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Intra-articular betamethasone plus medical-grade chitosan for primary adhesive capsulitis: a retrospective real-world pilot cohort with repeated measures

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Abstract

Background

Primary adhesive capsulitis causes persistent shoulder pain, stiffness, and functional limitation. Intra-articular corticosteroid injections provide short-term benefit, but durability varies. Medical-grade chitosan is a bioresorbable viscoelastic biomaterial with anti-inflammatory and lubricating properties; its clinical role in adhesive capsulitis remains unclear.

Methods

We conducted a single-center retrospective observational cohort including adults with primary adhesive capsulitis treated between February 2023 and March 2025 with a three-session, course-based, landmark-guided intra-articular anterior injection regimen of betamethasone plus medical-grade chitosan, combined with usual-care rehabilitation instructed by therapists. The Constant–Murley score (CMS; 0–100) was recorded at baseline and follow-ups (Week 2, 4, 6; and ~ 1, ~3, and ~ 6 months). The primary endpoint was the within-patient change at ~ 6 months; the key secondary endpoint was the change at Week 6. Paired mean changes were summarized with effect sizes (Cohen's dz) and 95% confidence intervals; responder proportions used 95% Wilson confidence intervals. Linear mixed-effects models (LMM) were used as supportive analyses under a missing-at-random assumption.

Results

Twenty-one patients were included (mean age 60.9 ± 10.2 years; range 47–82; 71.4% female). Mean CMS improvement was 39.2 points at Week 6 (n = 16; 95% CI 31.2–46.3) and 49.1 points at ~ 6 months (n = 7; 95% CI 42.9–55.3). LMM estimates versus baseline remained substantial (Week 6: 38.3; 95% CI 33.1–43.5; ~6 months: 43.5; 95% CI 36.4–50.5; all $p < 0.001$). Using a prespecified ≥ 10-point responder threshold, responder rates were 93.8% at Week 6 and 100% at ~ 6 months among paired observations. No injection-related adverse events were recorded in available documentation.

Conclusions

In this exploratory real-world cohort, a course-based intra-articular regimen combining betamethasone with medical-grade chitosan was associated with large improvements in CMS from early time points, with sustained gains observed among patients with available long-term follow-up. Given the retrospective single-arm design and attrition, findings should be interpreted cautiously and warrant prospective controlled validation.

Introduction

Adhesive capsulitis (frozen shoulder) is characterized by progressive shoulder pain with a global loss of glenohumeral motion due to capsular fibrosis and contracture[1, 2]. It commonly affects middle-aged adults (typically 40–60 years old) and has an estimated prevalence of ~ 2–5% in the general population, with women and individuals with metabolic comorbidities at higher risk[1–3]. Diabetes mellitus is among the most reproducible associations; contemporary meta-analytic evidence supports a substantially increased risk of adhesive capsulitis in patients with diabetes compared with non-diabetic controls, and diabetes is also linked to more severe symptoms and slower recovery[4–7]. Beyond pain and motion loss, frozen shoulder meaningfully disrupts sleep, work productivity, and activities of daily living, creating prolonged disability and healthcare utilization[1, 2].Although spontaneous improvement can occur, the clinical course is often prolonged and heterogeneous; many patients experience persistent stiffness or residual functional deficits even years after onset[2, 8, 9].

Non-operative management is the mainstay for frozen shoulder, including analgesics, supervised physical therapy, intra-articular corticosteroid injections, and hydrodilatation[3, 10]. Intra-articular corticosteroid injection is a common first-line intervention and is supported by evidence for short-term pain relief and improved range of motion in the early painful phase (within ~ 6–12 weeks)[11, 12]. However, the benefits of steroid injections tend to wane over time, and by mid- to long-term follow-up their advantage over other conservative treatments may diminish[10, 11]. The optimal injection strategy (e.g. single vs. repeated injections, with or without adjuncts) remains debated[3]. Therefore, there is interest in adjunct intra-articular therapies that could improve the joint milieu and potentially prolong the therapeutic gains from corticosteroids.

Medical-grade chitosan is a biocompatible, bioresorbable polysaccharide derived from chitin, often formulated as an injectable hydrogel. As an intra-articular agent, chitosan has demonstrated anti-inflammatory effects and boundary-lubrication properties in preclinical and clinical studies[13]. Notably, chitosan can act as a drug carrier that prolongs the residence time of co-injected medications in joints[14]. Chitosan-based intra-articular injections have been explored primarily in degenerative joint conditions like knee osteoarthritis. For example, sustained clinical benefit after chitosan viscosupplementation has been reported in controlled studies with follow-up extending to 12 months in OA settings[13, 15]. A separate clinical study also explored course-based intra-articular chitosan approaches in OA contexts[16]. These findings suggest that combining corticosteroids with chitosan could synergistically enhance and extend therapeutic effects in a joint. However, to our knowledge, clinical evidence for chitosan use in adhesive capsulitis is very limited.

Given this background, we hypothesized that a course-based intra-articular regimen combining betamethasone with medical-grade chitosan would be associated with durable improvements in shoulder function in patients with frozen shoulder. We conducted a pilot retrospective cohort study with repeated measures to characterize the 6-month outcomes of this combined injection approach, focusing on within-patient changes in Constant–Murley score (CMS) and the proportion of patients achieving clinically important improvements.

Methods

Study Design and Setting

We performed a single-center retrospective observational cohort study at the Department of Rehabilitation of Yanqing Hospital, Beijing, China. We identified all consecutive patients who received the combined betamethasone–chitosan injection series for primary adhesive capsulitis between February 2023 and March 2025 from institutional records. The requirement for individual informed consent was waived due to the retrospective design, and the study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Participants

Eligible patients were adults (≥ 18 years) diagnosed with primary (idiopathic) adhesive capsulitis of the shoulder. Diagnosis was based on a typical clinical presentation of insidious onset shoulder pain with global restriction of passive range of motion (especially external rotation) and exclusion of other causes (confirmed by imaging as needed). We excluded patients with secondary shoulder stiffness (due to trauma, prior surgery, rotator cuff tear, arthritis, or neurological conditions) and those with incomplete baseline CMS data. Patients who underwent other interventions during the injection series (e.g., manipulation under anesthesia, formal image-guided hydrodilatation/capsular distension performed as a separate procedure, or additional intra-articular injections such as hyaluronic acid) were excluded.

Intervention (Injection Protocol)

All patients received a course of three intra-articular glenohumeral injections administered via an anterior approach using anatomical landmarks (landmark-guided, without imaging). Injections were delivered at baseline (Week 0) and approximately 2-week intervals thereafter (around Week 2 and Week 4), with the patient in a supine or seated position and the needle inserted just inferior to the coracoid process toward the joint space. Each injection consisted of a mixture of compound betamethasone and medical-grade chitosan, combined with diluent and local anesthetic. Specifically, the injectate at each session included 2% lidocaine hydrochloride 2.5 mL (50 mg), 0.9% saline 5 mL, compound betamethasone 1 mL (betamethasone dipropionate 5 mg + betamethasone sodium phosphate 2 mg; ~7 mg total), and medical-grade chitosan solution 2 mL, for a total volume of ~ 10.5 mL. The chitosan used was a sterile, injectable-grade formulation intended to act as a viscoelastic synovial supplement and drug carrier within the joint. All components were mixed immediately prior to injection under aseptic conditions. Proper intra-articular placement was confirmed by anatomical landmarks and negative aspiration (to avoid intravascular injection), and the solution was injected slowly. The predefined injectate volume (≈ 10 mL) was selected to achieve controlled capsular distension without deliberately inducing capsular rupture. This volume is supported by a recent randomized trial suggesting comparable clinical improvements between 10-mL and 20-mL hydrodilatation protocols in adhesive capsulitis[17]. After each injection, patients were observed briefly for any acute reactions and instructed to rest the shoulder for 24–48 hours, apply ice for pain as needed, and then resume a guided home exercise

program. All patients followed a rehabilitation regimen supervised by physical therapists, focusing on pain-free pendulum exercises, gentle active range-of-motion, and gradual stretching within tolerance, avoiding excessive pain provocation in the early phase. Standard oral analgesics (e.g. NSAIDs or acetaminophen) were permitted as needed. No additional intra-articular steroid injections or distension procedures were allowed during the treatment course.

Outcome Measures and Follow-up: The primary outcome was the Constant–Murley Score (CMS), a 100-point composite shoulder score (higher scores = better function) that includes pain, activities of daily living, range of motion, and strength components. CMS was measured at baseline (pre-injection) and at serial follow-up time points: 2 weeks after the first injection (Week 2), 2 weeks after the second injection (Week 4), 2 weeks after the third injection (Week 6), and approximately 1 month, 3 months, and 6 months after the third injection. These time points correspond to immediate post-series follow-ups and longer-term follow-up visits. The primary endpoint was defined as the change in CMS from baseline to 6 months. The key secondary endpoint was the change in CMS from baseline to Week 6 (approximately the end of the injection series). Safety was assessed by retrospective review of routine clinical documentation for any injection-related adverse events or complications recorded during the injection course and follow-up.

Responder Definitions

We defined a priori a clinically important improvement on the CMS as a change (Δ) of ≥ 10 points from baseline, based on a conservative anchor-based MCID value commonly cited in shoulder outcome studies. Patients achieving ΔCMS ≥ 10 were considered “responders,” and those achieving ΔCMS ≥ 20 were considered “high responders,” reflecting a more robust improvement.

These thresholds were chosen in line with minimal clinically important difference concepts (approximately 0.5 standard deviation of baseline CMS, a distribution-based benchmark). For interpretability, we report responder rates using a prespecified improvement threshold on the Constant–Murley Score (CMS). The concept of the minimal clinically important difference (MCID) refers to the smallest change that patients perceive as beneficial and that would justify a change in clinical management[18]. Because published MCID/MID estimates vary across shoulder conditions and populations, responder thresholds in this pilot single-arm cohort are presented as descriptive, hypothesis-generating benchmarks rather than definitive clinical cut-offs.

Statistical Analysis

We summarized baseline characteristics and outcomes using descriptive statistics. Continuous variables are reported as mean ± standard deviation (SD) or median with interquartile range (IQR) if not normally distributed. Categorical variables are reported as counts and percentages. Within- patient changes in CMS from baseline at each follow-up time point were calculated for patients with available paired data. We computed the mean change (Δ) with 95% confidence interval (CI) at each time point. Effect sizes for paired changes were estimated with Cohen’s *dz* (mean change divided by the SD of the

change scores). Statistical significance of improvement at each time point was assessed with the non-parametric Wilcoxon signed-rank test (comparing the follow-up CMS to baseline), using a Holm–Bonferroni correction to adjust for multiple time points. In addition, to account for missing follow-up data over time, we fitted a linear mixed-effects model (LMM) with patient-specific random intercepts and a fixed effect for time, treating time as a categorical factor. The LMM provides an estimate of the mean change from baseline at each time point, under the assumption that data are missing at random (MAR). This approach allows inclusion of all available data points for each patient. Given the modest sample size and progressive loss to follow-up, all inferential analyses were considered exploratory. We did not impute missing data. Responder rates (proportions of patients meeting the ≥ 10 or ≥ 20 improvement thresholds) at key time points were calculated with Wilson score 95% confidence intervals (appropriate for binomial proportions in small samples). All analyses were performed using R (v4.2.0) and statistical significance was interpreted at the 0.05 level (two-tailed).

Results

Participant Characteristics:

A total of 21 patients met the inclusion criteria and were included in the cohort (Table 1). The mean age was 60.9 ± 10.2 years (range 47–82), and most patients were female (15/21, 71.4%). The median symptom duration before treatment was 6.0 months (IQR 4.0–11.0; range 2–24). The affected side was right in 13 patients (61.9%), left in 7 (33.3%), and bilateral in 1 (4.8%). Hypertension was documented in 8 patients (38.1%) and diabetes mellitus/abnormal glucose in 5 (23.8%). Prior conservative management was documented in 13 patients (61.9%). Baseline Constant–Murley score showed a wide distribution (mean 47.6 ± 14.6; median 45.0 [IQR 41.0–53.0]; range 14–89), indicating substantial functional impairment overall.

Table 1
Baseline characteristics of the cohort (n = 21)

Characteristic	Value
Age, years	60.9 ± 10.2; range 47–82
Female, n (%)	15/21 (71.4%)
Affected side, n (%)	Right 13/21 (61.9%); Left 7/21 (33.3%); Bilateral 1/21 (4.8%)
Symptom duration, months	median 6.0 (4.0–11.0); range 2.0–24.0
Hypertension, n (%)	8/21 (38.1%)
Diabetes/abnormal glucose, n (%)	5/21 (23.8%)
Prior conservative management documented, n (%)	13/21 (61.9%)
Baseline Constant–Murley score (CMS)	47.6 ± 14.6; median 45.0 (41.0–53.0); range 14–89
Notes: Data are presented as mean ± SD, median (IQR), or n/N (%), as appropriate.	

Injection Completion and Follow-up:

All 21 patients completed the planned three-injection series according to treatment records. Follow-up data availability declined over time: all 21 patients had outcome assessments through the first two post-injection visits (Week 2 and Week 4), 16/21 (76.2%) returned at Week 6 (two weeks after the third injection), 11/21 (52.4%) had data at ~ 1 month, 9/21 (42.9%) at ~ 3 months, and 7/21 (33.3%) completed the ~ 6-month follow-up. Baseline characteristics (age, sex, baseline CMS, and symptom duration) were broadly similar between patients with and without 6-month follow-up; however, given the small sample size, these comparisons were underpowered and attrition bias cannot be excluded. Reasons for missed later follow-up visits were not systematically documented in the medical records.

Primary and Secondary Outcomes:

Figure 1 shows individual CMS trajectories over time. Mean within-patient changes in CMS from baseline at each time point are summarized in Table 2 and visualized in Fig. 3. Improvements were apparent by Week 2 (mean Δ + 15.2; 95% CI 11.2–19.0; n = 21; Δ range 0–30) and increased through Week 6 at the end of the injection series (mean Δ + 39.2; 95% CI 31.2–46.3; n = 16), corresponding to a very large paired effect size (dz = 2.42). Among the 7 patients with ~ 6-month follow-up, the mean change from baseline was + 49.1 points (95% CI 42.6–55.6; dz = 5.47). After Holm adjustment for multiplicity across time points, Wilcoxon signed-rank tests remained statistically significant at all assessed visits (Holm-adjusted p-values ranged from < 0.001 to 0.022; Table 2). Figure 2 presents a Gardner–Altman estimation plot of the paired CMS change from baseline to Week 6.

Table 2
Time-course of within-patient changes in Constant–Murley score (CMS) from baseline

Timepoint	n (paired)	Mean ΔCMS	95% CI	Cohen's dz	Wilcoxon p (Holm)	Responder ≥ 10, % (95% CI)	Responder ≥ 20, % (95% CI)
Week 2 (after injection 1)	21.0	15.2	11.2–19.0	1.7	0.001	71.4 (50.0–86.2)	38.1 (20.8–59.1)
Week 4 (after injection 2)	21.0	28.2	22.4–33.6	2.1	< 0.001	90.5 (71.1–97.3)	81.0 (60.0–92.3)
Week 6 (after injection 3)	16.0	39.2	31.2–46.3	2.5	0.003	93.8 (71.7–98.9)	93.8 (71.7–98.9)
Month 1 (post-series)	11.0	42.9	36.0–49.9	3.5	0.011	100 (74.1–100)	100 (74.1–100)
Month 3 (post-series)	9.0	44.8	37.2–51.8	3.8	0.018	100 (70.1–100)	100 (70.1–100)
Month 6 (post-series)	7.0	49.1	42.9–55.3	5.5	0.022	100 (64.6–100)	100 (64.6–100)

Notes: ΔCMS = follow-up CMS − baseline CMS. 95% CIs for mean ΔCMS were obtained using nonparametric bootstrap resampling of paired change scores (5,000 resamples; percentile method). Cohen's dz = mean change / SD(change). Wilcoxon signed-rank tests used normal approximation with continuity correction; Holm adjustment across time points. Responder thresholds: ≥10 points (MCID) and ≥ 20 points; Wilson 95% CIs for proportions.

Mixed-Effects Model Analysis:

A linear mixed-effects model (random intercept for patient; time treated as a categorical fixed effect with baseline as the reference) was fitted to incorporate all available observations and to accommodate incomplete follow-up under a missing-at-random (MAR) assumption. The model-based mean change in CMS from baseline was estimated as + 15.2 at Week 2, + 28.2 at Week 4, + 38.3 at Week 6, + 40.2 at ~ 1 month, + 41.6 at ~ 3 months, and + 43.5 at ~ 6 months (Table 3). Improvements versus baseline were statistically significant at each time point in the model (all $p < 0.001$). Overall, these model-based estimates were broadly consistent with the paired-change analyses, although—as expected—the later follow-up estimates were modestly attenuated relative to completer-only means. The trajectory suggested that the largest gains occurred by Week 6, followed by a plateau thereafter; exploratory post-hoc contrasts among the 1-, 3-, and 6-month estimates did not identify clear additional gains. No convincing evidence of time-by-subgroup interaction was detected for prespecified baseline factors (e.g., age dichotomized at the median, sex, symptom duration ≥ 6 vs < 6 months, or diabetes status), but these analyses were underpowered and should be interpreted cautiously.

Table 3
Linear mixed-effects model (LMM) estimated mean change in CMS from baseline

Timepoint	n (observed)	Mean change vs baseline (LMM)	95% CI	p-value
Week2	21	15.2	10.5 to 20.0	< 0.001
Week4	21	28.2	23.5 to 33.0	< 0.001
Week6	16	38.3	33.1 to 43.5	< 0.001
Month1	11	40.2	34.3 to 46.1	< 0.001
Month3	9	41.6	35.2 to 47.9	< 0.001
Month6	7	43.5	36.4 to 50.5	< 0.001
Model: CMS ~ time (categorical; baseline reference) with patient random intercept; REML estimation. 95% CIs are Wald-type (estimate ± 1.96×SE). p-values are two-sided z-tests (exploratory).				

Responder Analysis:

Responder trajectories are shown in Fig. 4. Using the prespecified ≥ 10-point threshold, 15/21 patients (71.4%) met the responder criterion by Week 2, increasing to 19/21 (90.5%) at Week 4 and 15/16 (93.8%) at Week 6. Using the ≥ 20-point threshold, 8/21 (38.1%) met the criterion at Week 2, 17/21 (81.0%) at Week 4, and 15/16 (93.8%) at Week 6. At later follow-up visits, all evaluated patients maintained at least a 10-point gain (and all met the ≥ 20-point threshold), noting the progressively smaller denominators and wider confidence intervals (Table 2).

Safety:

No injection-related adverse events were documented in the available medical records during the injection course or follow-up. No cases of septic arthritis, allergic reactions, or other clinically significant complications were recorded.

Discussion

In this real-world pilot cohort of patients with primary adhesive capsulitis, a course of three intra-articular injections combining betamethasone with medical-grade chitosan—delivered alongside usual-care rehabilitation—was associated with rapid and substantial improvements in CMS. Improvements were apparent early, increased through the end of the injection series (Week 6), and were sustained among patients with longer-term follow-up. The magnitude of change (approximately 40–50 CMS points in paired analyses) is large relative to many musculoskeletal interventions, and responder rates based on conservative thresholds (ΔCMS ≥ 10) were high. These findings provide an initial clinical signal that an adjunct biomaterial approach may merit prospective validation, while also underscoring the need for careful interpretation given the uncontrolled design and attrition[19]. Context within existing evidence

and the “durability gap.” Our trajectory—marked early improvement followed by a plateau—aligns with a well-described pattern for intra-articular corticosteroids in frozen shoulder: strong early benefits, with diminishing between-group separation at later follow-up in controlled comparisons[11]. Network meta-analytic evidence indicates that corticosteroid injection is among the more consistently effective short-term options for pain and disability, but that relative advantages often shrink by mid-term horizons where rehabilitation and natural recovery play increasing roles[20]. Contemporary comparative analyses also highlight ongoing uncertainty regarding the best injection regimen (dose, timing, and repetition) and which adjuncts genuinely extend benefit[10]. In that context, the rationale for pairing steroids with chitosan is not to replace the steroid’s rapid anti-inflammatory effect, but to address the “durability gap”—the common clinical problem in which initial relief fades before full functional restoration[11]. Although cross-study comparisons must be cautious, the apparent maintenance of large gains at 3–6 months in those observed is directionally consistent with the hypothesis that chitosan may prolong intra-articular therapeutic effects. Importantly, a durability claim cannot be made definitively here because our study lacks a steroid-only comparator and because attrition was substantial. Nonetheless, the mixed-effects estimates, which use all available data under a missing-at-random assumption, suggested persistent improvements across time points. Given the real-world setting, this hypothesis is clinically relevant: in routine practice, patients often receive rehabilitation concurrently, and interventions that sustain early improvements may facilitate adherence to stretching and strengthening progressions, potentially accelerating the recovery arc[21]. Biological plausibility of adding medical-grade chitosan. Frozen shoulder involves synovial inflammation and capsular fibroproliferation, with pain and stiffness reinforcing protective disuse and perpetuating functional limitation[22]. Medical-grade chitosan offers mechanistically plausible contributions in this setting. First, as a biomaterial, chitosan and its derivatives have been discussed as candidates for joint “environment modulation,” including scaffold/hydrogel design for cartilage repair, viscosupplementation concepts, and local sustained delivery[23]. Second, intra-articular delivery platforms (notably hydrogel-based systems) have been extensively studied to extend local residence time and enable sustained release of co-delivered therapeutics—conceptually aligned with the goal of extending steroid exposure without increasing systemic burden[24]. Third, tribology-oriented work demonstrates that bioinspired mucoadhesive chitosan-based polymers can restore lubrication on degraded cartilage surfaces and reduce friction, providing a plausible mechanistic bridge for symptom modulation in an inflamed joint environment[25]. While osteoarthritis and adhesive capsulitis are distinct entities (cartilage degeneration vs capsule/synovium-driven fibrosis), the “joint environment modulation” concept—improving lubrication and sustaining anti-inflammatory exposure—provides a coherent translational bridge that justifies controlled testing in frozen shoulder[23].

Clinical interpretability of the magnitude of change. CMS is a composite measure spanning pain, daily activities, range of motion, and strength. Very large gains can occur when early pain relief enables rapid restoration of motion and permits more valid strength testing, which may partly explain the steep early improvement observed. For interpretability, we anchored response using conservative ΔCMS thresholds (≥ 10 and ≥ 20), consistent with published approaches to MCID and responsiveness for shoulder instruments[26]. The high responder rates therefore suggest not only statistical improvement but also

clinically meaningful change likely perceptible to patients[27]. That said, pilot cohorts can overestimate effect sizes due to small samples, regression to the mean, and selection effects; thus, the magnitude should be viewed as hypothesis-generating[19].

Limitations and threats to inference. Several limitations meaningfully constrain causal interpretation. First, the retrospective single-arm design precludes separating the effects of the injection contents from rehabilitation, natural history, expectation effects, and regression to the mean[19]. While rapid early gains are less consistent with untreated natural history, improvement over months can occur even without injections, and many patients improve substantially with structured therapy alone[21]. Second, follow-up attrition was substantial, creating vulnerability to missing-not-at-random mechanisms. Third, treatment fidelity elements—such as exact chitosan formulation parameters (molecular weight, degree of deacetylation), rehabilitation adherence, and standardized ROM goniometry—were not fully controlled[23]. Fourth, the injection technique was landmark-guided; although pragmatic, misplacement can occur, and image guidance may improve delivery consistency in some settings[28]. Finally, the small sample size limited subgroup inference and the precision of safety estimates; rare adverse events cannot be excluded.

Implications for future research and practice. The most direct next step is a prospective controlled trial comparing betamethasone + chitosan versus betamethasone alone, with a standardized rehabilitation protocol and prespecified follow-up at 6 weeks, 3 months, 6 months, and ideally 12 months. Outcomes should include patient-reported pain/disability (e.g., SPADI or DASH), goniometric ROM, and CMS to enable cross-study comparison. Given the “durability gap,” the trial should be powered for mid-term outcomes (3–6 months) rather than only early endpoints. Comparator choices could also reflect evolving practice syntheses (e.g., injectables and adjunct procedures evaluated in comparative meta-analyses)[11]. From a pragmatic perspective, if future controlled studies confirm added durability without safety tradeoffs, combining a steroid with a medical-grade biomaterial carrier could represent a scalable, minimally invasive strategy to accelerate functional recovery and reduce prolonged disability in frozen shoulder[24].

Conclusions

In this retrospective real-world pilot cohort, a course-based intra-articular regimen combining betamethasone with medical-grade chitosan, integrated with usual-care rehabilitation, was associated with rapid and large improvements in CMS from early time points, with sustained gains observed among patients with longer-term follow-up. Given the uncontrolled design and attrition, results are hypothesis-generating and warrant prospective controlled validation focused on mid-term durability and safety.

Declarations

Consent to participate

All patients provided written informed consent prior to the intra-articular injection treatment. Additional consent for participation in this retrospective analysis was waived by the ethics committee.

Consent for publication

Not applicable. This manuscript contains no identifiable individual participant data.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

JD and HW conceived and designed the study. JD performed the intra-articular injection procedures and supervised the usual-care rehabilitation protocol. XL, YL, XG, and LZ contributed to clinical assessments (including CMS scoring), data collection, and verification of source records. JD performed the statistical analyses and prepared the figures and tables. JD drafted the manuscript. All authors contributed to data interpretation, critically revised the manuscript for important intellectual content, and approved the final version.

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Data Availability

The de-identified dataset generated and analyzed during the current study is available from the corresponding author upon reasonable request for academic purposes.

Human Ethics

This retrospective study was reviewed by the Ethics Committee of Yanqing Hospital of Beijing Chinese Medicine Hospital and granted an exemption/waiver. No reference number is assigned for exempt retrospective analyses at our institution.

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Figures

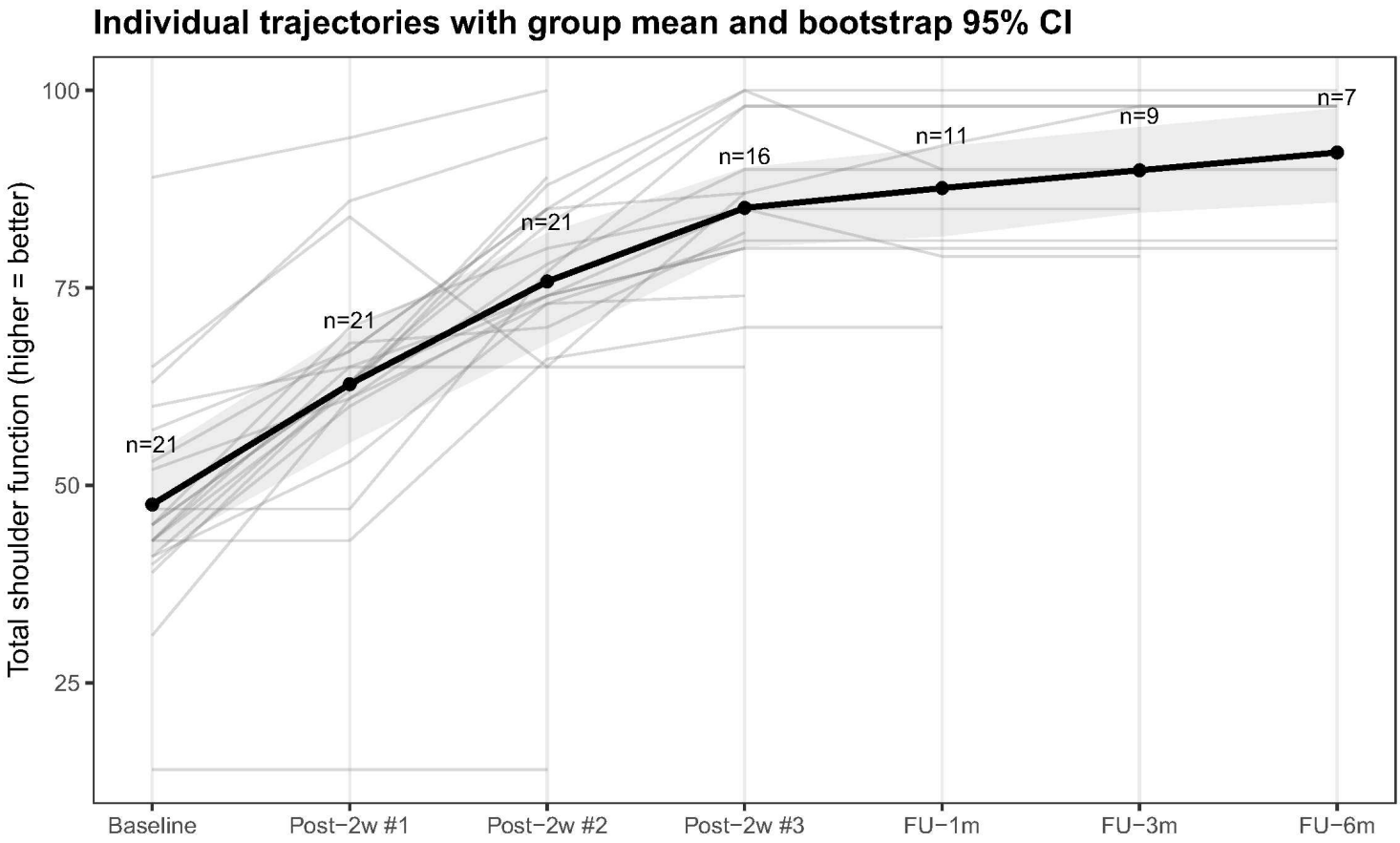


Figure 1

Individual Constant–Murley score (CMS, 0–100) trajectories across time points; the bold line shows the mean with 95% bootstrap CI and n at each visit.

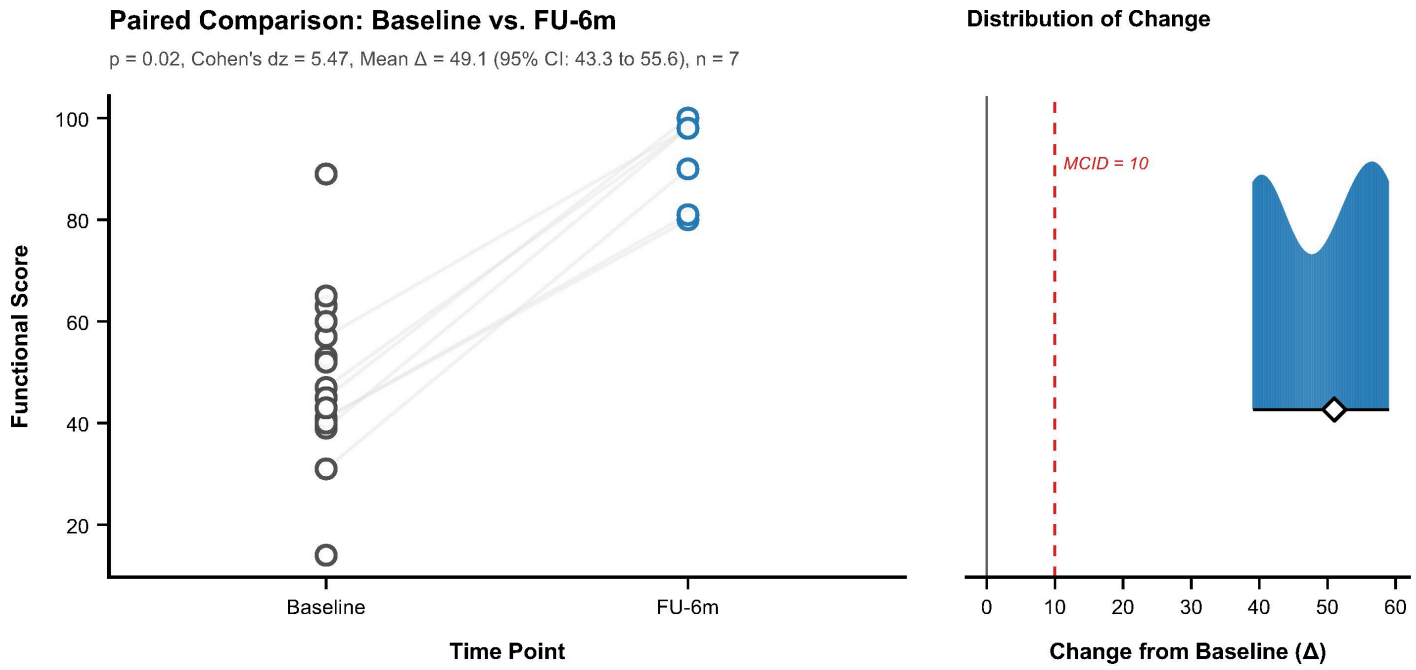


Figure 2

Gardner–Altman estimation plot for paired CMS (baseline vs ~6 months; n=7) showing the mean paired difference with 95% bootstrap CI.

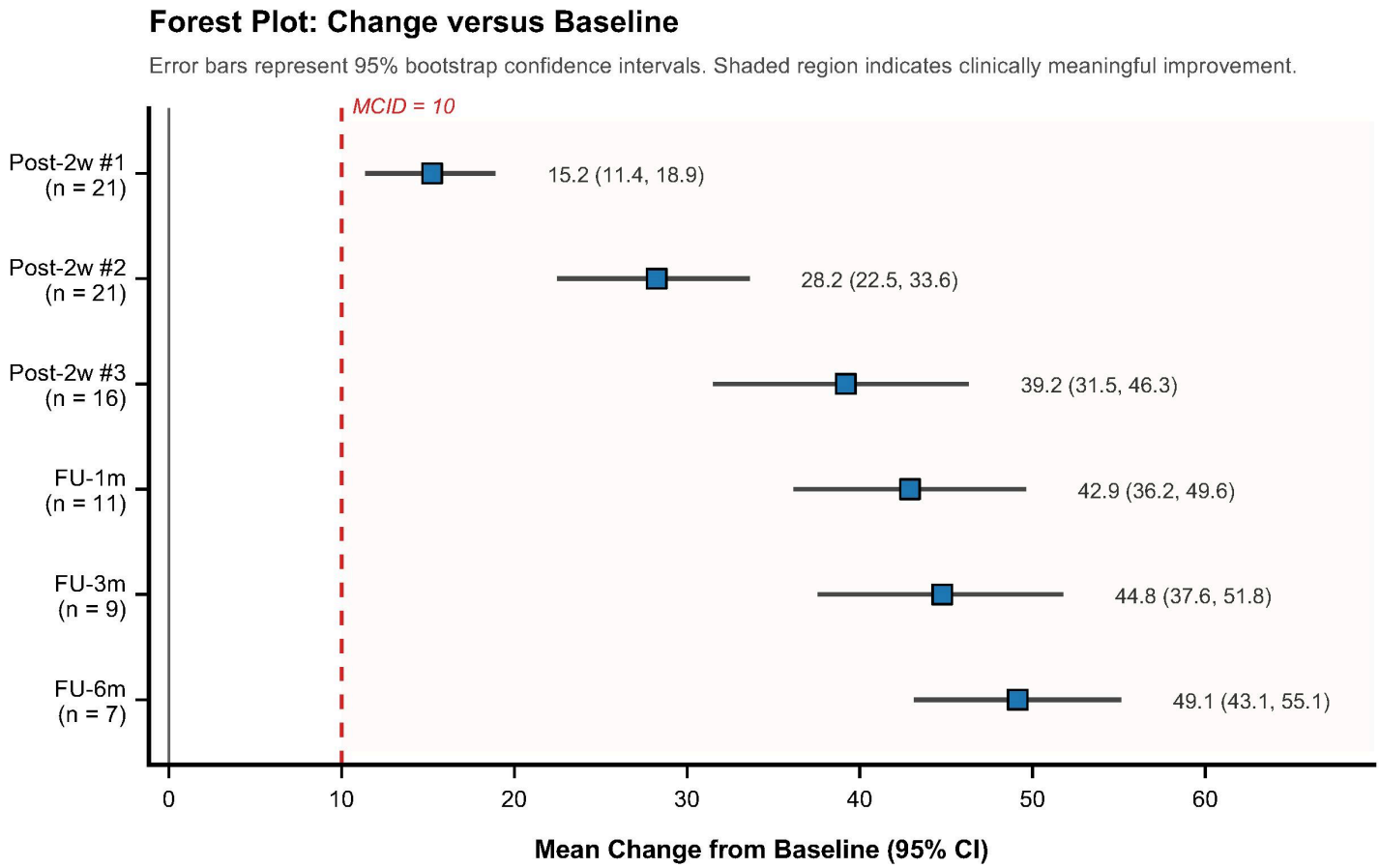


Figure 3

Forest plot of mean within-patient ΔCMS from baseline at each follow-up with 95% bootstrap CIs; dashed line indicates ΔCMS = 10.

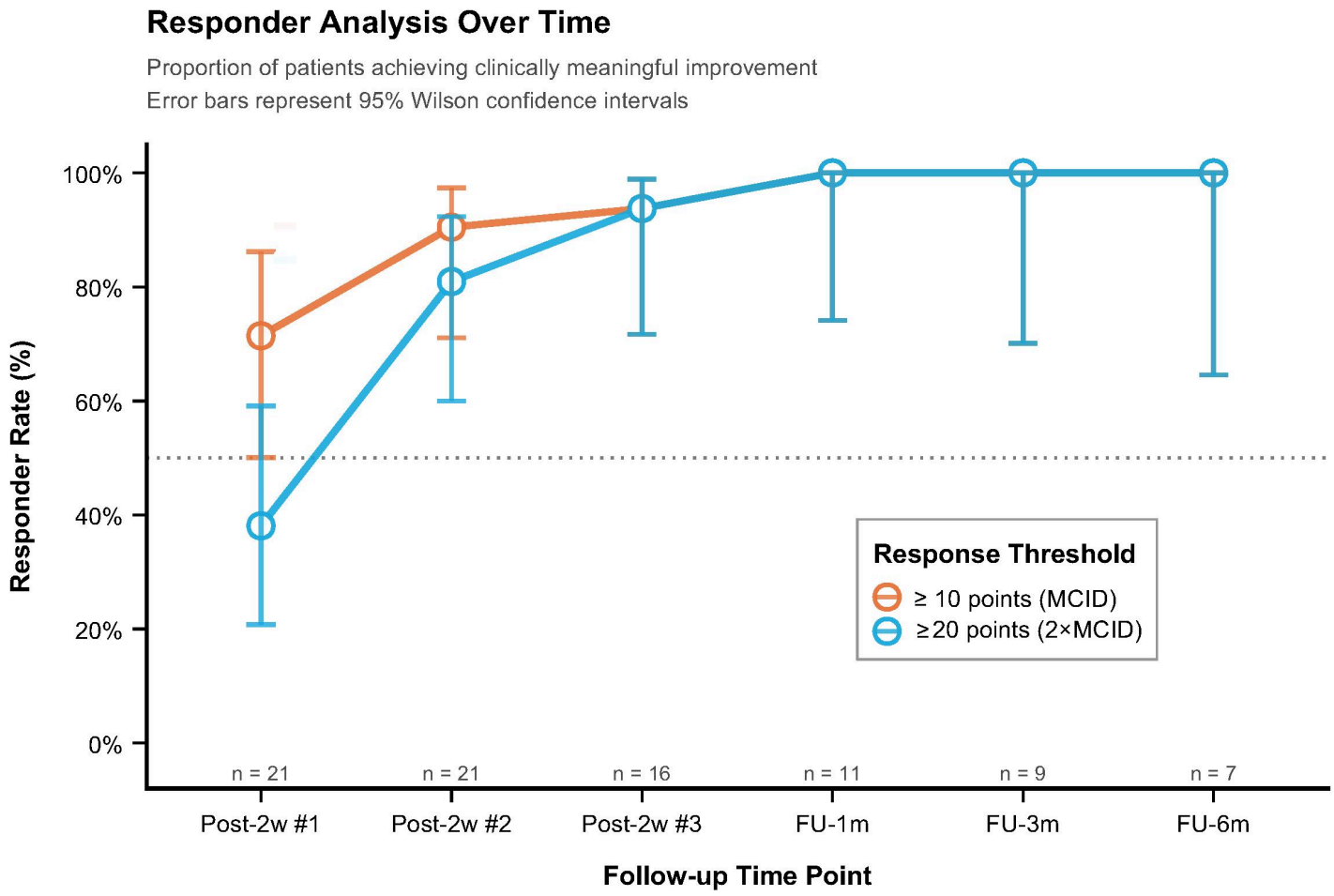


Figure 4

Responder rates over time for ΔCMS ≥10 and ≥20 with 95% Wilson CIs and denominators shown per time point.

Supplementary Files

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