JSES International 6 (2022) 1048–1053

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Recovery from open osteocapsular débridement for primary elbow osteoarthritis is rapid and does not depend on preoperative motion

Farhan Ahmad, MD[a,*], Sal Ayala, BS[b], Nabil Mehta, MD[a], Mark S. Cohen, MD[a], Xavier C. Simcock, MD[a], Robert W. Wysocki, MD[a]

[a]Rush University Medical Center, Chicago, IL, USA
[b]University of Illinois College of Medicine, Chicago, IL, USA

ARTICLE INFO

Keywords:
Elbow
Osteocapsular débridement
Primary osteoarthritis
Motion recovery
Open release

Level of evidence: Level IV; Case Series; Treatment Study

Background and Hypothesis: Osteocapsular débridement is a surgical treatment for functionally limiting primary elbow osteoarthritis (PEOA). We hypothesized that postoperative improvement in range of motion (ROM) following elbow osteocapsular débridement could be grouped into predictable patterns. We also hypothesized that significant improvements in ROM frequently take place for up to 6 months after surgery.

Methods: A retrospective chart review of patients who underwent open elbow débridement for PEOA was performed. Demographic information and surgical approach were recorded. ROM data were also collected at preoperative, intraoperative, and postoperative intervals of 2 weeks, 6 weeks, 3 months, and 6 months. Growth mixture modeling and latent class growth analysis were performed to identify groups of motion recovery trajectories, while Student's t-tests were performed to compare ROM data between intervals.

Results: Our study included 76 patients who underwent open elbow débridement (9 with a lateral approach, 55 medial, and 12 both) for PEOA. The mean preoperative arc of motion was 95° ± 22°. This improved to a mean final motion arc of 127° ± 11 at final follow-up, which was 92% of the mean intraoperative arc. The mean time to achieve final motion was 3 months, with 79% of patients achieving their final ROM arc by this point. Patients achieved an average of 85% of their final arc of motion by the 2-week postoperative visit (92% of final flexion and 61% of final extension). Growth mixture modeling and latent class growth analysis did not identify any statistically significant groupings for postoperative ROM progression trajectories. Arc of motion preoperatively, intraoperatively, and at 2 weeks postoperatively did not correlate with the final arc of motion. There were no characteristics or thresholds of motion which conferred a higher likelihood of achieving a better result postoperatively.

Conclusions: ROM recovery after osteocapsular débridement for PEOA is not dependent on preoperative, intraoperative, or 2-week postoperative arcs of motion. Most of the ROM recovery occurs in the early postoperative period, with flexion restored preferentially faster than extension. The final arc of motion can be expected by 3 months postoperatively. This knowledge has potential benefit in affecting patients' personal time commitment to rehabilitation and the overall cost for therapy and splinting beyond the 3-month time point.

Primary elbow osteoarthritis (PEOA) in the absence of trauma can be a debilitating condition consisting of pain and loss of range of motion (ROM) secondary to capsular contracture and osteophyte formation.[4,7] PEOA primarily affects middle-aged men who perform strenuous activity either through manual labor work or heavy recreational activity. The overall lifetime prevalence has been estimated at 2%-3%.[15] The primary surgical treatment for functionally limiting elbow arthritis is an open or arthroscopic capsular release with the removal of impinging osteophytes—though other procedures have been described in the literature.[1,2,13,19]

The goals of surgery in these cases include pain relief and ROM improvement.[20] Though open elbow release has been shown to improve pain and elbow ROM, heterogeneity in outcome exists.[13,17] To further improve the outcomes of elbow release and counsel patients appropriately as they plan and undergo their rehabilitation, understanding the patterns and differences in motion

Rush University Institutional Review Board approved this study: ORA #: 20092807-IRB01.

*Corresponding author: Farhan Ahmad, MD, Rush University Medical Center, Department of Orthopaedic Surgery, 1611 W. Harrison St., Chicago, IL 60612, USA.
E-mail address: ahmadfr@icloud.com (F. Ahmad).

https://doi.org/10.1016/j.jseint.2022.07.006
2666-6383/

outcomes following this procedure is paramount. A better understanding of progression can also help guide the duration for which supervised physiotherapy is prescribed. Growth mixture modeling (GMM) is a statistical tool that has been used in previous studies to establish patterns in postoperative recovery after other orthopedic procedures, such as total hip arthroplasty and hip arthroscopy.[9] This effect has not been investigated after open elbow release for PEOA.

The goal of this study was to identify recovery trajectories after open elbow osteocapsular débridement for PEOA and identify risk factors associated with better or worse postoperative ROM. We hypothesized that there are distinct recovery trajectories after this procedure and that patients with relatively worse preoperative motion would recover more slowly due to the need for more aggressive débridement and increased time to recover larger deficits in motion. We hypothesized that motion would also recover more slowly or potentially incompletely in patients with a more limited ROM at their 2-week visit, possibly secondary to a tendency toward swelling, fibrosis, or subjective pain/guarding that could negatively affect long-term motion recovery.

Materials & methods

Patient selection

Following institutional review board approval, we identified 442 patients who underwent radical resection and contracture release of the elbow at our institution from January 2010 to December 2019. All procedures were performed by two of our fellowship-trained hand and upper extremity surgeons at a tertiary referral center.

Patients who received osteocapsular débridement for PEOA, as confirmed on radiographs, were included in this study. Patients who had prior osteocapsular débridement in the affected elbow, prior elbow surgery (eg, elbow arthroscopy), an etiology other than PEOA (eg, trauma), or those aged <18 years old were excluded.

Patient charts and preoperative radiographs were assessed to confirm that patients had PEOA and no significant post-traumatic arthritis as their indication for their elbow osteocapsular débridement procedure. The electronic health record was examined to collect data on demographics and history of symptoms and treatment. Flexion and extension data were collected at the following intervals: preoperative, intraoperative, and postoperative at approximately 2 weeks, 6 weeks, 3 months, and 6 months. All measurements were made with a standard goniometer by the attending surgeon, with the exception being intraoperative measurements, which were purely surgeon estimates.

Surgical technique

All patients included in this study underwent open débridement. Two approaches were utilized, medial and lateral. No arthroscopic techniques were included.

The medial approach was typically performed if there was concomitant ulnar neuropathy requiring neuroplasty and transposition or if there was primary disease in the ulnohumeral joint and little in the radiocapitellar joint. Through a curvilinear incision centered behind the medial epicondyle, the ulnar nerve was decompressed and transposed. Posterior joint débridement was performed by elevating the triceps and posterior capsule. The posterior capsule and fat pad were sharply resected, any loose bodies excised, and then impinging osteophytes on the olecranon tip or within the olecranon fossa were débrided with a highspeed burr. The posteromedial capsule (posterior band of the ulnar collateral ligament) was typically released to maximize joint flexion. Next, the ulnar nerve was returned to its posterior position, and an anterior working window was then established. Dissection was developed between the brachialis and the distal humerus, with an extension distally through the posterior third of the flexor pronator mass. This muscle was then elevated off of the anterior capsule with the brachialis. The capsule was then widely excised. Any loose bodies and impinging osteophytes were excised analogous to the posterior débridement. Manipulation was performed, and direct visualization was used to confirm no remaining impingement anteriorly or posteriorly. The muscle origins were then repaired, and a subcutaneous ulnar nerve transposition was completed.

The lateral approach was typically performed if extensive débridement of the radiocapitellar joint was anticipated, especially in the setting of abundant posterior radiocapitellar osteophytes. A combined medial/lateral approach was considered for extensive ulnohumeral and radiocapitellar disease. The lateral incision was made proximally over the supracondylar ridge of the humerus, extending over the lateral epicondyle, and in line with the anconeus-extensor carpi ulnaris tendon interval. The anconeus and triceps were then reflected posteriorly off the ulnar and supracondylar ridge of the humerus, with particular care to stay posterior and proximal to the LCL. The posterior débridement was carried out in a manner analogous to the medial approach. The anterior working window was then made between the brachialis and humerus, extending into the ECRL/ECRB interval. After elevating the muscle sleeve off of the anterior capsule with the brachialis, the anterior joint capsule was excised, and débridement was carried out in a manner analogous to the medial approach. Hemovac drains were placed overnight per surgeon preference in some cases with larger bony resections. After wound closure, a soft dressing was applied with a full-thickness hole cut out anteriorly to allow full flexion without impingement from the dressings.

Rehabilitation protocol

All patients received the same rehabilitation protocol. Immediately postoperatively, the patient was maintained in continuous passive motion as an inpatient and then as an outpatient twice per day for 30-45 minutes for 4 weeks, set from 0 to 140° in all patients. Static progressive splints for flexion in the evening and extension in the morning for 30 minutes each were continued for 3-6 months postoperatively as needed. Additionally, patients were seen by a therapist within 24 hours for removal and debulking of the surgical dressing and to begin supervised occupational therapy and home exercises with a focus on concentrated weighted forearm stretches, and aggressive active and passive exercises encouraged. Strengthening was begun at 6-8 weeks postoperatively.

Statistical analysis

Using the software MPlus (version 8.5; Muthen & Muthen, Los Angeles, CA, USA), GMM and then latent class growth analysis (LCGA) with 1-7 classes were performed (for further reading, see Ram et al[14]). By using this range of classes, up to 7 distinct groups in our data could be identified if statistically significant. Variations on model parameters were employed. First, the preoperative flexion was fixed to 0, and the last measurement (6 months follow-up) was fixed to 1. Additional combinations of analyses wherein the first and last measurements were not fixed followed. Models were assessed by the size of the output groups and statistical significance via the Vuong-Lo-Mendell-Rubin test.

Subsequently, the authors manually consulted the database to perform statistical and subjective testing to identify any

Table I
Mean range of motion data at each follow-up interval.

Motion parameter	Preop	1-2 weeks	6 weeks	3 mo	6 mo (final)
Flexion	121° ± 15	124° ± 11	131° ± 8	134° ± 7	135° ± 6
Extension	25° ± 12	16° ± 10	12° ± 9	9° ± 8	9° ± 8
Arc	95° ± 22	108° ± 16	119° ± 15	125° ± 13	127° ± 11

Table II
Percent of final flexion, extension, and arc at each follow-up interval.

Motion parameter	1-2 weeks	6 weeks	3 mo	6 mo (final)
Percent of final flexion	92% ± 7	97% ± 5	100% ± 2	-
Percent of final extension	61% ± 97	86% ± 129	100% ± 43	-
Percent of final arc	85% ± 10	94% ± 8	99% ± 5	-

Table III
Time to final arc, by interval.

Follow-up interval	When patients achieved 100% of their final arc	Running total
1-2 weeks (%)	7 (9.2)	7 (9.2)
6 weeks (%)	18 (23.7)	25 (32.9)
3 mo (%)	35 (46.1)	60 (79.0)
6 mo (final) (%)	16 (21.1)	76 (100)

progression patterns and test various groups to identify flexion progression patterns.

Quantitative interval variables were analyzed by comparison of means and unpaired t-test for *P* values. Firstly, the preoperative arc of motion was compared with the final arc of motion at 6 months, followed by the intraoperative arc with the final arc. Secondly, at the first follow-up of approximately 2 weeks, the percentage of final arc was calculated, and patients were grouped accordingly to track progression—and then grouped as either ≥80% of final arc at first follow-up or <80%. Thirdly, two groups were created by endpoint flexion, either <135° or ≥135°—and t-tests comparing the endpoint flexion to intraoperative and first follow-up flexions were performed. Additional subgroup analyses by age, sex, and surgical approach (medial vs. lateral) were also performed with Student's t-test comparisons of all of the ROM outcomes.

Results

After applying inclusion and exclusion criteria, 76 patients were included in this study (68 males and 8 females). The average age was 47 ± 12 years. An isolated medial approach was used for 55 patients, a lateral approach for 9 patients, and combined medial/lateral approaches for 12 patients. Preoperative elbow flexion averaged 121° ± 15, and extension averaged 25° ± 12 (arc of motion 95° ± 22). For the unaffected arm, flexion averaged 136° ± 8, and extension averaged 7° ± 10 (arc 128° ± 16). After release, intraoperative flexion averaged 140° ± 6, and extension averaged 2° ± 7 (arc 138° ± 11).

The ROM data are summarized in Table I. At the first follow-up interval of approximately 2 weeks, average elbow flexion was 124° ± 11, extension 16° ± 10, and arc 108° ± 16. At 6 weeks, the flexion averaged 131° ± 8, extension 12° ± 9, and arc 119° ± 15. At 3 months, the flexion averaged 134° ± 7, extension 9° ± 8, and arc 125° ± 13. At 6 months, the flexion averaged 135° ± 6, extension 9° ± 8, and arc 127° ± 11. There was a statistically significant difference between preoperative and final arcs of motion ($P < .05$).

With the 6-month data being considered the final ROM, calculation of the percentage of final flexion, extension, and arc was also performed at each interval (Table II). At the 2 weeks follow-up, the percentage of final flexion averaged 92% ± 7. At 6 weeks, the percentage of final flexion averaged 97% ± 5. At 3 months, the percentage of final flexion averaged 100% ± 2. For extension, at 1-2 weeks the percentage of final was 61% ± 97. At 6 weeks, the percentage of final extension was 86% ± 129. At 3 months, the percentage of final extension was 100% ± 43. For arc, at 1-2 weeks the percentage of final was 85% ± 10. At 6 weeks, the percentage of final arc was 94% ± 8. At 3 months, the percentage of final arc was 99% ± 5. Additionally, patients achieved 92% of their intraoperative arc by the 6-month follow-up visit.

Table III shows the percentage of each patient achieving their final arc of motion at each postoperative time point. The mean time to the final arc was 3 months. By this time point, nearly 80% of patients had reached their final arc. Some patients achieved the final arc even sooner. At 2 weeks, 7 patients (9%) achieved their final arc. At 6 weeks, an additional 18 patients (24%) achieved their final arc. At 3 months, an additional 35 patients (46%) achieved their final arc. The remaining 16 patients were still approaching 100% before the last visit.

1-class to 7-class modeling in the form of a LCGA and a GMM was performed to identify distinct progression trajectories within our cohort. The first measurement (preoperative flexion) was fixed to 0, and the last measurement (6 months follow-up) was fixed to 1. Then, additional combinations of analyses wherein the first and last measurements were not fixed were performed, as well as analyses with variations on the model parameters and constraints. While some analyses identified viable groups, they were either too small to be clinically useful or statistically insignificant on a Vuong-Lo-Mendell-Rubin test. Figure 1 visualizes the flexion, extension, and arc progressions for each patient in our cohort.

Consequently, to generate a single model to best describe our data in lieu of identifying different patterns using GMM or LCGA, a traditional time series analysis was performed in the form of nonlinear regression, fitted by the least squares method. The regression model is depicted in Figure 2, and the values of our functions for flexion, extension, and arc are presented in the Supplementary Appendix S1.

Subsequently, the data set was reviewed manually to identify trends or groups both subjectively and with the use of two-tailed t-tests for quantitative interval variables (eg, ROM). The preoperative arc of motion was significantly different from the postoperative arc ($P < .05$). However, matching preoperative arcs to postoperative arcs to identify progression patterns was not possible, as the trajectory differed between patients.

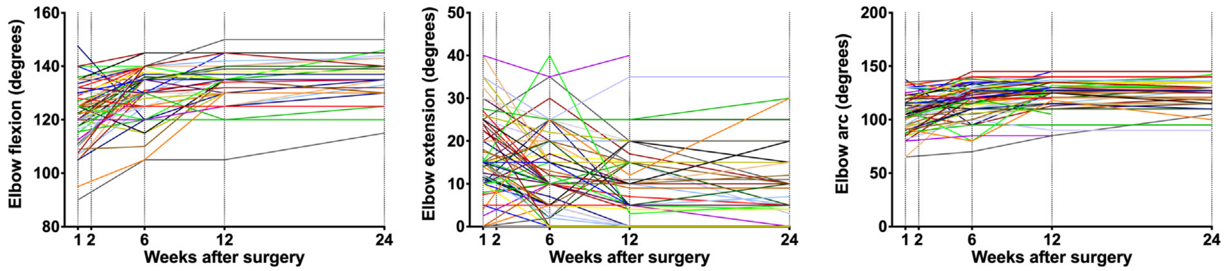

Figure 1 Spaghetti plot of flexion, extension, and arc progressions.

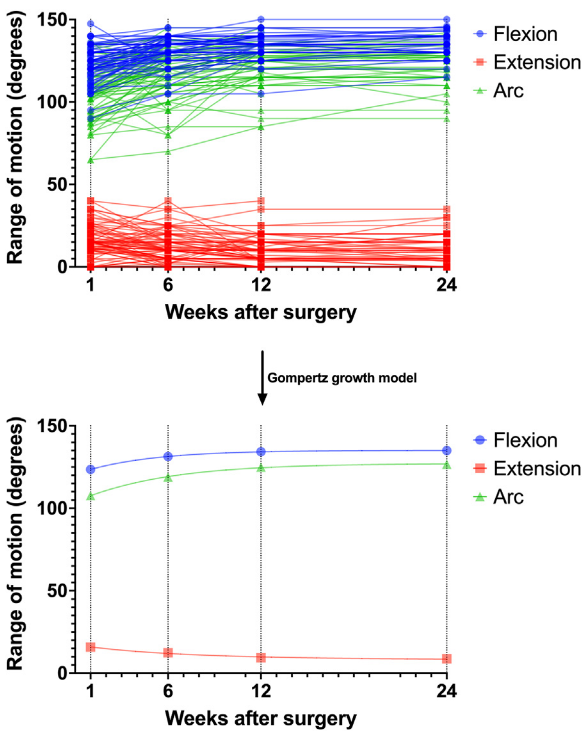

Figure 2 Gompertz growth modeling of flexion, extension, and arc.

Table IV
Overview of pertinent negatives.

Findings
Preoperative arc is not a predictor for the final arc.
Intraoperative arc is not a predictor for the final arc.
There is no distinction between rapid or slow progressors through the duration of follow-up.
Patients at ≥80% vs. <80% of endpoint arc by the first 2 weeks postoperatively did not have statistically significant differences in final arc.
Patients <135 or ≥135 degrees of final flexion did not have statistically significant differences in intraoperative and first follow-up flexions.

Neither preoperative nor intraoperative arc of motion predicted the final arc at 6 months. After calculating the percentage of the final arc for each interval, no trend was apparent that could be used to identify groups of rapid or slow progressors. Subgrouping at the first follow-up by 80% of final arc did not result in significant t-tests between groups or any obvious differences in endpoint arc. Another subgroup analysis by endpoint flexion, either <135° or ≥135°, did not have significant t-tests when looking at the intraoperative and first follow-up flexions. An overview of these pertinent negatives is in Table IV.

After grouping by age (<40, 40-50, 51-59, and >60), analysis of variance for final flexion, extension, and arc were all insignificant. Subgroup analysis by sex and surgical approach (medial vs. lateral) was also not statistically significant ($P > .05$) on Student's t-tests for final flexion, extension, and arc.

Discussion

Open débridement, osteoplasty, and capsular release are common treatments for elbow stiffness and have been shown to provide durable benefit to patients with PEOA.[7,13] The main findings of our study were 1) the mean time to achieve the final arc of motion after elbow release was 3 months postoperatively, with 79% of patients achieving their final ROM arc by that time; 2) our cohort in total achieved 85% of their final arc at 2 weeks postoperatively, and 99% of their final arc at 3 months; 3) preoperative, intraoperative, and 2-week postoperative arc of motion do not correlate with the final arc of motion; and 4) there were no characteristics or thresholds of motion which conferred a higher likelihood of achieving a better result postoperatively.

Our cohort demonstrated a final mean improvement in the flexion-extension arc of 32° ± 11, which is similar to the mean 28.6° improvement demonstrated in a review of 323 elbows undergoing open débridement for PEOA.[13] Similarly, another review of 300 elbows in 292 patients undergoing open elbow release for PEOA showed a mean arc improvement of 29.4° ± 9.7 at a mean follow-up of 55 ± 20 months.[7] Our cohort achieved similar increases in arc of motion at just 3 months postoperatively, which represented 99% of the final arc of motion. This difference may be due to the increased granularity of our results, as the de Klerk et al study reported ROM at final follow-up and excluded studies with follow-up of fewer than 12 months.

Our cohort largely achieved their final arc of motion by 3 months postoperatively, with most of the improvement seen in the early postoperative period. A long-term outcomes study by Wada et al reported that ten years after débridement arthroplasty for PEOA, the flexion arc remained consistent and extension decreased by 7°.[18] Their work implies that the bulk of motion improvements from this surgery occur in the immediate and near-term postoperative follow-up periods, which we sought to characterize in this study. While operative technique and extent of débridement undoubtedly play a role in the outcome of the procedure, rehabilitation after elbow release also influences outcome. The benefits of splinting have been demonstrated in the literature for post-traumatic elbow stiffness.[2,10,16] In a randomized controlled trial, Lindenhovius et al demonstrated substantial improvement in ROM with both static and dynamic splinting upward of one year after initiation in patients with post-traumatic elbow stiffness, indicating that the capsule is able to be stretched over time.[9] However, our results of PEOA patients show that the average time to maximal improvement occurs after 3 months, with minimal improvement occurring thereafter. Our results suggest that in the setting of PEOA there may be potentially more pliable soft tissue than in a post-traumatic elbow, indicating that a shorter duration of treatment with either splinting or supervised physiotherapy may be sufficient to achieve maximal recovery. This knowledge has potential benefit in affecting patients' personal time commitment to rehabilitation and the overall cost for therapy and splinting beyond the 3-month time point, although confirmation with future studies is recommended.

Our findings that patients' ROM improves in a shorter timeline compared to results reported in the literature have implications both for healthcare utilization and for providing optimal care to patients with this pathology. The timeline of recovery after elbow release in patients with PEOA has not been fully explored in the literature to date. Understanding the expected postoperative recovery timeline can help providers counsel patients preoperatively and ensure that they are on track after the procedure. Furthermore, knowing when patients are likely to achieve maximum ROM can avoid unnecessary interventions beyond certain time points once certain ROM goals are achieved, thereby reducing the overall cost to the patient and the healthcare system and increasing its value. Optimizing clinical pathways for patients in this way is cost-effective as healthcare delivery in the United States shifts from service-based to value-based care.

Our GMM analysis did not identify any preoperative or intraoperative value or threshold of flexion or extension that predicts postoperative ROM. Likewise, a manual data review did not identify any patterns in recovery trajectory to target interventions or risk factors for slow or fast progression, even when divided into subgroups based on the final arc of motion according to intraoperative ROM or ROM at the first postoperative visit. Similarly, age, sex, and surgical approach were not found to be significant predictors of final ROM. Predictors of outcome after elbow débridement and capsular release for PEOA have not been widely reported to date, and our results add to this literature. In a cohort of patients undergoing open elbow release for post-traumatic OA, Lindenhovius et al found that pain was the strongest predictor of final health status and arm-specific disability.[10] This study did not investigate the effect of preoperative ROM on postoperative values but found no correlation between final flexion or extension and postoperative DASH scores. Gundes et al examined 77 patients undergoing open elbow release and found that a postoperative flexion cutoff value of 115° was predictive of increased patient satisfaction.[5] The majority of our cohort reached this threshold prior to their first postoperative visit.

Similar statistical methods have been used to identify rapid and slow progressors after other orthopedic procedures. Nguyen et al showed that "fast starters" (those with lower visual analog scale pain scores at 1-week postoperatively) had sustained improvements in outcomes after hip arthroscopy for femoroacetabular impingement syndrome.[12] Using GMM, Hesseling et al investigated recovery trajectories after total hip arthroplasty and similarly found 3 distinct groups based on comorbidities and surgical approach.[6] Our results show that these trajectories may not cross over to the elbow when considering ROM after open débridement.

The limitations of this study include: First, comorbidities and in-depth patient information were not available for our cohort, so there may be other predictors of postoperative ROM that were unable to be detected. Second, radiographs and advanced imaging could not be accessed reliably for OA classification and staging in our cohort.[8] However, it is our opinion that most patients were later-stage, since they presented with functional limitations and pain. Recently, an epidemiologic study identified that 0.9% of people with PEOA are symptomatic with motion pain or elbow tenderness.[11] Third, it has been suggested that ROM alone may be insufficient to sufficiently assess outcome after elbow release.[3] Since our study did not include postoperative patient-reported outcomes scores or strength measurements, our results may represent just one aspect of a patient's overall outcome. Finally, although we had sufficient postoperative observations to employ a latent basis model, it is possible that the true underlying trajectories could have been more accurately assessed with more observations or a larger cohort size, which would have given the model a better chance of demonstrating clearer group differences.

Conclusions

Patients undergoing elbow débridement for PEOA reach their maximum arc of motion at an average of 3 months postoperatively. GMM of motion values revealed no factors or preoperative ROM thresholds that predicted recovery trajectory. Our results have implications in counseling patients and reducing the overall economic burden and healthcare utilization associated with this procedure.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jseint.2022.07.006.

References

1. Baghdadi YMK, Morrey BF, Sanchez-Sotelo J. Anconeus interposition arthroplasty: mid- to long-term results. Clin Orthop 2014;472:2151-61. https://doi.org/10.1007/s11999-014-3629-3.
2. Doornberg JN, Ring D, Jupiter JB. Static progressive splinting for posttraumatic elbow stiffness. J Orthop Trauma 2006;20:400-4. https://doi.org/10.1097/00005131-200607000-00006.
3. Gosling T, Blauth M, Lange T, Richter M, Bastian L, Krettek C. Outcome assessment after arthrolysis of the elbow. Arch Orthop Trauma Surg 2004;124:232-6. https://doi.org/10.1007/s00402-003-0524-x.
4. Gramstad GD, Galatz LM. Management of elbow osteoarthritis. J Bone Joint Surg Am 2006;88:421-30. https://doi.org/10.2106/JBJS.E.00568.
5. Gundes H, Selek Ö, Gok U, Gumuslu B, Buluc L. The relation between elbow range of motion and patient satisfaction after open release of stiff elbow. Acta Orthop Traumatol Turc 2017;51:303-7. https://doi.org/10.1016/j.aott.2017.05.005.
6. Hesseling B, Mathijssen NMC, van Steenbergen LN, Melles M, Vehmeijer SBW, Porsius JT. Fast starters, slow starters, and late dippers: trajectories of patient-reported outcomes after total hip arthroplasty: results from a Dutch nationwide database. J Bone Joint Surg Am 2019;101:2175-86. https://doi.org/10.2106/JBJS.19.00234.
7. de Klerk HH, Welsink CL, Spaans AJ, Verweij LPE, van den Bekerom MPJ. Arthroscopic and open debridement in primary elbow osteoarthritis: a systematic review and meta-analysis. EFORT Open Rev 2020;5:874-82. https://doi.org/10.1302/2058-5241.5.190095.
8. Kwak J-M, Kim H, Sun Y, Kholinne E, Koh KH, Jeon I-H. Arthroscopic osteocapsular arthroplasty for advanced-stage primary osteoarthritis of the elbow using a computed tomography-based classification. J Shoulder Elbow Surg 2020;29:989-95. https://doi.org/10.1016/j.jse.2019.09.036.
9. Lindenhovius ALC, Doornberg JN, Brouwer KM, Jupiter JB, Mudgal CS, Ring D. A prospective randomized controlled trial of dynamic versus static progressive elbow splinting for posttraumatic elbow stiffness. J Bone Joint Surg Am 2012;94:694-700. https://doi.org/10.2106/JBJS.J.01761.
10. Lindenhovius ALC, Doornberg JN, Ring D, Jupiter JB. Health status after open elbow contracture release. J Bone Joint Surg Am 2010;92:2187-95. https://doi.org/10.2106/JBJS.H.01594.

11. Nakayama K, Kato H, Ikegami S, Hayashi M, Hashimoto S, Sakai N, et al. Prevalence and associated factors of primary elbow osteoarthritis in the Japanese general elderly population: a Japanese cohort survey randomly sampled from a basic resident registry. J Shoulder Elbow Surg 2022;31:123-32. https://doi.org/10.1016/j.jse.2021.07.015.
12. Nguyen TQ, Friedman JM, Flores SE, Zhang AL. Fast starters and slow starters after hip arthroscopy for femoroacetabular impingement: correlation of early postoperative pain and 2-year outcomes. Am J Sports Med 2020;48:2903-9. https://doi.org/10.1177/0363546520952406.
13. Poonit K, Zhou X, Zhao B, Sun C, Yao C, Zhang F, et al. Treatment of osteoarthritis of the elbow with open or arthroscopic debridement: a narrative review. BMC Musculoskelet Disord 2018;19:394. https://doi.org/10.1186/s12891-018-2318-x.
14. Ram N, Grimm KJ. Growth mixture modeling: a method for identifying differences in longitudinal change among unobserved groups. Int J Behav Dev 2009;33:565-76. https://doi.org/10.1177/0165025409343765.
15. Stanley D. Prevalence and etiology of symptomatic elbow osteoarthritis. J Shoulder Elbow Surg 1994;3:386-9.
16. Veltman ES, Doornberg JN, Eygendaal D, van den Bekerom MPJ. Static progressive versus dynamic splinting for posttraumatic elbow stiffness: a systematic review of 232 patients. Arch Orthop Trauma Surg 2015;135:613-7. https://doi.org/10.1007/s00402-015-2199-5.
17. Vincent JI, Vandervoort AA, Macdermid JC. A literature synthesis indicates very low quality, but consistent evidence of improvements in function after surgical interventions for primary osteoarthritis of the elbow. Arthritis 2013;2013:487615: https://doi.org/10.1155/2013/487615.
18. Wada T, Isogai S, Ishii S, Yamashita T. Debridement arthroplasty for primary osteoarthritis of the elbow. J Bone Joint Surg Am 2004;86:233-41. https://doi.org/10.2106/00004623-200402000-00004.
19. Welsink CL, Lambers KTA, van Deurzen DFP, Eygendaal D, van den Bekerom MPJ. Total elbow arthroplasty: a systematic review. JBJS Rev 2017;5: e4. https://doi.org/10.2106/JBJS.RVW.16.00089.
20. Wysocki RW, Cohen MS. Primary osteoarthritis and posttraumatic arthritis of the elbow. Hand Clin 2011;27:131-7, v. https://doi.org/10.1016/j.hcl.2011.02.001.