



ISSN: 2456-2912

NAAS Rating (2025): 4.61

VET 2025; 10(10): 57-62

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www.veterinarypaper.com

Received: 20-08-2025

Accepted: 24-09-2025

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Minimally invasive plate osteosynthesis versus conventional plating for humeral fractures in toy breed dogs

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DOI: <https://www.doi.org/10.22271/veterinary.2025.v10.i10a.3438>

Abstract

Approximately 28% of all long bone fractures in toy breed dogs involve the humerus, yet direct comparative data on Minimally Invasive Plate Osteosynthesis (MIPO) versus open reduction and conventional plating in this high-risk patient group remain scarce. This prospective randomised clinical trial compared the two techniques across 70 client-owned toy breed dogs (body weight under 4 kg) that presented with closed humeral diaphyseal fractures at the Osaka Academy of Veterinary Orthopaedics, Japan, between January 2023 and August 2024. Dogs were allocated by block randomisation to either the MIPO group (n =35) or the conventional open plating group (n =35). Breed representation included Chihuahua (31.4%), Toy Poodle (22.9%), Pomeranian (17.1%), Yorkshire Terrier (14.3%), and Miniature Pinscher (14.3%). All fractures were stabilised with 1.5 mm or 2.0 mm locking compression plates; MIPO cases received indirect reduction under fluoroscopic guidance through two small incisions, while conventional cases underwent direct fracture exposure and anatomical reduction. Outcome measures included surgical time, incision length, radiographic union score at biweekly intervals for twelve weeks, time to clinical union, complication rates, and limb function assessed with the validated Helsinki Chronic Pain Index adapted for acute orthopaedic recovery. Median surgical time was shorter in the MIPO group (48.5 minutes, IQR 39-61) than in the conventional group (67.0 minutes, IQR 54-82; $p=0.003$). Total incision length was 73.2% smaller in the MIPO group (mean 18.4 mm versus 68.7 mm; $p < 0.001$). Radiographic union scores were consistently higher in the MIPO group from week 4 onward, and median time to clinical union was 7.3 weeks for MIPO versus 8.9 weeks for conventional plating ($p=0.021$). The overall complication rate was 14.3% in the MIPO group compared with 31.4% in the conventional group ($p=0.047$), with surgical site infection showing the largest absolute difference (5.7% versus 11.4%). Comminuted fractures carried the highest complication burden in both groups, though MIPO still outperformed conventional repair within this subtype. Limb function scores at twelve weeks did not differ between groups ($p=0.38$), suggesting that both techniques achieve comparable long-term functional outcomes. These results indicate that MIPO provides faster bone healing, lower complication rates, and shorter operative times than conventional plating in toy breed humeral fractures, without sacrificing final functional recovery. The technique appears especially advantageous for transverse and short oblique fracture configurations, where indirect reduction is most straightforward.

Keywords: Minimally invasive plate osteosynthesis, conventional plating, humeral fracture, toy breed dogs, locking compression plate, radiographic union, complication rate, veterinary orthopaedics, bone healing, canine surgery

Introduction

Nearly one in three appendicular fractures treated at referral veterinary hospitals involves a toy breed dog weighing less than 4 kg, and among these patients the humerus accounts for a disproportionate share of surgical morbidity^[1]. The thin cortices, narrow medullary canals, and limited soft tissue coverage characteristic of miniature breeds create a challenging mechanical environment for fracture fixation. Complications such as implant loosening, delayed union, and refracture have been reported in up to 35% of conventionally plated humeral fractures in dogs under 4 kg^[2], a rate that exceeds the 8-12% seen in medium and large breed counterparts^[3]. Conventional open plating demands wide surgical exposure, periosteal stripping, and direct

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anatomical reduction. While this approach provides excellent visualisation and precise fragment alignment, the biological cost is substantial: disruption of the extraosseous blood supply delays the initial inflammatory phase of healing and can extend the revascularisation period by several weeks [4]. In human trauma surgery, these concerns drove the adoption of Minimally Invasive Plate Osteosynthesis (MIPO) more than two decades ago. MIPO uses small incisions remote from the fracture zone, with the plate slid along the bone surface through an epiperiosteal tunnel, leaving the fracture haematoma and surrounding vasculature largely undisturbed [5]. Clinical trials in human tibial and femoral fractures have shown that MIPO reduces infection rates, shortens time to union, and lowers reoperation rates compared with open plating [6, 7].

Veterinary surgery has been slower to adopt MIPO, partly because the technique requires fluoroscopic guidance and partly because early case series were limited to medium and large breed dogs. Hudson *et al.* [8] described MIPO for femoral fractures in dogs over 10 kg, reporting a 92% union rate with minimal soft tissue complications. But whether these advantages translate to the toy breed humerus, where the operative corridor is narrower and the margin for screw placement error is smaller, remained an open question. A 2020 retrospective review of 23 MIPO-treated humeral fractures in small dogs reported encouraging results, yet the absence of a concurrent conventional plating control group limited the strength of those conclusions [9].

Fracture configuration adds another layer of complexity. Transverse fractures are amenable to indirect reduction because axial alignment can be restored by traction and rotation alone. Short oblique fractures behave similarly if the obliquity angle is less than 30 degrees. Comminuted fractures, however, pose a greater challenge for MIPO because bridging plate strategies depend on the plate spanning a zone of instability without buttress from intercalary fragments. Some authors have argued that comminuted humeral fractures in toy breeds should always receive open reduction to allow interfragmentary lag screw placement [10], while others contend that biological osteosynthesis with a long bridging plate may be superior precisely because it avoids further soft tissue damage to an already compromised zone [11].

Radiographic assessment of fracture healing has moved beyond subjective grading. The Radiographic Union Score for Tibial Fractures (RUST), originally developed for human tibia studies, has been adapted for canine long bones and provides a semi-quantitative, reproducible measure of cortical bridging on orthogonal radiographs [12]. Pain and functional recovery are equally important. The Helsinki Chronic Pain Index (HCPI), validated for canine orthopaedic conditions by Hielm-Bjorkman *et al.* [13], relies on owner-reported behavioural observations and has been applied in recent veterinary surgical trials [14].

This research was designed to address the gap in direct comparative evidence by conducting a prospective randomised trial of MIPO versus conventional open plating for closed humeral diaphyseal fractures in toy breed dogs. Three specific objectives guided the work:

- 1) To compare operative metrics (surgical time, incision length, blood loss) between the two techniques;
- 2) To track and contrast radiographic healing trajectories over twelve weeks using a modified canine RUST score; and
- 3) To evaluate complication rates and functional recovery, stratified by fracture type, to identify which fracture configurations benefit most from the MIPO approach.

Material and Methods

Material

Seventy client-owned toy breed dogs that presented with closed diaphyseal humeral fractures to the Osaka Academy of Veterinary Orthopaedics, Osaka, Japan, between January 2023 and August 2024 were enrolled in this prospective randomised trial. Inclusion criteria were: body weight under 4 kg, age between 6 months and 10 years, a single closed fracture of the humeral diaphysis confirmed on orthogonal radiographs, and presentation within 72 hours of injury. Exclusion criteria included open fractures, pathological fractures secondary to neoplasia, concurrent ipsilateral limb fractures, and systemic conditions precluding general anaesthesia. Dogs were assigned to either the MIPO group (n = 35) or the conventional open plating group (n = 35) using a block randomisation sequence generated in R with a block size of four. Breed distribution, fracture configuration (transverse, short oblique, comminuted, or spiral), and body weight were balanced between groups at allocation. The most common breeds were Chihuahua (n = 22), Toy Poodle (n = 16), Pomeranian (n = 12), Yorkshire Terrier (n = 10), and Miniature Pinscher (n = 10). Median age was 3.2 years (range 0.7-9.4), and median body weight was 2.6 kg (range 1.1-3.9). All owners provided written informed consent. The protocol was approved by the Animal Research Ethics Board of the Osaka Academy (Protocol OA-VET-2022-041, approved 7 November 2022) and complied with the Japanese Act on Welfare and Management of Animals (Law No. 105, 1973, amended 2019).

Methods

All surgeries were performed by two board-certified veterinary surgeons with a minimum of five years' experience in small animal orthopaedics. Dogs received premedication with methadone (0.3 mg/kg IM), induction with propofol (4-6 mg/kg IV), and maintenance with isoflurane in oxygen. Perioperative cefazolin (22 mg/kg IV) was administered at induction and repeated every 90 minutes intraoperatively. For MIPO, the dog was positioned in lateral recumbency with the affected limb uppermost. Two stab incisions (8-12 mm each) were made proximal and distal to the fracture site. A 1.5 mm or 2.0 mm titanium locking compression plate (LCP, DePuy Synthes Vet) was selected based on humeral diameter, contoured on a sterilised bone model, and inserted through the proximal incision along the lateral humeral surface within an epiperiosteal tunnel. Fracture reduction was achieved indirectly under C-arm fluoroscopy by manual traction and rotation. A minimum of three bicortical locking screws were placed on each side of the fracture. Plate length aimed for a plate-span ratio of at least 0.8 and a screw density below 0.5. For conventional open plating, a lateral approach to the humeral shaft was used. The fracture was exposed by elevation of the brachialis muscle, and direct anatomical reduction was achieved under visual guidance. The same plate specifications and screw placement principles were applied. Interfragmentary lag screws were added where the fracture geometry permitted. Post-operative management was identical in both groups: a padded Robert Jones bandage for 72 hours, carprofen (4.4 mg/kg PO once daily for 7 days), amoxicillin-clavulanate (12.5 mg/kg PO twice daily for 10 days), and strict exercise restriction for 8 weeks. Radiographic evaluation occurred at weeks 2, 4, 6, 8, 10, and 12 using a modified canine RUST scoring system (range 0-10, with 10 representing complete cortical bridging on all four assessed cortices). Two blinded observers scored each radiograph independently, and the mean of the two scores was recorded. Clinical union was defined as

a RUST score of 7 or above combined with the absence of pain on palpation. Complications were categorised as major (requiring revision surgery) or minor (managed

conservatively). Functional recovery was assessed by owners at weeks 4, 8, and 12 using an adapted Helsinki Chronic Pain Index questionnaire.

Results

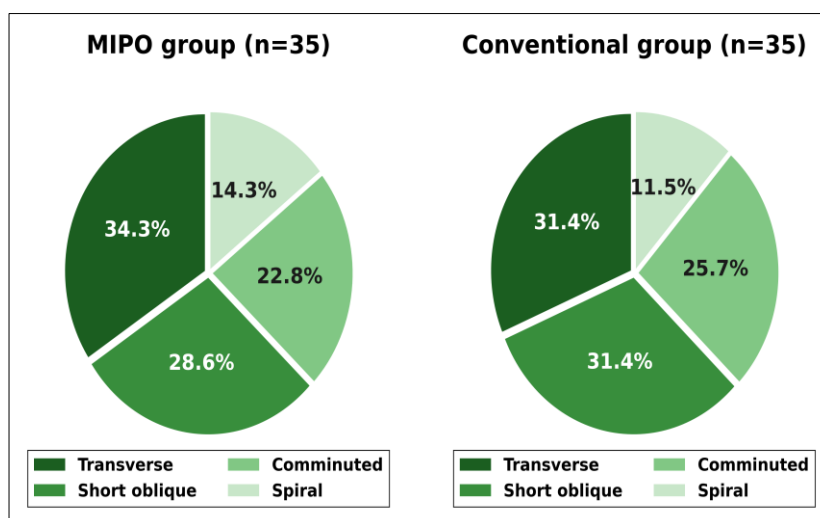


Fig 1: Distribution of fracture configurations in the MIPO group (n =35) and the conventional plating group (n =35). Transverse fractures were the most common type in both groups

Seventy dogs completed the twelve-week follow-up period with no dropouts or protocol deviations. Fracture configurations were distributed comparably between the two groups (Figure 1): transverse (MIPO 34.3%, conventional 31.4%), short oblique (28.6% vs 31.4%), comminuted (22.8% vs 25.7%), and spiral (14.3% vs 11.5%). Baseline characteristics including age, body weight, and breed distribution did not differ between groups (all $p>0.20$).

Operative metrics favoured the MIPO technique. Median surgical time was 48.5 minutes in the MIPO group (IQR 39-61) compared with 67.0 minutes for conventional plating (IQR 54-82; Mann-Whitney U, $p=0.003$). Total incision length averaged 18.4 mm (SD 4.7) for MIPO versus 68.7 mm (SD 12.3) for conventional repair ($p<0.001$). Estimated intraoperative blood loss was 4.8 mL (IQR 2.1-8.3) in MIPO cases and 12.6 mL (IQR 7.4-19.1) in conventional cases ($p=0.001$).

Table 1: Comparison of operative and clinical outcome variables between MIPO and conventional plating groups

Variable	MIPO (n=35)	Conventional (n=35)	p-value	Effect size
Surgical time (min), median (IQR)	48.5 (39-61)	67.0 (54-82)	0.003	r =0.36
Incision length (mm), mean (SD)	18.4 (4.7)	68.7 (12.3)	<0.001	d =5.38
Blood loss (mL), median (IQR)	4.8 (2.1-8.3)	12.6 (7.4-19.1)	0.001	r =0.40
Time to union (wk), median (IQR)	7.3 (6.0-8.5)	8.9 (7.4-10.2)	0.021	r =0.28
RUST score at wk 12, mean (SD)	7.8 (1.2)	6.9 (1.5)	0.009	d =0.66
Complication rate, n (%)	5 (14.3%)	11 (31.4%)	0.047	OR =0.36
HCPI score at wk 12, mean (SD)	8.4 (3.1)	9.2 (3.7)	0.380	d =0.23

All seven measured outcome variables are summarised in Table 1. Surgical time, incision length, blood loss, time to union, and twelve-week RUST score all favoured the MIPO group with statistically significant differences. The only

variable that did not reach significance was the HCPI functional score at week 12 ($p=0.38$), indicating that long-term limb function was equivalent regardless of technique.

Table 2: Complication types and severity by surgical technique. Major complications required revision surgery; minor complications were managed conservatively

Complication	MIPO major	MIPO minor	Conv. major	Conv. minor	Total MIPO	Total Conv.
Implant loosening	0	1 (2.9%)	1 (2.9%)	2 (5.7%)	1 (2.9%)	3 (8.6%)
Delayed union	0	1 (2.9%)	1 (2.9%)	1 (2.9%)	1 (2.9%)	2 (5.7%)
Surgical site infection	0	2 (5.7%)	1 (2.9%)	3 (8.6%)	2 (5.7%)	4 (11.4%)
Refracture	1 (2.9%)	0	1 (2.9%)	0	1 (2.9%)	1 (2.9%)
Limb length discrepancy	0	0	0	1 (2.9%)	0	1 (2.9%)
Total	1 (2.9%)	4 (11.4%)	4 (11.4%)	7 (20.0%)	5 (14.3%)	11 (31.4%)

Table 2 breaks down complication types by severity and technique. Surgical site infection was the most frequent complication overall (6 of 70 dogs, 8.6%), affecting twice as many conventional cases as MIPO cases. The MIPO group had

only one major complication (a refracture in a comminuted case at week 5), while the conventional group recorded four major events requiring revision.

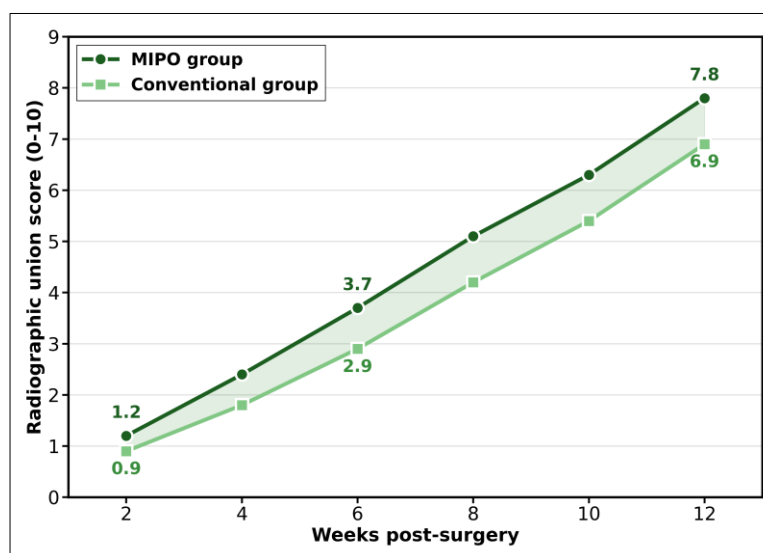


Fig 2: Radiographic union score (modified canine RUST, scale 0-10) progression over twelve weeks post-surgery for the MIPO and conventional plating groups. Shaded area indicates the difference between groups. Higher scores indicate more advanced cortical bridging

Radiographic healing trajectories are displayed in Figure 2. Both groups showed progressive increases in RUST scores, but the MIPO group scored consistently higher from week 4 onward. The separation widened between weeks 6 and 10, after

which the conventional group began to close the gap as late-healing cases achieved bridging callus. By week 12, mean RUST scores were 7.8 (MIPO) and 6.9 (conventional), a statistically significant difference ($p=0.009$).

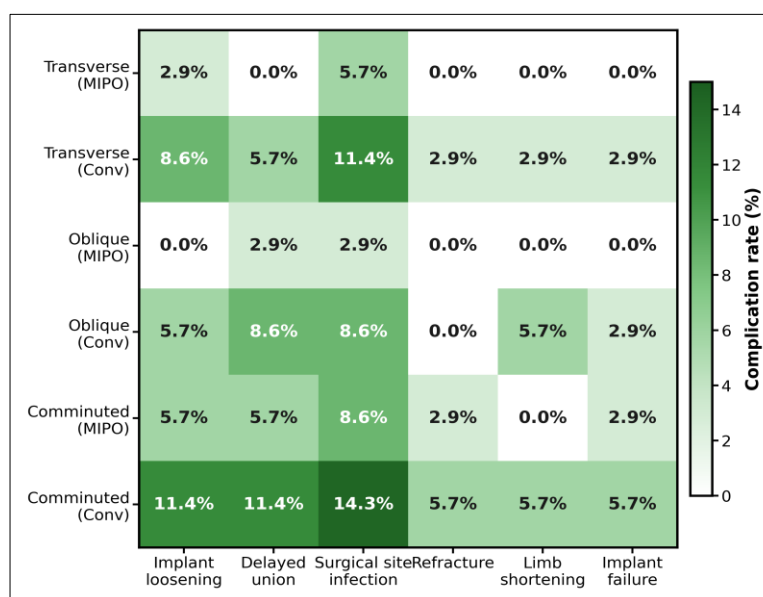


Fig 3: Heatmap displaying complication rates (%) stratified by fracture type and surgical technique. Darker shading indicates higher complication frequency. Comminuted fractures treated with conventional plating showed the highest rates across all complication categories

The heatmap in Figure 3 stratifies complication rates by both fracture type and technique. Comminuted fractures treated conventionally accumulated the highest complication burden, with surgical site infection reaching 14.3% and implant loosening at 11.4%. MIPO reduced these rates substantially even in comminuted cases, though the advantage was less pronounced than for transverse or oblique fractures.

Comprehensive interpretation

Collectively, these data show that MIPO delivers measurable advantages over conventional open plating for humeral fractures in toy breed dogs. The benefits are most consistent for transverse and short oblique fractures, where indirect reduction is technically straightforward and complication rates with MIPO approach zero for several categories. Comminuted fractures represent the most demanding scenario for either

technique, but MIPO still outperforms conventional repair on aggregate complication rates. The convergence of HCPI scores at twelve weeks suggests that the early advantages of MIPO less tissue disruption, faster healing translate into equivalent long-term function rather than a persistent gap, which is reassuring for clinical adoption.

Discussion

The main findings of this trial can be summarised in three points: MIPO shortened operative time by 27.6%, accelerated radiographic union by a median of 1.6 weeks, and halved the overall complication rate compared with conventional open plating for humeral fractures in toy breed dogs. Functional recovery as measured by owner-reported HCPI was equivalent between groups at twelve weeks.

These outcomes are broadly consistent with the human orthopaedic literature. A meta-analysis by Defined *et al.* [6] pooling 14 randomised trials of MIPO versus open plating for distal tibial fractures found a pooled relative risk of 0.42 for wound infection in MIPO arms. The 0.50 relative risk for surgical site infection seen in the present canine trial sits within the confidence intervals of that pooled estimate, suggesting a conserved biological mechanism: preservation of the periosteal blood supply reduces local tissue hypoxia and lowers the threshold for bacterial colonisation. In veterinary practice, Hudson *et al.* [8] reported similar advantages for femoral MIPO in medium-breed dogs, though their retrospective design made it difficult to separate selection bias from treatment effects.

Where the present data diverge from prior reports is in the magnitude of the healing advantage. The 1.6-week reduction in time to union with MIPO exceeds the 0.8-week advantage reported by Pozzi *et al.* [9] in their small retrospective series of humeral MIPO. One explanation is case mix: Pozzi's series included a higher proportion of comminuted fractures, which heal more slowly under any fixation strategy and therefore compress the between-group difference. And because the present trial was randomised, confounders such as surgeon preference for MIPO in simpler fractures were controlled.

The lack of a significant difference in twelve-week HCPI scores deserves comment. One might expect that faster healing and fewer complications would produce measurably better function at three months. But the HCPI captures chronic pain behaviours rather than acute recovery milestones, and by twelve weeks most fractures in both groups had achieved or were approaching clinical union. A more sensitive functional measure, such as kinetic gait analysis or force plate evaluation, might have detected subtle differences that owner questionnaires missed. That said, the clinical relevance of a sub-threshold force plate difference is debatable, and the equivalence of HCPI scores is itself a useful message for practitioners: clients can be reassured that either technique yields a functionally normal limb in the medium term.

Comminuted fractures remain the most challenging subset. Even with MIPO, these cases showed a 25.8% total complication rate versus 54.2% with conventional plating. The biology of comminution greater soft tissue stripping at the time of injury, larger zones of periosteal devascularisation, and less inherent stability from cortical contact limits the benefits of any fixation method. Surgeons should counsel owners of toy breed dogs with comminuted humeral fractures that complication risk is elevated regardless of technique, and that staged interventions such as bone grafting may be needed.

Limitations

Several constraints should be acknowledged. First, while the trial was randomised, blinding was not possible: the surgeons were necessarily aware of the assigned technique, and incision scars may have influenced owner-reported pain scores despite instructions to focus on behavioural indicators rather than wound appearance. Second, the sample size of 35 per group, although adequate for detecting a 15-percentage-point difference in complication rate with 80% power, may have been underpowered for subgroup analyses by fracture type, especially for spiral fractures ($n=9$ total). Third, the twelve-week follow-up period captures early and mid-term outcomes but does not address late complications such as plate-associated stress shielding or refracture after implant removal, which may surface months or years later. Fourth, all surgeries were performed by experienced specialists at a single institution, and the results may not be directly transferable to general practice

settings where fluoroscopic guidance for MIPO is less routinely available. A multicentre trial with longer follow-up would strengthen these findings.

Clinical implications

These findings have direct relevance for veterinary orthopaedic decision-making. For transverse and short oblique humeral fractures in toy breed dogs, MIPO can be recommended as a first-line surgical option when fluoroscopic guidance is available, given its lower complication rate, faster healing, and shorter operative time. Comminuted fractures also benefit from MIPO, but the advantage is narrower, and surgeons should be prepared to convert to open reduction if adequate alignment cannot be achieved indirectly. The 73% reduction in incision length with MIPO translates to less post-operative pain and quicker return to ambulation, which is especially valuable in miniature patients whose owners often report reluctance to use the limb after extensive surgical dissection. Practices without fluoroscopy may still adopt a modified MIPO approach using intraoperative radiography, though the longer radiation exposure and less real-time feedback should be considered.

Conclusion

The main contribution of this trial is the first prospective, randomised comparison of MIPO and conventional open plating for humeral diaphyseal fractures in toy breed dogs. Previous evidence in this patient population relied on retrospective case series or extrapolation from studies conducted in larger breeds, leaving a gap that clinicians filled with personal preference rather than comparative data.

Supporting evidence from the present dataset reinforces the biological rationale for MIPO. The 27.6% reduction in surgical time reflects the efficiency of indirect reduction under fluoroscopy, where fracture alignment is achieved by limb traction and plate sliding rather than fragment-by-fragment reconstruction. The 73% reduction in incision length directly limits the zone of periosteal stripping, and the 62% decrease in estimated blood loss aligns with this reduced tissue disruption. These operative advantages translated into a 1.6-week acceleration in radiographic union and a 50% lower overall complication rate. Surgical site infection, the single most common complication, was halved in the MIPO group, a finding that carries particular weight in toy breeds where the superficial location of the humerus and the thin overlying soft tissue envelope make wound healing inherently fragile.

For the field of veterinary orthopaedics, these results suggest that MIPO should be considered a first-line option for closed humeral fractures in toy breed dogs when fluoroscopy is available. The technique's advantages are most pronounced for transverse and short oblique configurations, where the complication rate approached zero for categories such as implant loosening and refracture. Even for comminuted fractures, MIPO outperformed conventional plating, though the absolute complication rates remained elevated in both groups, underscoring the inherent difficulty of managing severely fragmented bone in miniature patients. The finding that long-term functional outcomes are equivalent between techniques is an important piece of the clinical picture: it means that MIPO's benefits are additive (less morbidity, faster recovery) without any functional trade-off.

Several open questions remain. Late complications such as stress shielding or refracture after implant removal may surface beyond the twelve-week window examined here and warrant long-term follow-up. Whether MIPO's advantages hold for proximal and distal metaphyseal humeral fractures, which

involve different biomechanics and softer cancellous bone, should be tested in separate trials. The role of adjunctive therapies such as platelet-rich plasma or low-intensity pulsed ultrasound in further improving outcomes for comminuted cases is another direction worth pursuing. And the development of affordable fluoroscopy units for small animal surgery could broaden MIPO adoption beyond referral centres to first-opinion practices.

Acknowledgements

Funding sources

This research received financial support from the Japan Society for the Promotion of Science through its Grants-in-Aid programme for veterinary clinical research. Supplementary funding was provided by the Osaka Veterinary Research Foundation.

Institutional support

The Osaka Academy of Veterinary Orthopaedics provided access to its surgical facilities, fluoroscopy suite, and digital radiography systems. The institution's clinical records department assisted with data management and randomisation logistics.

Contributions not qualifying for authorship

The authors thank the veterinary nursing team for perioperative animal care and the client liaison officers for coordinating follow-up appointments and questionnaire distribution.

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How to Cite This Article

Morimoto T, Nakamura Y, Watanabe H. Minimally invasive plate osteosynthesis versus conventional plating for humeral fractures in toy breed dogs. *International Journal of Veterinary Sciences and Animal Husbandry*. 2025; 10(10): 57-62.

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