RESEARCH PAPER

Comparison Between Ultrasound Guided Ozone, Platelet-Rich Plasma or Steroid Injection in the Treatment of Sacroiliitis: A Randomized Double Blinded Controlled Study

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ABSTRACT

Background and Aims:

Sacroiliac joint (SIJ) pain is a common cause of chronic low back pain, and comparative evidence regarding corticosteroid, platelet-rich plasma (PRP), and ozone injections remains limited. This study aimed to compare the efficacy of ultrasound-guided corticosteroid, PRP, and ozone injections in patients with chronic SIJ pain.

Methods:

This prospective, randomised, assessor-blinded, three-arm trial enrolled 105 patients with chronic SIJ pain, randomised equally to receive a single ultrasound-guided corticosteroid injection, three PRP injections, or three ozone injections. Pain and functional disability were assessed using the Visual Analogue Scale (VAS) and Modified Oswestry Disability Questionnaire (MODQ) over 12 months, with statistical significance set at $P < 0.05$.

Results:

All groups improved from baseline. At the predefined 6-month primary endpoint, median VAS score was 6 (interquartile range [IQR] 5.5–7) with corticosteroid, 3 (IQR 2–3) with PRP, and 2 (IQR 2–3.5) with ozone ($P < 0.001$), with PRP and ozone superior to corticosteroid and no significant difference between them. By 12 months, median VAS score was 8 (IQR 8–9) with corticosteroid, 5 (IQR 5–5.5) with PRP, and 8 (IQR 8–9) with ozone, indicating symptom recurrence with corticosteroid and ozone but sustained benefit with PRP.

Conclusion:

Ultrasound-guided PRP and ozone injections provided greater and more sustained pain relief than corticosteroid, with PRP demonstrating the most durable benefit at 12 months.

Keywords: Glucocorticoids, ozone, platelet-rich plasma, sacroiliac joint, ultrasonography

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Introduction

Sacroiliac joint (SIJ) dysfunction accounts for 10–25% of chronic low back pain and may arise from degenerative or inflammatory changes in the joint and surrounding ligaments.[(1)] Management is multimodal, including medications, physiotherapy, and image-guided injections.[(2)] Corticosteroid injections give temporary relief, while platelet-rich plasma (PRP) and ozone may offer longer-lasting regenerative effects.[(3, 4)] Comparative evidence is still limited. This study aimed to compare ultrasound-guided corticosteroid, PRP, and ozone injections in reducing pain (VAS) and improving

functional ability (MODQ) in patients with chronic SIJ pain over a 12-month period.

Methods

This prospective, randomised, assessor-blinded, three-arm study was conducted at pain unit of Anesthesiology, Surgical Intensive Care and Pain Management department in Tanta University Hospitals and included 105 patients with SIJ pain over 18 months (April 2023–September 2024). Ethics approval was obtained (36264MD46/3/23, 7 March 2023) and the trial registered (NCT05914350, 23 June 2023). The protocol conformed to the 2013 Declaration of Helsinki and Good Clinical Practice; written informed consent was obtained.

Patients aged 21–65 years with chronic SIJ pain refractory to ≥6 weeks of conservative therapy were included. Diagnosis required buttock/lower back pain with ≥3 positive provocative SIJ tests (Gaenslen, FABER [Flexion, Abduction, and External Rotation], thigh thrust, distraction, sacral thrust, active straight leg raise) and baseline visual analogue scale (VAS) score ≥4/10.[5] Diagnosis was confirmed by an ultrasound-guided diagnostic SIJ block with 1–2 mL of 1% lidocaine; only patients with ≥50% pain relief were randomised. Patients with inadequate relief were considered to have alternative pain sources and were excluded.

Plain radiography was performed in all patients; Magnetic resonance imaging was used when inflammatory or alternative pathology was suspected, and computed tomography (CT) for detailed osseous assessment, mainly to exclude alternatives. Patients with lumbar disc pathology, significant lumbar degenerative disease, prior spine surgery, or other lumbosacral/pelvic disorders were excluded.

Baseline outcomes were assessed 48 hours after the diagnostic block, after the anaesthetic effect had resolved and before the first therapeutic injection.

Further exclusions included injection-site infection, coagulopathy, pregnancy, spondyloarthritis or other autoimmune disease, psychiatric illness, chronic opioid use, allergy to study agents, corticosteroid injection within 3 months, bilateral symptoms, prior spine surgery, or uncontrolled systemic disease. Inflammatory features were screened with erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) testing where indicated to exclude spondyloarthritis.

Before enrolment, complete blood count, prothrombin time/international normalised ratio(INR), and activated partial thromboplastin time(aPTT) were checked. Eligibility required a platelet count ≥150 × 10^9/L, normal INR/aPTT, and no anticoagulant or antiplatelet therapy. Baseline and final PRP platelet counts were recorded to calculate the platelet-fold increase.

Randomisation used a computer-generated sequence (1:1:1) with sequentially numbered, sealed opaque envelopes, generated by an investigator not involved in recruitment. Group I received a single ultrasound-guided injection of 40 mg methylprednisolone acetate with 1 mL lidocaine 2% in 1st week, followed by sham injections in 2nd and 3rd weeks. Group II received 3 mL platelet-rich plasma and 1 mL lidocaine once weekly for 3 injections. Group III received 10 mL ozone (20 µg/mL) once weekly for 3 injections under ultrasound guidance within a controlled research setting approved by the institutional ethics committee.[6] Ozone therapy, though not universally approved for routine clinical use, is investigated in musculoskeletal pain and used clinically in several countries, particularly in Europe; its use here was strictly for research purposes, with participants fully informed of its investigational nature.

Participant blinding was not feasible due to differences between interventions; however, outcome assessors, data collectors, and statisticians were blinded. The corticosteroid group received sham injections of subcutaneous 1 mL sterile normal saline with simulated ultrasound pressure during weeks 2 and 3 to maintain comparable schedules. A 5 mL blood sample was also taken from the corticosteroid and ozone groups to minimise procedural differences related to PRP preparation, not to achieve blinding.[7]

All injections were performed using ultrasound by a single experienced pain physician using a standardised posterior SIJ approach, targeting SIJ which is a hypoechoic cleft between sacrum and ilium (Figure 1A). As ultrasound cannot reliably confirm intra-articular placement, the technique targeted the posterior joint/peri-articular region; injectate dispersion was confirmed with colour Doppler aliasing (Figure 1A).

Medical ozone (20 µg/mL) was generated immediately before injection using a certified ozone generator with a characteristic pungent odour (Figure 1B).

PRP was prepared using a standardised manual double-spin centrifugation, without a proprietary commercial kit (Figure 1C). Non-steroidal anti-

inflammatory drugs (NSAIDs) were avoided for 1–2 weeks before the procedure to preserve platelet function. Thirty millilitres of venous blood was collected in anticoagulant tubes and centrifuged using a Centurion Scientific PrO-Hospital GP6 centrifuge equipped with a BRK5412 fixed-angle rotor, at 1200 revolutions per minute (rpm; ≈153 × g , where g is the relative centrifugal force) for 15 minutes (soft spin) to separate plasma/buffy coat from red cells, then at 2700 rpm (≈772 × g) for 5 minutes (hard spin).[8] Platelet-poor supernatant was discarded, yielding ~3 mL of PRP enriched approximately 2–3-fold over baseline platelet count, confirmed by platelet counts (Figure 1D). Platelets were activated with calcium chloride (0.1 mL per 0.9 mL PRP) immediately before injection under sterile conditions.

Patients were observed for 30 minutes after the injection for any immediate complications. They rested 48 hours, then resumed normal activity and physiotherapy (stretching, mobility, trunk/hip/gluteal strengthening) as tolerated. Rescue medications (acetaminophen up to 1 g every 8 hours and cyclobenzaprine up to 5 mg every 12 hours) were permitted and recorded at each visit; no other analgesics were routinely prescribed.

The primary outcome was pain intensity (VAS), while the secondary outcome was functional disability (Modified Oswestry Disability Questionnaire, MODQ).[9, 10] Therapeutic injection was performed 48 hours after diagnostic block. Assessments occurred at baseline, immediately post-injection, every 3 weeks to 3 months, and every 3 months thereafter to 12 months. Based on Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials (IMMPACT) recommendations, clinically meaningful improvement was defined as ≥50% VAS reduction, ≥2-point absolute VAS reduction, and/or ≥15-point MODQ improvement.[11]

Adverse events (nausea, headache, injection-site bruising, numbness, paraesthesia) were recorded at all visits if they occurred.

VAS at 6 months was predefined as the primary endpoint for between-group comparisons; other timepoints were secondary. Follow-up data were collected during clinic visits or by telephone.

Sample size was based on 6-month VAS. Pilot data from 30 patients (10/group) showed mean±SD VAS of 3.0±1.3 in PRP, 3.4±1.4 in ozone, and 4.2±1.7 in corticosteroid, corresponding to Cohen's f=0.335. With three equal groups, alpha 0.05, and 80% power, 90 patients (30/group) were required. A 15% increase for deviations/non-parametric methods gave a final sample of 105 patients (35/group).

Data was analysed using Statistical Package for the Social Sciences (SPSS) version 25. Normality was assessed with the Shapiro–Wilk test; as repeated outcome data were not normally distributed, non-parametric methods were used. Continuous variables are presented as mean (SD) or median (interquartile range), categorical variables as number (%). Between-group comparisons used one-way ANOVA or Kruskal–Wallis tests followed by Dunn's post hoc test with Bonferroni correction; repeated measures used Friedman's ANOVA, and categorical data used Chi-square or Monte Carlo exact tests. Significance was set at $P < 0.05$, with 95% confidence interval (CI) reported for key outcomes. No outcome data were missing; all 105 patients completed 12-month follow-up.

Results:

Of 131 patients assessed, 26 were excluded (9 declined, 17 ineligible); 105 were randomised equally (35 each) and all completed follow-up, included in intention-to-treat analysis. (Figure 2).

Baseline demographic and clinical characteristics including age, gender, weight, height, BMI, American Society of Anesthesiologists (ASA) physical status, VAS, MODQ were comparable across groups (all $P > 0.05$) (Tables 1–3).

VAS did not differ at baseline (Kruskal–Wallis H(2)=1.717, $P = 0.424$). Between-group comparisons showed significant differences immediately post-injection and at 3, 6, 9, and 12 weeks (all $P < 0.001$): corticosteroid and ozone gave lower VAS score than PRP, with no difference between corticosteroid and ozone. At 6 months, the predefined primary endpoint, both PRP and ozone had significantly lower VAS score than corticosteroid (H(2)=70.761, $P < 0.001$), with no PRP–ozone difference. At 9 and 12 months, sustained relief was seen mainly with PRP, while corticosteroid and ozone trended back toward baseline (Table 2).

MODQ scores were comparable at baseline (Kruskal–Wallis H(2)=1.112, $P = 0.574$). Between-group comparisons showed greater functional improvement with corticosteroid and ozone than PRP immediately post-injection and at 3 weeks, with no difference between them; differences were not significant by 6 weeks ($P = 0.484$). At 9 weeks, ozone outperformed both the others ($P < 0.001$); at 12 weeks, ozone remained best, with corticosteroid

also better than PRP (*P1* = 0.034). At 6 months, ozone had the lowest MODQ score, followed by PRP, while corticosteroid worsened toward baseline (H(2)=78.985, $P < 0.001$). At 9–12 months, sustained improvement was mainly maintained by PRP (Table 3).

Clinically meaningful improvement analysis supported these findings (Table 4). At 3 and 6 weeks, meaningful VAS improvement was more frequent with corticosteroid and ozone than PRP; by 9–12 weeks, most patients across all groups achieved meaningful relief. For MODQ, ozone showed the highest response rates at 9 and 12 weeks. At 6 months, all PRP patients and most ozone patients achieved ≥50% VAS reduction, versus none in the corticosteroid group ($P < 0.001$); by 9–12 months, this benefit was mainly sustained in PRP (Table 4).

Analgesic use was similar pre-injection (100% all groups). PRP required significantly more analgesics at 3 weeks (100% versus (vs) 74.3% steroid/ozone, $P = 0.004$), 6 weeks (77.1% vs 17.1%/31.4%, $P < 0.001$), and 9 weeks (45.7% vs 8.6%/14.3%, $P < 0.001$), with steroid and ozone comparable throughout. By 12 weeks, use was low across groups ($P = 0.357$). This reversed later: at 6 months, steroid group required more analgesics than PRP/ozone group (68.6% vs 0%/5.7%, $P < 0.001$); at 9 months, steroid and ozone exceeded PRP (94.3% vs 31.4%, $P < 0.001$); at 12 months the same pattern persisted (steroid 97.1%, PRP 48.6%, ozone 100%, $P < 0.001$), with steroid and ozone comparable.

Muscle relaxant use was similar at baseline (P =0.927). At 3 weeks, use was higher in PRP than in ozone (94.3% vs. 62.9%, $P = 0.008$). At 6 weeks, use was higher in PRP than in both steroid and ozone (80.0% vs. 11.4% and 25.7%, $P < 0.001$). At 9 weeks, use remained higher in PRP than in steroid (34.3% vs. 5.7%, P =0.017). At 6 months, use in steroid increased markedly compared with both PRP and ozone (74.3% vs. 2.9% in each group, $P < 0.001$). This difference between steroid and PRP persisted at 9 and 12 months (P <0.001), whereas no significant difference was observed between steroid and ozone.

Adverse events were mild, infrequent, and did not differ significantly among groups (steroid/PRP/ozone): nausea 8.6%/5.7%/2.9%; headache 11.4%/5.7%/5.7%; injection-site bruising 2.9%/14.3%/5.7%; numbness 2.9%/0%/5.7%; paraesthesia 5.7%/2.9%/2.9% (all $P > 0.05$, including after Bonferroni correction).

Discussion

This trial compared ultrasound-guided corticosteroid, PRP, and ozone injections for chronic SIJ pain and found three distinct temporal profiles: corticosteroid gave rapid but short-lived relief, ozone intermediate-duration benefit, and PRP delayed onset but the most durable improvement in pain and function through 12 months, consistent with recent comparative literature.

Ultrasound-guided SIJ injection is practical and radiation-free, though it cannot confirm intra-articular placement as reliably as fluoroscopy, the diagnostic reference standard; periarticular structures may still contribute to relief. Prior work supports reasonable accuracy of ultrasound-guided periarticular blocks combined with multiple positive provocative tests, supporting our diagnostic approach.[12]

In the present study, corticosteroid produced marked early improvement that waned over time, consistent with its anti-inflammatory but non-regenerative mechanism—a pattern reported previously.[13-16] Similarly, a 2026 randomised double-blind trial found faster corticosteroid relief within 2–4 weeks, whereas PRP provided more sustained benefit from approximately 8 weeks to 6 months.[17] Differences in early outcomes may reflect variations in PRP preparation, injection frequency, and follow-up duration.

In contrast, PRP injection showed delayed but sustained benefit, plausibly reflecting growth-factor-mediated tissue repair, angiogenesis, and modulation of chronic inflammation.[17-20] Repeated injections may provide longer-lasting relief than single injections, consistent with our findings.[21] Recent studies also reported slower PRP onset but more durable benefit than corticosteroids, with meta-analytic evidence favouring PRP at 3 and 6 months, although heterogeneity in PRP protocols limits certainty.[21, 22] Our repeated-injection protocol and longer follow-up may explain the sustained benefit observed.[23]

Greater early analgesic or muscle-relaxant use in the PRP group (weeks 3–9) likely reflects a transient post-injection inflammatory response preceding regenerative effects.[24] In contrast, the increased medication use in corticosteroid group from 6 months onward coincided with gradual attenuation of pain relief and functional benefit.[25]

These trends are secondary, not direct measures of efficacy.

Some studies reported greater short-term corticosteroid benefit over PRP reflecting differences in design, follow-up, and protocols.[23] In contrast, most studies favour the long-term superiority of PRP over corticosteroid. Evidence for PRP monotherapy remains limited but supportive.[8] Findings may be attributable to the repeated PRP injection protocol and longer follow-up.

Ozone produced significant early and intermediate improvements in pain and function, consistent with its anti-inflammatory and antioxidative effects.[26] Evidence specific to SIJ dysfunction remains limited, but recent studies support ozone as a potential corticosteroid alternative.[27, 28] Its effects may involve controlled oxidative stimulation of redox-sensitive antioxidant pathways, explaining the intermediate, time-limited benefit observed.[26]

To our knowledge, few if any randomised trials have directly compared corticosteroid, PRP, and ozone within a single three-arm design for SIJ pain; most evidence remains limited to pairwise comparisons. A recent three-arm trial applying the same comparison to lateral epicondylitis found no significant differences between modalities at 8 weeks or 6 months, contrasting with the clearer separation seen here—possibly reflecting differences between tendon and synovial joint pathophysiology and injection protocol.[29] The present study addresses this evidence gap by comparing all three modalities head-to-head specifically in the SIJ.

In patients with inadequate or recurrent pain relief, alternative pain sources should be considered, including lumbar facet or discogenic pain, radiculopathy, hip disorders, and myofascial pain.[30] Use of predefined clinically meaningful thresholds strengthens the clinical relevance of these findings for treatment selection and shared decision-making.

The current study has several limitations. First, intervention schedules differed among groups (one corticosteroid injection versus three PRP or ozone sessions), which may have affected outcomes and expectations despite sham procedures. Complete participant blinding was not feasible, and patient-reported outcomes may be subject to expectation bias. Ultrasound guidance may provide less certainty of intra-articular placement than fluoroscopy or CT, potentially affecting injectate distribution. The absence of local anaesthetic in ozone group and differences in injectate volume may also have influenced procedural discomfort and blinding.[30]

Systemic absorption of corticosteroids cannot be completely excluded. Platelet counts were measured to confirm adequate enrichment, but leucocyte characterisation of the final PRP preparation was not routinely performed limiting reproducibility. Finally, rescue medication use was documented prospectively but relied mainly on patient self-report; complete verification of medication use outside the study protocol was not feasible.

Conclusion

In conclusion, corticosteroid injection provided rapid but short-term relief of SIJ pain and disability, ozone gave intermediate-duration benefit, and PRP showed delayed onset but the most sustained improvement through 12 months. PRP may therefore be a promising option for longer-term relief in chronic SIJ pain, though multicentre studies with standardised PRP characterisation are needed to confirm these findings.

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Tables titles:

Table 1: Demographic and anthropometric characteristics of the three groups.

Table 2: Comparison between the three groups according to Visual Analog Scale (VAS) score at different follow-up intervals.

Table 3: Comparison between the three groups according to Modified Oswestry Disability Questionnaire (MODQ) scores at different follow-up intervals.

Table 4: Comparison between the three study groups according to clinically meaningful improvement across follow-up time points.

Table 1: Demographic and anthropometric characteristics of the three groups

Data are presented as Mean (SD) with 95% confidence intervals (CI)s for continuous variables, and as number (No.) and percentage (%) for categorical variables. The 95% CI for continuous variables was calculated as Mean, plus or minus t(34) × SD/√n (t = 2.032, n = 35 per group). Comparisons were made using one-way ANOVA (F-test) for continuous variables and the Chi-square test (χ^2) for categorical variables; the Monte Carlo (MC) exact method was used for the ASA classification due to low expected cell counts.

	Steroid group (n=35)		**PRP group (n=35)**		**Ozone group (n=35)**		**Test of significance**	***P* value**
Age (years), Mean (SD)	50.20 (SD: 9.58) (95% CI: 46.91, 53.49)		46.20 (SD: 11.00) (95% CI: 42.42, 49.98)		48.00 (SD: 11.17) (95% CI: 44.16, 51.84)		F(2, 102) = 1.230	0.297
Sex	**No.**	**%**	**No.**	**%**	**No.**	**%**	$\chi^2(2)$ = 0.641	0.726
Male	12	34.3	9	25.7	10	28.6		
Female	23	65.7	26	74.3	25	71.4		
Weight (kg), Mean (SD)	76.70 (SD: 13.01) (95% CI: 72.23, 81.17)		78.00 (SD: 10.63) (95% CI: 74.35, 81.65)		81.30 (SD: 8.24) (95% CI: 78.47, 84.13)		F(2, 102) = 1.690	0.190
Height (m), Mean (SD)	1.69 (SD: 0.08) (95% CI: 1.66, 1.72)		1.71 (SD: 0.08) (95% CI: 1.68, 1.74)		1.72 (SD: 0.05) (95% CI: 1.70, 1.74)		F(2, 102) = 0.796	0.454
BMI (kg/m²), Mean (SD)	26.60 (SD: 4.21) (95% CI: 25.15, 28.05)		26.90 (SD: 4.07) (95% CI: 25.50, 28.30)		27.50 (SD: 2.35) (95% CI: 26.69, 28.31)		F(2, 102) = 0.532	0.589
ASA	**No.**	**%**	**No.**	**%**	**No.**	**%**	$\chi^2(4)$ = 0.880	p (MC) = 0.934
ASA 1	20	57.1	22	62.9	23	65.7		
ASA 2	11	31.4	10	28.6	8	22.9		
ASA 3	4	11.4	3	8.6	4	11.4		

$P \leq 0.05$ (statistically significant). ASA: American Society of Anesthesiologists physical status classification; BMI: Body mass index; CI: Confidence interval; F: Analysis of variance F-test; MC: Monte Carlo exact test; SD: Standard deviation; χ^2: Chi-square test.

Table 2: Comparison between the three groups according to VAS

Data are presented as median (IQR) with bootstrap 95% confidence intervals (CI). Between-group comparisons

Time point	Steroid (n=35) Median (IQR) (95% CI)	PRP (n=35) Median (IQR) (95% CI)	Ozone (n=35) Median (IQR) (95% CI)	Kruskal-Wallis H (df = 2)	Overall P	*P*1 (Steroid vs PRP) Bonferroni-adjusted	*P*2 (Steroid vs Ozone) Bonferroni-adjusted	*P*3 (PRP vs Ozone) Bonferroni-adjusted
Before injection	8 (IQR: 7, 9) (95% CI: 7, 8)	8 (IQR: 8, 9) (95% CI: 8, 9)	8 (IQR: 7, 9) (95% CI: 8, 8)	1.717	0.424	0.688	1.000	0.877
Immediately after injection	3 (IQR: 2, 3) (95% CI: 2, 3)	8 (IQR: 8, 9) (95% CI: 8, 9)	4 (IQR: 4, 5) (95% CI: 4, 5)	88.275	**<0.001**	**<0.001**	**<0.001**	**<0.001**
After 3 weeks	5 (IQR: 4, 5) (95% CI: 4, 5)	8 (IQR: 8, 9) (95% CI: 8, 9)	5 (IQR: 4.5, 6) (95% CI: 5, 5)	73.653	**<0.001**	**<0.001**	0.578	**<0.001**
After 6 weeks	4 (IQR: 3, 4) (95% CI: 3, 4)	5 (IQR: 4, 5) (95% CI: 4, 5)	4 (IQR: 3, 4) (95% CI: 3, 4)	20.541	**<0.001**	**<0.001**	1.000	**<0.001**
After 9 weeks	3 (IQR: 2, 3) (95% CI: 2, 3)	4 (IQR: 3.5, 4) (95% CI: 4, 4)	3 (IQR: 2, 3) (95% CI: 3, 3)	33.313	**<0.001**	**<0.001**	1.000	**<0.001**
After 12 weeks	2 (IQR: 1, 2) (95% CI: 1, 2)	3 (IQR: 2, 3) (95% CI: 3, 3)	2 (IQR: 1, 2) (95% CI: 2, 2)	31.385	**<0.001**	**<0.001**	0.830	**<0.001**
After 6 months	6 (IQR: 5.5, 7) (95% CI: 6, 6)	3 (IQR: 2, 3) (95% CI: 2, 3)	2 (IQR: 2, 3.5) (95% CI: 2, 3)	70.761	**<0.001**	**<0.001**	**<0.001**	1.000
After 9 months	8 (IQR: 7.5, 8) (95% CI: 8, 8)	4 (IQR: 3, 4) (95% CI: 4, 4)	8 (IQR: 7.5, 8) (95% CI: 8, 8)	77.704	**<0.001**	**<0.001**	1.000	**<0.001**
After 12 months	8 (IQR: 8, 9) (95% CI: 8, 9)	5 (IQR: 5, 5.5) (95% CI: 5, 5)	8 (IQR: 8, 9) (95% CI: 8, 9)	72.401	**<0.001**	**<0.001**	1.000	**<0.001**

were performed using the Kruskal–Wallis test (degree of freedom = 2), followed by Dunn's post hoc test with Bonferroni correction for pairwise comparisons. *P*1 = Steroid vs PRP; *P*2 = Steroid vs Ozone; *P*3 = PRP vs Ozone. Statistically significant values after Bonferroni correction are shown in bold (adjusted $P < 0.05$). CI: Confidence interval; IQR: Interquartile range; VAS: Visual Analogue Scale; PRP: Platelet-rich plasma; VAS: Visual analogue scale

Table 3: Comparison between the three studied groups according to MODQ score

Data are presented as median (IQR) with bootstrap 95% confidence intervals (CI). Between-group comparisons

Time point	Steroid (n=35) Median (IQR) (95% CI)	PRP (n=35) Median (IQR) (95% CI)	Ozone (n=35) Median (IQR) (95% CI)	Kruskal-Wallis H (df = 2)	Overall *P* value	*P*1 (Steroid vs PRP) Bonferroni-adjusted	*P*2 (Steroid vs Ozone) Bonferroni-adjusted	*P*3 (PRP vs Ozone) Bonferroni-adjusted
Before injection	21 (IQR: 20, 22.5) (95% CI: 20, 22)	22 (IQR: 20, 23.5) (95% CI: 20, 23)	21 (IQR: 20, 22.5) (95% CI: 20, 22)	1.112	0.574	1.000	1.000	1.000
Immediately after injection	10 (IQR: 8, 10.5) (95% CI: 8, 10)	23 (IQR: 22, 23) (95% CI: 22, 23)	10 (IQR: 9, 11) (95% CI: 9, 11)	71.131	**<0.001**	**<0.001**	1.000	**<0.001**
After 3 weeks	16 (IQR: 14, 17) (95% CI: 15, 17)	21 (IQR: 21, 22) (95% CI: 21, 22)	18 (IQR: 16, 19) (95% CI: 16, 18)	65.226	**<0.001**	**<0.001**	0.144	**<0.001**
After 6 weeks	14 (IQR: 12, 16) (95% CI: 12, 16)	13 (IQR: 12, 15) (95% CI: 12, 14)	14 (IQR: 11.5, 15) (95% CI: 12, 15)	1.452	0.484	0.691	1.000	1.000
After 9 weeks	11 (IQR: 10, 14) (95% CI: 10, 12)	11 (IQR: 9.5, 12) (95% CI: 11, 12)	7 (IQR: 6, 8) (95% CI: 7, 8)	60.772	**<0.001**	1.000	**<0.001**	**<0.001**
After 12 weeks	8 (IQR: 6, 9) (95% CI: 7, 8)	9 (IQR: 8, 10) (95% CI: 8, 10)	5 (IQR: 4.5, 6) (95% CI: 5, 6)	66.446	**<0.001**	**0.034**	**<0.001**	**<0.001**
After 6 months	18 (IQR: 17, 19) (95% CI: 17, 19)	8 (IQR: 7, 9) (95% CI: 7, 8)	6 (IQR: 6, 7) (95% CI: 6, 7)	78.985	**<0.001**	**<0.001**	**<0.001**	**0.010**
After 9 months	21 (IQR: 20, 22.5) (95% CI: 20, 22)	10 (IQR: 8, 11) (95% CI: 9, 11)	21 (IQR: 18, 22.5) (95% CI: 19, 22)	70.024	**<0.001**	**<0.001**	1.000	**<0.001**
After 12 months	21 (IQR: 20, 23) (95% CI: 20, 22)	13 (IQR: 10, 14) (95% CI: 12, 14)	22 (IQR: 19.5, 23.5) (95% CI: 20, 22)	67.379	**<0.001**	**<0.001**	1.000	**<0.001**

were performed using the Kruskal–Wallis test (degree of freedom = 2), followed by Dunn's post hoc test with Bonferroni correction for pairwise comparisons. *P*1 = Steroid vs PRP; *P*2 = Steroid vs Ozone; *P*3 = PRP vs Ozone. Statistically significant values after Bonferroni correction are shown in bold (adjusted $P < 0.05$). CI: Confidence interval; IQR: Interquartile range; MODQ: Modified Oswestry Disability Questionnaire; PRP: Platelet-rich plasma

Table 4: Comparison between the three studied groups according to clinically meaningful improvement across time points

Time Point	Improvement Criteria	Steroid Group (n=35) n/N (%) (95% CI)	PRP Group (n=35) n/N (%) (95% CI)	Ozone Group (n=35) n/N (%) (95% CI)	overall *P* value (χ^2, df = 2)	*P*1 (Steroid vs PRP) Bonferroni-adjusted	*P*2 (Steroid vs Ozone) Bonferroni-adjusted	*P*3 (PRP vs Ozone) Bonferroni-adjusted
3 weeks	≥50% pain relief (VAS)	11/35 (31.4%) (95% CI: 18.6, 48.0%)	0/35 (0%) (95% CI: 0.0, 9.9%)	5/35 (14.3%) (95% CI: 6.3, 29.4%)	**0.001**	**<0.001**	0.263	0.061
	≥2-point improvement in VAS	32/35 (91.4%) (95% CI: 77.6, 97.0%)	0/35 (0%) (95% CI: 0.0, 9.9%)	34/35 (97.1%) (95% CI: 85.5, 99.5%)	**<0.001**	**<0.001**	0.909	**<0.001**
	≥15-point improvement in MODQ	0/35 (0%) (95% CI: 0.0, 9.9%)	0/35 (0%) (95% CI: 0.0, 9.9%)	0/35 (0%) (95% CI: 0.0, 9.9%)	Not Applicable	Not Applicable	Not Applicable	Not Applicable
6 weeks	≥50% pain relief	27/35 (77.1%) (95% CI: 61.0, 87.9%)	15/35 (42.9%) (95% CI: 28.0, 59.1%)	25/35 (71.4%) (95% CI: 54.9, 83.7%)	**0.006**	**0.010**	1.000	**0.047**
	≥2-point VAS improvement	35/35 (100%) (95% CI: 90.1, 100%)	35/35 (100%) (95% CI: 90.1, 100%)	35/35 (100%) (95% CI: 90.1, 100%)	Not Applicable	Not Applicable	Not Applicable	Not Applicable
	≥15-point MODQ improvement	0/35 (0%) (95% CI: 0.0, 9.9%)	1/35 (2.9%) (95% CI: 0.5, 14.5%)	0/35 (0%) (95% CI: 0.0, 9.9%)	0.364	0.941	Not Applicable	0.941
9 weeks	≥50% pain relief	33/35 (94.3%) (95% CI: 81.4, 98.4%)	26/35 (74.3%) (95% CI: 57.9, 85.8%)	33/35 (94.3%) (95% CI: 81.4, 98.4%)	**0.014**	0.065	Not Applicable	0.065
	≥2-point VAS improvement	35/35 (100%) (95% CI: 90.1, 100%)	35/35 (100%) (95% CI: 90.1, 100%)	35/35 (100%) (95% CI: 90.1, 100%)	Not Applicable	Not Applicable	Not Applicable	Not Applicable
	≥15-point MODQ improvement	0/35 (0%) (95% CI: 0.0, 9.9%)	4/35 (11.4%) (95% CI: 4.5, 26.0%)	16/35 (45.7%) (95% CI: 30.5, 61.8%)	**<0.001**	0.118	**<0.001**	**0.004**
	≥50% pain relief	35/35	35/35	35/35	Not	Not Applicable	Not Applicable	Not Applicable

12 weeks		(100%) (95% CI: 90.1, 100%)	(100%) (95% CI: 90.1, 100%)	(100%) (95% CI: 90.1, 100%)	Applicable			
	≥2-point VAS improvement	35/35 (100%) (95% CI: 90.1, 100%)	35/35 (100%) (95% CI: 90.1, 100%)	35/35 (100%) (95% CI: 90.1, 100%)	Not Applicable	Not Applicable	Not Applicable	Not Applicable
	≥15-point MODQ improvement	12/35 (34.3%) (95% CI: 20.8, 50.8%)	9/35 (25.7%) (95% CI: 14.2, 42.1%)	29/35 (82.9%) (95% CI: 67.3, 91.9%)	**<0.001**	1.000	**<0.001**	**<0.001**
6 months	≥50% pain relief	0/35 (0%) (95% CI: 0.0, 9.9%)	35/35 (100%) (95% CI: 90.1, 100%)	32/35 (91.4%) (95% CI: 77.6, 97.0%)	**<0.001**	**<0.001**	**<0.001**	0.230
	≥2-point VAS improvement	28/35 (80%) (95% CI: 64.1, 90.0%)	35/35 (100%) (95% CI: 90.1, 100%)	35/35 (100%) (95% CI: 90.1, 100%)	**<0.001**	**0.016**	**0.016**	N/A
	≥15-point MODQ improvement	0/35 (0%) (95% CI: 0.0, 9.9%)	10/35 (28%) (95% CI: 16.3, 45.1%)	16/35 (45.7%) (95% CI: 30.5, 61.8%)	**<0.001**	**0.002**	**<0.001**	0.413
9 months	≥50% pain relief	0/35 (0%) (95% CI: 0.0, 9.9%)	30/35 (85.7%) (95% CI: 70.6, 93.7%)	0/35 (0%) (95% CI: 0.0, 9.9%)	**<0.001**	**<0.001**	Not Applicable	**<0.001**
	≥2-point VAS improvement	0/35 (0%) (95% CI: 0.0, 9.9%)	35/35 (100%) (95% CI: 90.1, 100%)	1/35 (2.9%) (95% CI: 0.5, 14.5%)	**<0.001**	**<0.001**	0.941	**<0.001**
	≥15-point MODQ improvement	0/35 (0%) (95% CI: 0.0, 9.9%)	7/35 (20%) (95% CI: 10.0, 35.9%)	0/35 (0%) (95% CI: 0.0, 9.9%)	**<0.001**	**0.016**	Not Applicable	**0.016**
12 months	≥50% pain relief	0/35 (0%) (95% CI: 0.0, 9.9%)	6/35 (17.1%) (95% CI: 8.1, 32.7%)	0/35 (0%) (95% CI: 0.0, 9.9%)	**0.002**	**0.031**	Not Applicable	**0.031**
	≥2-point VAS improvement	0/35 (0%) (95% CI: 0.0,	34/35 (97.1%) (95% CI:	0/35 (0%) (95% CI: 0.0,	**<0.001**	**<0.001**	Not Applicable	**<0.001**

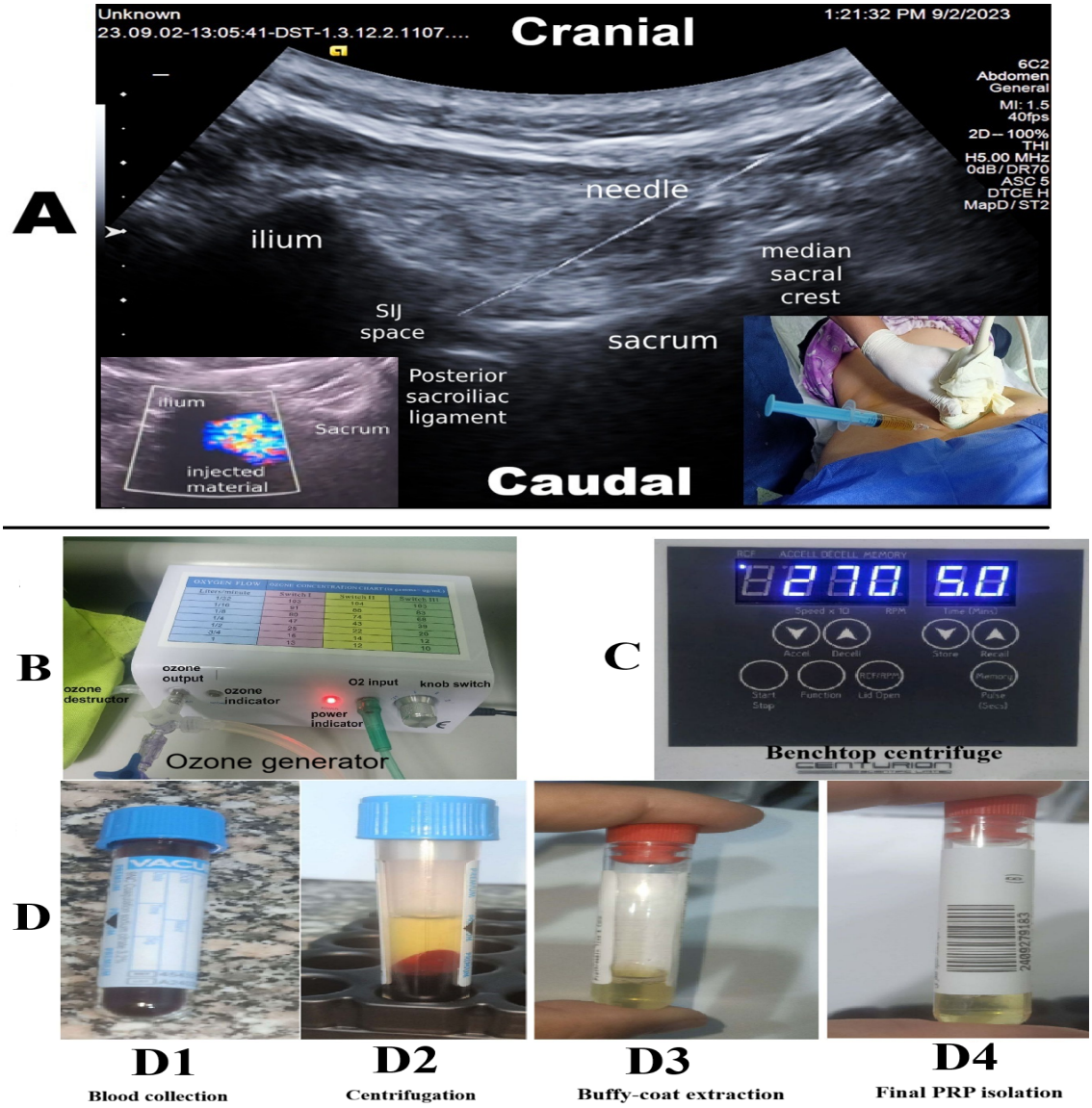
		9.9%)	85.5, 99.5%)	9.9%)				
	≥15-point MODQ improvement	0/35 (0%) (95% CI: 0.0, 9.9%)	2/35 (5.7%) (95% CI: 1.6, 18.6%)	0/35 (0%) (95% CI: 0.0, 9.9%)	0.130	0.454	Not Applicable	0.454

Data are presented as n/N (%) with 95% Wilson confidence intervals (CI), calculated using the Wilson score method for binomial proportions (n = 35 per group). Overall between-group comparisons were performed using the Chi-square test (degree of freedom = 2). Pairwise comparisons between groups were performed using the Chi-square test with Bonferroni correction for multiple testing. "Not Applicable" indicates cells where the test statistic could not be computed because response rates were identical or equal to 0% in the compared groups. *P*1 = Steroid vs PRP; *P*2 = Steroid vs Ozone; *P*3 = PRP vs Ozone. Statistically significant values after Bonferroni correction are shown in bold (adjusted $P < 0.05$). CI: Confidence interval; MODQ: Modified Oswestry Disability Questionnaire; VAS: Visual analogue scale; PRP: Platelet-rich plasma

Figure legends:

Figure 1: Study interventions (A) Ultrasound-guided sacroiliac joint injection. (B) Ozone generator. (C) PRP centrifuge. (D1–D4) Sequential steps of PRP preparation

Figure 2: Consolidated Standards of Reporting Trials (CONSORT) flow chart showing patient enrolment, allocation, follow-up, and analysis



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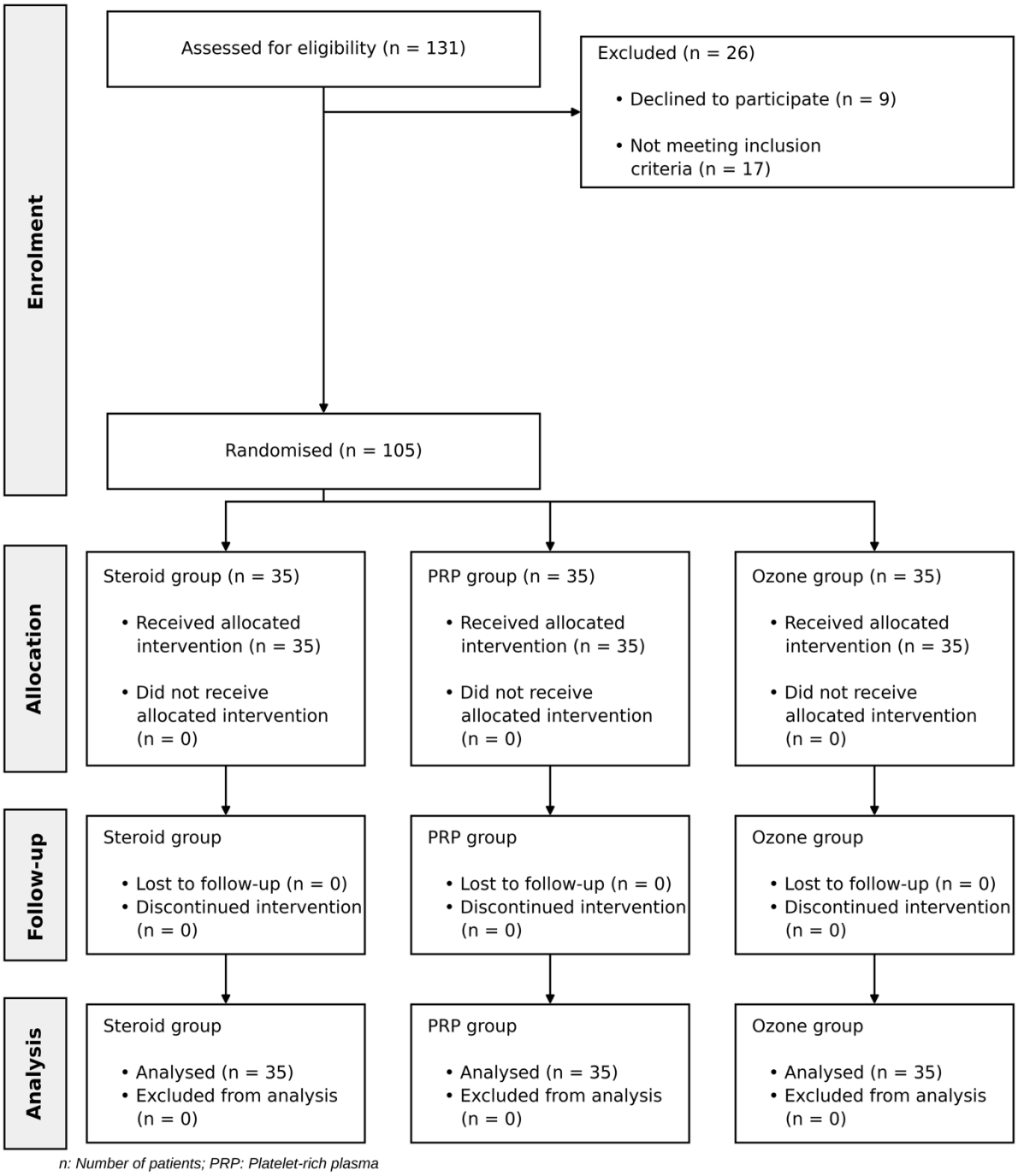

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