunions.

In nonunion surgery, iliac crest autograft is among the most frequently employed methods, serving as an adjunct to mechanical stabilization. Its notable advantages include ease of application, low associated morbidity for the patient, and a demonstrated capacity to increase union rates. However, its use is not without drawbacks. Disadvantages include the need for extensive dissection when applied to nonunion areas, the potential for nerve damage, and considerable donor site morbidity.[13,14] Rajan et al. reported that 26% of patients

still had pain at the donor site and 13% had numbness radiating to the thigh at one year postoperatively in patients who received an iliac autograft. Accordingly, they reported that iliac autograft harvesting should be limited in the absence of an absolute indication.[29]

Preoperative and postoperative mean QuickDASH scores were 89.4±6.2 and 17.5±13.3, respectively, while Visual Analog Scale scores were 7.7±1.1 and 1.7±1.1, respectively ($p<0.001$). At the last follow-up visit, the Constant-Murley score was 85.2±12.9 (range: 60-99). According to the Constant-Murley score, 10 patients were classified as very good and four patients as good. At the last follow-up visit, shoulder flexion was 152.5±34.6° (range: 100-180), shoulder abduction was 134.6±43.0° (range: 80-180), shoulder extension was 35.3±11.3° (range: 15-50), elbow flexion was 133.9±4.8° (range: 120-140), and elbow extension was -1.4±3.6° (range: 0 to -10). The results were quite satisfactory except for two patients. Outcomes were mediocre in one patient who failed to achieve union and declined reoperation, and in another patient who was treated for adhesive capsulitis after surgery. Shoulder and upper extremity function can be well preserved after IMN in the treatment of nonunion when an appropriate surgical technique is used.[14,15,23]

In two patients in this study, proximal screw loosening was observed after union and was considered a minor complication. Nonunion occurred in three patients, and union was achieved in two after revision surgery. One patient who underwent revision developed transient radial nerve palsy with complete functional recovery. One patient developed postoperative adhesive capsulitis. In a systematic review, Peters et al.[6] reported total complication rates of 12% for nonunion surgeries with plate and graft, 15% for IMN with graft, and 8% for IMN without graft. While local infection and nerve disorders are more common after osteosynthesis with plating, shoulder-related problems (rotator cuff tear, shoulder impingement, adhesive capsulitis) and union problems are more common after nailing. In a prospective study by Singh et al.[8] comparing patients with nonunion treated with plate and nailing, no statistically significant difference was found between the groups in terms of nonunion; one patient in the nail group had nonunion requiring revision, and two patients in the plate group developed transient radial palsy that completely resolved. In a study by Martinez et al.[30] comparing nonunion patients treated with plate and nailing, no statistically significant difference in complications was reported; three patients in the nail group healed with acceptable angulation, and three patients in the plate group developed transient radial palsy that completely resolved. Many studies have reported that nailing is safer in terms of radial nerve palsy, whereas plate osteosynthesis is safer in terms of union-related complications.[6,8,30]

This retrospective study is limited by its small sample size and lack of a control group. Prospective, controlled studies with larger cohorts are needed to validate these findings.

Intramedullary nailing without grafting is an effective and safe treatment for aseptic humeral shaft nonunion in selected patients, particularly those with prior conservative treatment. However, omitting grafting in cases of atrophic nonunion or nail exchange may negatively affect healing.

Ethics Committee Approval: This study was approved by the Göztepe Prof. Dr. Süleyman Yalçın City Hospital Ethics Committee (Date: 25.09.2025, Decision No: 2025/0177).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: F.A., T.O., M.N.T.; Design: T.O., M.N.T.; Supervision: F.A., T.O.; Resource: F.A., M.D.; Materials: F.A., M.D., O.Ö.; Data collection and/or processing: M.N.T., M.D., O.Ö.; Analysis and/or interpretation: M.N.T., O.Ö.; Literature review: M.N.T., T.O.; Writing: M.N.T., T.O.; Critical review: T.O., F.A.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Aseptik humerus şaft kaynamama tedavisinde alternatif bir yöntem: Greftsiz İntramedüller çivileme

AMAÇ: Bu çalışma, aseptik humerus cisim psödoartrozu tedavisinde greftsiz intramedüller çivilemenin klinik ve fonksiyonel sonuçlarını değerlendirmektedir.
GEREÇ VE YÖNTEM: Ocak 2017-Ocak 2024 tarihleri arasında, tek merkezde humerus cisim kırığı nedeniyle psödoartroz tanısı almış ve greftsiz intramedüller çivileme ile tedavi edilmiş 14 hasta retrospektif olarak incelendi. Demografik ve klinik özellikler, kaynama durumu, ameliyat öncesi ve sonrası eklem hareket açıklığı, Görsel Analog Skala (VAS), QuickDASH ve Constant-Murley skorları kaydedildi.
BULGULAR: Çalışmaya yaş ortalaması 49.2±17.5 yıl (26-80) olan 14 hasta (9 kadın, 5 erkek) dahil edildi. Psödoartroz tipleri olguların %64.3'ünde (n=9) oligotrofik, %28.6'sında (n=4) atrofik, %7.1'inde (n=1) hipertrofik olarak saptandı. Greftsiz intramedüller çivileme sonrası kaynama oranı %78.5 (11/14) idi. Kaynama sağlanamayan 2 olguya iliak otogreft ile çivi değişimi uygulandı ve toplam kaynama oranı %92.9'a (13/14) ulaştı. Ortalama kaynama süresi 4.3±2.8 ay (2-12 ay) idi. Ameliyat öncesi ve sonrası QuickDASH skorları sırasıyla 89.4±6.2 ve 17.5±13.3; VAS skorları ise 7.7±1.1 ve 1.7±1.1 bulundu ($p<0.001$). İlk tedavi sonrası kaynamayan 2 olgunun psödoartroz tipi atrofik, birinin ise oligotrofikti. Revizyon gerektiren olgularda atrofik psödoartroz oranı anlamlı derecede yüksek bulundu ($p<0.01$). Bir hastada adeziv kapsülit gelişti, revizyon uygulanan başka bir hastada ise geçici radial sinir felci gözlendi ve tam fonksiyonel iyileşme sağlandı. İki hastada proksimal vida gevşemesi minör komplikasyon olarak kaydedildi.
SONUÇ: Greftsiz intramedüller çivileme, özellikle daha önce konservatif tedavi uygulanmış seçilmiş hastalarda aseptik humerus cisim psödoartrozu için etkili ve güvenli bir tedavi seçeneğidir. Ancak atrofik psödoartroz veya çivi değişimi gereken olgularda greft kullanılmaması iyileşme sürecini olumsuz etkileyebilir.

Anahtar sözcükler: Greft; humerus kırığı; intramedüller çivileme; kaynamama; psödoartroz.

Ulus Travma Acil Cerrahi Derg 2026;32(2):197-203 DOI: 10.14744/tjtes.2025.42888