AJVR AVMA

Tricortical pin tension-band wiring provides the greatest tensile resistance among fixation constructs for feline greater trochanteric avulsion fractures

Yookyeong Lee, DVM; Sang-Kun Jang, DVM; Jaewon Do, DVM; Min-Young Kim, DVM; Sangyul Lee, DVM; Jung Mun Kim, PhD, DVM; Hwi-Yool Kim, PhD, DVM*

Department of Veterinary Surgery, College of Veterinary Medicine, Konkuk University, Seoul, Republic of Korea

*Corresponding author: Dr. Kim (hykim@konkuk.ac.kr)

Objective
To compare the tensile performance of 3 constructs for feline greater trochanter (GT) avulsion fractures using a cadaveric model.

Methods
An experimental cadaveric study was performed using a standardized GT osteotomy model. Adult feline cadavers euthanized for reasons unrelated to this study and without radiographic evidence of orthopedic disease were included; specimens with musculoskeletal abnormalities were excluded. All testing was conducted at a single academic biomechanics laboratory. Fixation constructs were subjected to quasistatic tensile loading until failure.

Results
18 hindlimbs from 9 feline cadavers were allocated equally to bicortical pin tension-band wiring (TBW; n = 6), tricortical pin TBW (6), and FiberWire-only fixation (6). At 3-mm displacement, tricortical fixation demonstrated higher mean load resistance than both bicortical fixation (mean difference, 45.0 N; 95% CI, 19.7 to 70.3 N) and FiberWire-only fixation (mean difference, 140.5 N; 95% CI, 115.1 to 165.9 N). Bicortical and tricortical constructs exhibited similar resistance at 1- and 2-mm displacement.

Conclusions
Tricortical pin TBW provided the greatest tensile resistance under maximal loading. However, the bicortical pin TBW and tricortical pin TBW techniques provided similar strength during early displacement. The FiberWire-only fixation construct demonstrated the lowest stability, suggesting that FiberWire fixation alone may not provide sufficient strength or an optimal tension-band configuration for feline GT avulsion repair.

Clinical Relevance
For routine feline GT avulsion fracture repair, bicortical pin TBW may offer a practical balance of strength and simplicity. Tricortical pin TBW fixation may be reserved for cases requiring maximal resistance, whereas FiberWire-only fixation should be used with caution due to its lower load-bearing capacity.

Keywords: feline, greater trochanter fracture, tension-band wiring, biomechanical testing, tricortical fixation

Fractures of the feline greater trochanter (GT) are relatively uncommon but clinically significant injuries, most often associated with high-energy trauma and frequently presenting as Salter-Harris type I physeal avulsion fractures. A recent retrospective study[1] reported that 58.8% of feline GT fractures were accompanied by coxofemoral luxation and 52.9% by pelvic fractures, underscoring the magnitude of forces required to disrupt the abductor mechanism. Because the middle and deep gluteal muscles insert onto the GT, inadequate fixation may compromise hip biomechanics and result in persistent gait abnormalities, particularly when abductor tension is not effectively neutralized.[2,3]

Several feline orthopedic conditions involving the proximal femur have demonstrated that open physes or delayed physeal closure create a mechanically vulnerable region under muscular loading. Spontaneous femoral capital physeal fractures and slipped capital femoral epiphysis have been reported predominantly in young male neutered cats with delayed physeal

Received November 26, 2025
Accepted February 3, 2026

doi.org/10.2460/ajvr.25.11.0415

closure and relatively high body weight.[4–6] Although these disorders affect different anatomic locations, they collectively highlight the susceptibility of feline physes to tensile and shear forces generated by surrounding musculature. By analogy, delayed closure of the GT physis may similarly predispose the GT to avulsion under gluteal muscle tension, particularly in juvenile cats. Reviews[7] of feline femoral fracture fixation further indicate that physeal-related injuries, including avulsion-type fractures, are most commonly observed in young cats before physeal closure, reinforcing the clinical relevance of physeal vulnerability in proximal femoral injuries.

Biomechanically, the GT serves as a major lever arm for hip abduction and extension, transmitting substantial tensile forces from the gluteal musculature to the proximal femur. The feline proximal femur is characterized by relatively thin cortices and reduced structural stiffness compared with larger species, which may increase susceptibility to bending, implant migration, or cortical failure under tensile loading.[8,9] The small size of the GT fragment and limited available bone stock further complicate stable fixation, emphasizing the need for constructs that effectively counteract gluteal tension while minimizing iatrogenic damage to the fragment.

Tension-band wiring (TBW) with parallel Kirschner wires is the conventional fixation technique, converting tensile forces into compression across the fracture interface.[10–14] However, bicortical pin TBW (BC) in cats may provide limited purchase due to short pin trajectories and thin cortices, potentially predisposing constructs to pin migration or pullout.[9] Increased cortical engagement has been shown to enhance fixation stability in tension-band constructs, including a human cadaveric biomechanical study[15] evaluating bicortical versus tricortical Kirschner wire fixation and veterinary cadaveric models of olecranon and GT fixation.[9,16] Extending the pin purchase to achieve tricortical pin TBW (TC) may therefore improve rigidity and resistance to tensile displacement by increasing the effective pin-bone interface and improving load transfer.[13,15,16]

Recent investigations[15,17,18] have explored FiberWire (Arthrex) as a nonmetallic alternative to stainless-steel wire for tension-band constructs because of its high tensile strength, flexibility, and resistance to fatigue failure. Suture-based constructs may also reduce implant prominence and soft-tissue irritation in regions with minimal soft-tissue coverage, such as the feline GT.[3] Evaluating a FiberWire-only loop fixation (FWF) allows for the isolation of the mechanical contribution of the tension band itself from that of the supporting pins and may provide insight into its potential role when pin placement is limited, such as after total hip replacement or in revision procedures.[19] Recent biomechanical studies[18,20] have shown that suture-based tension-band constructs using FiberWire can provide comparable tensile strength to metal wire while exhibiting lower stiffness and reduced resistance to rotational forces, which may influence failure behavior depending on construct configuration.

To date, no biomechanical study has directly compared fixation constructs for the feline GT fractures. This study aimed to quantify the tensile behavior of 3 constructs (BC, TC, and FWF) using a controlled cadaveric model.

The rationale for evaluating TC was based on the premise that increased cortical engagement would enlarge the functional pin-bone interface, thereby enhancing load transfer and resistance to pin migration under tensile loading. Accordingly, we hypothesized that TC would demonstrate the greatest resistance to tensile displacement and maximal load to failure, followed by BC, whereas the FWF would exhibit lower but measurable mechanical stability.

Methods

Cadaver preparation

A total of 18 cadaveric femurs were harvested from 9 adult feline cadavers that had been euthanized for reasons unrelated to the present study. The animals underwent orthopedic evaluation to exclude musculoskeletal disorders. The mean body weight was 3.77 ± 1.15 kg (range, 2.5 to 5.4 kg). The femurs were isolated by disarticulating the coxofemoral and femorotibial joints, followed by careful dissection. All soft tissues were removed except for the fascia of the piriformis, middle, and deep gluteal muscle groups. Radiographs were obtained to identify any osseous abnormalities and to confirm appropriate implant lengths. Specimens were then wrapped in gauze soaked with 0.9% saline solution and stored at −70 °C until use. Before surgical procedures, the femurs were thawed at room temperature for 24 hours

GT osteotomy model

A simulated simple transverse avulsion fracture of the GT was created by performing a standardized GT osteotomy. The GT osteotomy was performed just below the insertion of the piriformis, middle, and deep gluteal muscle complex, following a transverse plane to mimic the avulsion fracture.

Experimental procedure

The 18 prepared cadaveric hindlimbs were randomly assigned to 3 equal groups (n = 6 per group). The osteotomy site was anatomically reduced and held temporarily until definitive fixation was achieved. All fixation techniques utilized #0 FiberWire (Arthrex) for the tension band or fixation loop. Kirschner wires used in groups 1 and 2 had a diameter of 0.8 mm.

Group 1: BC—In this group, the GT fracture was stabilized using the BC technique **(Figure 1)**. Two parallel 0.8-mm Kirschner wires were inserted bicortically from the GT fragment into the femoral shaft. The Kirschner wires were inserted horizontally into the GT, aiming to be perpendicular to the fracture line, parallel to each other, and equidistant to the edges of the fragment. The ends of the Kirschner wires were bent and cut. A 0.8-mm transverse hole was drilled distal to the fracture line to anchor the tension band. The #0 FiberWire (Arthrex) was threaded through the transverse hole and configured into a figure-of-

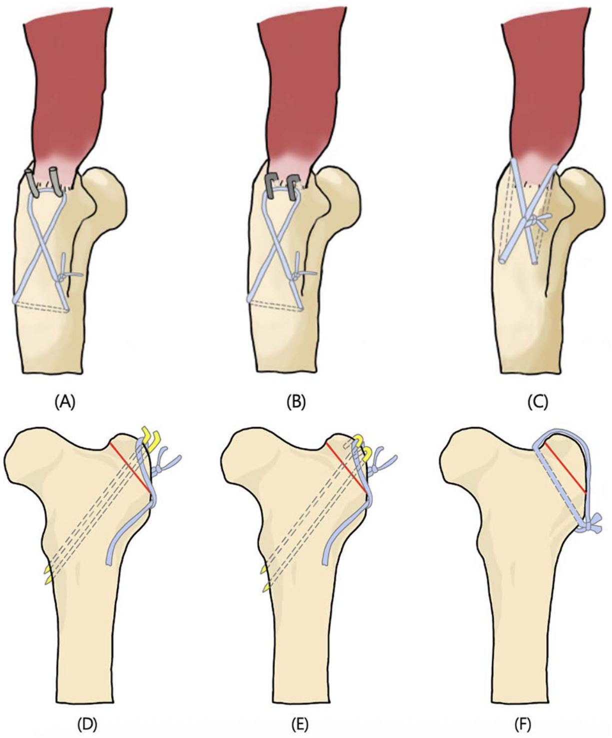

Figure 1—Mediolateral (A to C) and ventrodorsal (D to F) illustrations of the 3 fixation constructs used for feline greater trochanter fractures. A and D—Bicortical fixation with tension-band wiring (group 1): 2 parallel 0.8-mm Kirschner wires were advanced across the fracture line to engage both cortices of the proximal femur, and a figure-of-eight FiberWire loop was applied to provide compression along the osteotomy plane. B and E—Tricortical fixation with tension-band wiring (group 2): the proximal Kirschner wire trajectory included an additional purchase through the third cortex, enhancing pin pullout resistance, combined with a FiberWire figure-of-eight loop positioned in the same manner as the bicortical group. C and F—FiberWire fixation without pin support (group 3): a circumtrochanteric FiberWire loop was placed without any intramedullary pin fixation, relying solely on the suture-bone interface for stabilization.

eight pattern, looping around the exposed Kirschner wire ends to create the tension band. The suture ends were tied using the static surgeon's knot technique. To maximize knot quality and minimize potential damage to the suture material, all knots were hand tied without the use of specialized instruments.

Group 2: TC—Two parallel 0.8-mm Kirschner wires were inserted normograde fashion from the GT fragment into the femoral shaft (Figure 1). These Kirschner wires were inserted horizontally into the GT, aiming to be perpendicular to the fracture line, parallel to each other, and equidistant from the edges of the fragment. This initial insertion process was performed identically to that of group 1. A 0.8-mm transverse hole was then drilled distal to the fracture line. A #0 FiberWire (Arthrex) was passed through this hole and configured into a figure-of-eight pattern around the exposed Kirschner wire ends. The suture was hand tied using the static surgeon's knot technique. Finally, the exposed Kirschner wire tips distal to the TBW loop were trimmed to 10 mm from the GT tip and bent 180°. Because the cut wire ends were blunt, a pilot hole was created at the intended seating site in the proximal cortical bone using a 0.8-mm Kirschner wire. The bent wire ends were then gently tapped into the performed cortical recess with a mallet to achieve stable seating and minimize implant prominence.

Group 3: FWF—In group 3, the GT fragment itself remained intact with no drill holes. Instead, 2 parallel 0.8-mm vertical holes were drilled through the cortex of the proximal femoral shaft, positioned distal to the osteotomy line and approximately 5 mm apart (Figure 1). These tunnels served as the anchoring points for the fixation material. The #0 FiberWire (Arthrex) was passed sequentially through these 2 parallel vertical bone tunnels. The suture was then brought proximally over the top of the GT fragment and configured in a crossing "X" pattern on the lateral aspect of the fragment. The 2 ends were then tied together below the distal anchor tunnels using the static surgeon's knot technique to achieve stable tension and fixation of the osteotomy site, relying entirely on the suture loop and bone tunnel interface.

Biomechanical testing

The femoral diaphysis was transected at two-thirds of its length, and the distal segment was rigidly fixed to a custom wooden platform. Each specimen was mounted on a universal testing machine (Minos 100; MDTI) with the femoral axis positioned at a 135° angle relative to the direction of tensile loading to approximate the hip angle during the stance phase. The preserved gluteal fascia and tendon insertions were used as the load-application site and secured using a Krackow suture reinforced with gauze **(Figure 2)**. Rotational and translational motion was minimized by inserting 2 transverse 1.4-mm pins (Topmedical) through the femoral shaft into the platform and by placing longitudinal screws along the shaft. The muscle-tendon complex was clamped into the upper testing jig attached to the load cell. A quasistatic tensile load was applied at a crosshead speed of 10 mm/min until construct failure. Load values at 1, 2, and 3 mm of displacement were recorded, with displacement monitored continuously at the lateral aspect of the osteotomy site. Maximum failure load was defined as the point at which implant bending or breakage, pin pullout, loop disruption, or a sudden drop in the load-displacement curve occurred. A tendon-driven tensile loading model was selected because this configuration reflects the direction of physiological distraction generated by the gluteal musculature, consistent with previous trochanteric avulsion biomechanical studies[12] employing similar loading paradigms.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics (version 31.0.0.0; IBM Corp). The Kruskal-Wallis test was used for the overall

Figure 2—A photograph of the biomechanical testing. Samples were affixed to a wooden board while mimicking the normal standing joint angle by positioning the long axis of the femur at a 135° angle relative to the vertically aligned middle gluteal muscle and tendon as previously described.

comparison among the 3 fixation groups. Post hoc comparisons between groups were conducted using the Mann-Whitney *U* test, applying the Bonferroni correction for multiple comparisons. A *P* value of < .05 was considered statistically significant.

The sample size (n = 6 specimens per group) was determined based on precedent from prior feline and small-animal cadaveric biomechanical studies, which commonly employ 5 to 8 specimens per group to detect differences in fixation strength and failure behavior.

To further assess statistical adequacy, a post hoc power analysis was performed using the maximum failure load data obtained in this study, confirming that the current sample size provided a statistical power greater than 0.8 for detecting differences between pin-based constructs (BC and TC) and the pinless construct (FWF).

Results

Body weight distribution

The mean body weights of the feline cadavers were similar among all groups, indicating uniform specimen allocation. Group 1 (BC) had a mean body weight of 3.88 ± 1.19 kg, group 2 (TC) had a mean body weight of 3.78 ± 1.33 kg, and group 3 (FWF) had a mean body weight of 3.63 ± 1.15 kg (Figure 1). No statistically significant difference in body weight was found among the 3 groups (Figure 2).

Tensile loads (newtons) at 1-mm displacement

At 1-mm displacement, the mean load was highest in group 2 (TC; 177.33 ± 28.36 N), followed by group 1 (BC; 147.33 ± 52.68 N), and lowest in group 3 (FWF; 83.67 ± 16.07 N). This represented an approximate 2-fold increase in load resistance for the pin-based constructs compared with the pinless construct. Group 3 exhibited significantly lower resistance compared with both group 1 and group 2 (*P* < .05), whereas no significant difference was observed between group 1 and group 2.

Tensile loads (newtons) at 2-mm displacement

At 2-mm displacement, group 2 (TC) maintained the highest mean load (226.50 ± 23.91 N), followed by group 1 (BC; 190.67 ± 43.89 N) and group 3 (FWF; 106.67 ± 17.81 N). This corresponded to an approximately 20% higher load resistance for TC compared with BC and more than a 2-fold increase relative to FWF. Group 3 demonstrated significantly lower resistance compared with both group 1 and group 2 (*P* < .05), while the difference between group 1 and group 2 was not statistically significant.

Tensile loads (newtons) at 3-mm displacement

At 3-mm displacement, group 2 (TC) showed the greatest mean load (266.50 ± 20.02 N), followed by group 1 (BC; 221.50 ± 19.25 N) and group 3 (FWF; 126.00 ± 19.47 N). At this displacement threshold, TC demonstrated higher mean load resistance than both BC (mean difference, 45.0 N; 95% CI, 19.7 to 70.3 N) and FWF (mean difference, 140.5 N; 95% CI, 115.1 to 165.9 N). The separation between constructs widened at this displacement, with the TC demonstrating approximately 20% greater load resistance than the BC and more than twice the resistance of the FWF **(Table 1; Figure 3)**.

Maximum failure load (newtons)

For the maximum failure load, all groups exhibited statistically distinct results (*P* < .05). The TC construct sustained approximately 30% greater maximal load than BC and more than double the failure load observed in FWF. Group 2 (TC) achieved the highest mean failure load (318.50 ± 39.69 N), which was significantly greater than group 1 (BC; 245.17 ± 34.33 N), and both were significantly higher than group 3 (FWF; 145.83 ± 19.93 N; detailed load values are presented in Table 1, and the distribution is shown in Figure 3).

Modes of failure in the tensile test

Failure patterns differed by construct **(Table 2)**. In group 1 (BC), the predominant mode was Kirschner wire migration or pullout in 4 of 6 (66.7%) specimens, with trochanteric fragment fracture in 1 of 6 (16.7%) and suture loosening in 1 of 6 (16.7%). In group 2 (TC), failure modes were Kirschner wire migration or pullout in 3 of 6 (50.0%), trochanteric fragment fracture in 2 of 6 (33.3%), and suture loosening in 1 of 6 (16.7%). In contrast, group 3 (FWF), which lacked pin support, failed via the suture-bone interface with suture loosening in 4 of 6 (66.7%), suture slippage in

Table 1—Tensile loads (newtons) and maximum failure loads (newtons) of the 3 fixation constructs in the simulated feline greater trochanter (GT) avulsion model (mean ± SD).

Parameter	Group 1 (n = 6)	Group 2 (n = 6)	Group 3 (n = 6)
Loads at 1-mm displacement (N)	147.33 ± 52.68[a]	177.33 ± 28.36[a]	83.67 ± 16.07[b]
Loads at 2-mm displacement (N)	190.67 ± 43.89[a]	226.50 ± 23.91[a]	106.67 ± 17.81[b]
Loads at 3-mm displacement (N)	221.50 ± 19.25[b]	266.50 ± 20.02[a]	126.00 ± 19.47[c]
Maximum failure load (N)	245.17 ± 34.33[b]	318.50 ± 39.69[a]	145.83 ± 19.93[c]

Group 1 = Bicortical fixation with tension-band wiring. Group 2 = Tricortical fixation with tension-band wiring. Group 3 = FiberWire fixation without pin.

[a,b,c] Values with different superscripts differ significantly ($P < .05$).

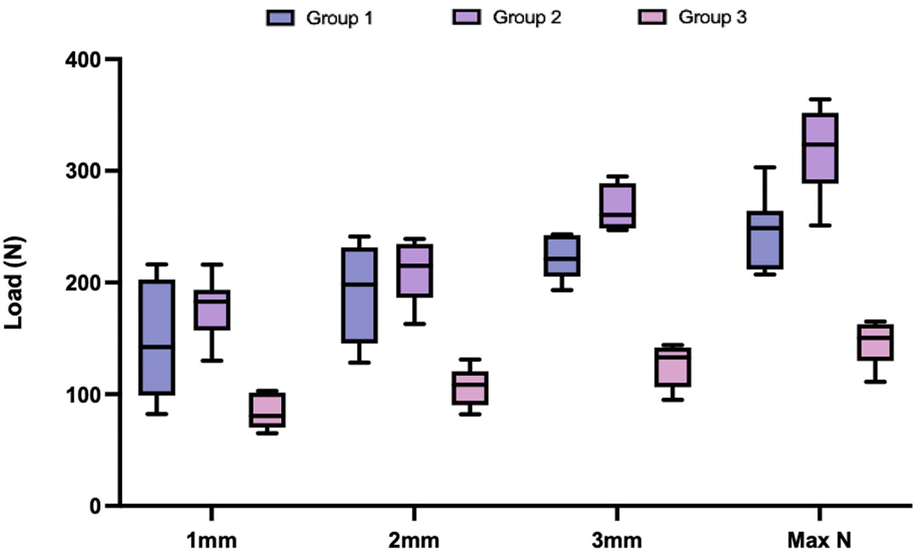

Figure 3—Load-displacement responses at 1-, 2-, and 3-mm displacement (newtons) and maximum (Max) failure load (newtons) for the 3 fixation groups. Across all displacement points, the tricortical group (group 2) consistently demonstrated the highest load tolerance, followed by the bicortical group (group 1). The FiberWire-only construct (group 3) showed the lowest values throughout testing, including at the maximum failure load.

Table 2—Modes of failure observed during tensile testing of the feline GT fixation constructs.

Group	Modes of failure
Group 1 (BC)	Kirschner wire migration or pullout (n = 4), trochanteric fragment fracture (n = 1), and suture material loosening (n = 1)
Group 2 (TC)	Kirschner wire migration or pullout (n = 3), trochanteric fragment fracture (n = 2), and suture material loosening (n = 1)
Group 3 (FWF)	Suture material loosening (n = 4), suture material slippage (n = 1), and suture material cut through the bone (n = 1)

Summary of the specific failure mechanisms and anatomical locations identified at the point of ultimate failure during vertical tensile loading in a simulated feline GT avulsion fracture model. Failure modes were classified based on primary site and mechanism of construct failure for each fixation group, including Kirschner wire migration or pullout, trochanteric fragment fracture, and suture-related loosening, slippage, or cut through (n = number of specimens).

BC = Bicortical fixation with tension-band wiring. FWF = FiberWire-only fixation without pin support. TC = Tricortical fixation with tension-band wiring.

1 of 6 (16.7%), and suture cut through the bone in 1 of 6 (16.7%). Collectively, pin-related constructs (BC and TC) tended to fail through hardware migration or pullout or focal fragment fracture, whereas the pinless construct (FWF) predominantly failed through loss of suture purchase at the loop-bone interface.

Discussion

This study compared 3 fixation methods for feline GT avulsion fractures (BC, TC, and FWF) to evaluate their biomechanical stability under quasi-static tensile loading. The TC exhibited the highest load-bearing capacity at both 3-mm displacement and maximum failure load, followed by the BC, whereas the FWF displayed the weakest mechanical stability. These findings correspond with previous studies emphasizing that greater cortical engagement enhances fixation strength by increasing the effective moment arm, frictional surface, and bone-implant interface.[12,16] Furthermore, these results underscore the biomechanical importance of maximizing the conversion of tensile forces into compression across the fracture gap.[13,15,17,21]

The superior performance of the TC configuration aligns with the mechanical principles, suggesting that engaging additional cortices improves rigidity and resistance to tensile and torsional loads. The added cortical purchase likely increased frictional resistance and extended the load path through the femoral shaft, thereby delaying failure under tensile stress. These results also mirror the findings of Jo[16] and Kim,[12] who demonstrated that enhanced cortical engagement or compression fixation increased pullout strength in canine trochanteric models. Collectively, the evidence supports that maximizing cortical contact improves mechanical performance under axial traction. In addition to axial tensile loading, the GT is subjected to rotational and shear forces generated by the oblique lines of action of the middle and deep gluteal muscles during hip abduction and propulsion. While TBW is primarily designed to neutralize tensile forces by converting them into compression across the fracture interface, its ability to resist rotational displacement is inherently dependent on the rigidity and cortical engagement of the supporting fixation. Accordingly, increased pin purchase, such as TC, may enhance resistance to rotational forces by improving construct stiffness and limiting micromotion at the pin-bone interface.

However, despite this mechanical superiority, the clinical significance of the TC configuration may be limited. At physiologic displacement levels (≤ 2 mm), corresponding to tensile forces generated during normal ambulation or controlled weight bearing,[8,22] no significant difference was found between BC and TC constructs. Both constructs therefore appear to provide adequate resistance to early postoperative loads. The advantage of TC engagement becomes apparent only under supraphysiologic or traumatic stress, suggesting limited relevance to typical feline gait conditions. Furthermore, in practice, the TC approach is technically demanding and time-consuming, requiring careful trajectory control to prevent cortical blowout.

Notably, the TC group exhibited a higher incidence of iatrogenic trochanteric fragment fracture (n = 2) compared with the BC group (1). This observation warrants biomechanical attention. While engaging 3 cortices improves pullout resistance, it simultaneously increases the bending moment and local stress concentration within the small trochanteric fragment. In cats, the GT is thin walled and cortically delicate,[9] and deeper pin penetration across 3 cortices may act as a stress riser, amplifying localized strain near the pin exit site. According to the lever-arm principle, tricortical pins distribute load along a longer mechanical axis, generating higher torque and bending forces at the proximal pin-bone interface.[11,13] When applied to a small fragment with limited bone stock, this results in cortical splitting and propagation of microfractures, as confirmed in the current model. The feline femur's relatively low elastic modulus makes it susceptible to structural compromise.[9] Thus, the TC configuration represents a trade-off between maximizing mechanical purchase and preserving fragment integrity: a critical consideration for clinical decision-making in small patients.

In contrast, the BC configuration demonstrated consistent mechanical performance across all displacement levels and no catastrophic failure under the test conditions. Its strength comfortably exceeded physiologic tensile loads of the gluteal musculature, which range between approximately 20 N during walking and 75 N during landing from a 1-m jump.[22,23] Combined with simpler execution, shorter operative time, and lower risk of fragment comminution, the BC construct remains the most clinically practical and biomechanically sufficient option for most feline GT fractures or osteotomies.

Importantly, the loads sustained by all constructs exceeded estimated physiologic tensile forces associated with routine feline ambulation, suggesting that each fixation method may provide sufficient stability under normal postoperative conditions.

The FWF construct displayed the weakest tensile resistance yet exhibited a distinct failure mode. All failures were related to suture loosening, slippage, or cut through of bone, consistent with the mechanical behavior of FiberWire (Arthrex), which provides high tensile strength but limited stiffness and micromotion resistance.[18,19] Although sutures exhibit greater movement under low compressive force compared with cables,[21] the absence of metallic pins means the FWF construct lacks the shear resistance and antirotational stability normally supplied by the Kirschner wire moment arm. Once the loop-bone interface begins to slip, there is no internal reinforcement to oppose translation or torsion, leading to an abrupt loss of fixation. This explains why suture loosening is more catastrophic in the FWF construct than in Kirschner wire-based constructs, where metal deformation allows for gradual energy dissipation before failure. Recent biomechanical evaluations of alternative tension-band configurations further indicate that variations in fixation geometry and material properties significantly influence construct stiffness and failure patterns, particularly under nonaxial and rotational loading conditions.[24–27]

The mechanical behavior observed in all constructs should be interpreted within the anatomical and physiologic framework of feline hindlimb biomechanics. Cats exhibit lower peak ground reaction forces than dogs,[22] and their gluteal muscles primarily function in abduction and propulsion rather than sustained load bearing.[1,2] Consequently, even the weakest construct tested in this study (FWF) withstood loads several times greater than estimated physiologic tensile forces generated during normal feline ambulation. These results imply that, under normal activity, each fixation method can provide sufficient stability for biological healing. Differences among constructs become relevant primarily under abnormal or high-impact conditions such as traumatic reinjury or unrestricted early ambulation.

Nonetheless, several limitations must be recognized. A stainless-steel wire TBW control and other commonly used clinical constructs were not included, as the study was designed to standardize the tension-band material and isolate the biomechanical effects of pin-bone engagement. The testing protocol employed uniaxial, quasistatic loading, which evaluates ultimate strength but not fatigue resistance under cyclic or multidirectional forces. In vivo, the trochanteric region experiences complex loading vectors produced by the gluteal and rotator muscle groups. Future investigations employing dynamic cyclic testing, micro-CT morphometric assessment, or finite element modeling would provide greater insight into construct fatigue performance and load distribution. Moreover, anatomical variability among feline specimens, including bone density, muscle insertion geometry, and cortical thickness, could have influenced load-transfer patterns, as noted by Nurra et al.[1] The cadaveric design also excludes biological healing responses, which could alter fixation longevity and clinical outcomes.

In conclusion, the TC construct achieved superior mechanical resistance at higher displacement but was associated with a higher incidence of trochanteric fragment fracture in this ex vivo model, underscoring the need to balance strength with preservation of fragment integrity. The BC configuration remains the most practically applicable and biomechanically reliable fixation method for feline GT repair, offering adequate stability within physiologic limits and favorable handling characteristics. The FWF construct, although mechanically weaker, may serve as a supplementary or load-sharing fixation option in clinical scenarios where pin insertion is not feasible or when additional reinforcement of soft-tissue attachment is required. The FWF may be considered when intramedullary access is limited (eg, following total hip replacement with a femoral stem). These findings should be interpreted in light of the study's ex vivo cadaveric design and the absence of clinical outcome data. Accordingly, fixation selection should consider not only peak mechanical strength but also surgical feasibility, preservation of bone integrity, and the specific biomechanical environment of the feline hip. Further studies incorporating cyclic loading protocols and clinical follow-up are warranted to refine fixation strategies and optimize outcomes in feline GT repair.

Acknowledgments

None reported.

Disclosures

The authors have nothing to disclose. No AI-assisted technologies were used in the composition of this manuscript.

Funding

The authors have nothing to disclose.

ORCID

Yookyeong Lee https://orcid.org/0000-0003-1277-0590
Sang-Kun Jang https://orcid.org/0009-0002-7128-5886
Jaewon Do https://orcid.org/0009-0009-1173-0213
Min-Young Kim https://orcid.org/0009-0009-6194-2222
Sangyul Lee https://orcid.org/0009-0006-5984-4381
Jung Mun Kim https://orcid.org/0000-0002-6425-7716
Hwi-Yool Kim https://orcid.org/0000-0001-6237-9958

References

1. Nurra G, Pilot M, Grek-Fritzner B, Coppola M, Grierson JM, Langley-Hobbs S. Fracture of the greater trochanter of the femur in 17 cats: imaging, clinical features and concurrent injuries. *J Feline Med Surg.* 2025;27(4):1098612X241305918. doi:10.1177/1098612X241305918
2. Swanson EA, Tomlinson JL, Dismukes DI, Fox DB. Measurement of femoral and tibial joint reference angles and pelvic limb alignment in cats. *Vet Surg.* 2012;41(6):696–704. doi:10.1111/j.1532-950X.2012.00996.x
3. Johnston S, Tobias K. *Veterinary Surgery, Small Animal.* 2nd ed. Elsevier; 2018:1050–1065.
4. McNicholas WT, Wilkens BE, Blevins WE, et al. Spontaneous femoral capital physeal fractures in adult cats: 26 cases (1996–2001). *J Am Vet Med Assoc.* 2002;221(12):1731–1736. doi:10.2460/javma.2002.221.1731
5. Craig LE. Physeal dysplasia with slipped capital femoral epiphysis in 13 cats. *Vet Pathol.* 2001;38(1):92–97. doi:10.1354/vp.38-1-92
6. Borak D, Wunderlin N, Brückner M, Schwarz G, Klang A. Slipped capital femoral epiphysis in 17 Maine Coon cats. *J Feline Med Surg.* 2017;19(1):13–20. doi:10.1177/1098612X15598551
7. Roberts VJ, Meeson RL. Feline femoral fracture fixation: what are the options? *J Feline Med Surg.* 2022;24(5):442–463. doi:10.1177/1098612X221090391
8. Beck AL, Pead MJ, Draper E. Regional load bearing of the feline acetabulum. *J Biomech.* 2005;38(3):427–432. doi:10.1016/j.jbiomech.2004.04.035
9. Gibson TWG, Moens NMM, Runciman RJ, Holmberg DL, Monteith GM. The biomechanical properties of the feline femur. *Vet Comp Orthop Traumatol.* 2008;21(4):312–317. doi:10.3415/VCOT-07-08-0077
10. Charnley J, Ferreira ADSD. Transplantation of the greater trochanter in arthroplasty of the hip. *J Bone Joint Surg Br.* 1964;46(2):191–197. doi:10.1302/0301-620X.46B2.191
11. Clark CR. Biomechanical efficacy of greater trochanteric fixation. *J Orthop Res.* 1983;(3):76–80.
12. Kim JH. *Comparative Study of Tensile Strength between Two Types of Headless Screws in Canine Greater Trochanteric Avulsion Fractures*. Master's thesis. Konkuk University; 2025.
13. Markolf KL, Hirschowitz DL, Amstutz HC. Mechanical stability of the greater trochanter following osteotomy and reattachment by wiring: *Clin Orthop.* 1979;141:111–121. doi:10.1097/00003086-197906000-00013
14. Johnson K. *Piermattei's Atlas of Surgical Approaches to the Bones and Joints of the Dog and Cat.* 5th ed. Elsevier/Saunders; 2014:350–362.
15. Nowotny J, Bischoff F, Ahlfeld T, et al. Biomechanical comparison of bi- and tricortical k-wire fixation in tension band wiring osteosynthesis. *Eur J Med Res.* 2019;24(1):33. doi:10.1186/s40001-019-0392-7
16. Jo J. *Proximal Bicortical K-Wire Fixation as a Potential Surgical Option for Olecranon Fracture Stabilization a Canine Cadaveric Study*. Master's thesis. Konkuk University; 2025.
17. Thompson E, Robe AK, Roe SC, Cole JH. Evaluating wire configurations for tension band constructs using a canine greater trochanteric osteotomy model. *engrXiv*. Preprint posted online May 21, 2018. doi:10.31224/osf.io/5yfsx
18. Hwang BM, Kim MS. Biomechanical comparison of metal wire and FiberWire as tension band techniques: an ex vivo study. *Iran J Vet Res.* 2021;22(2):150–154. doi:10.22099/ijvr.2021.37914.5523
19. Nimura A, Nakagawa T, Wakabayashi Y, Sekiya I, Okawa A, Muneta T. Repair of olecranon fractures using fiberWire without metallic implants: report of two cases. *J Orthop Surg.* 2010;5(1):73. doi:10.1186/1749-799X-5-73
20. Lee MY, Ahn TH, Son SI, Kim HY. Biomechanical evaluation of three fixation methods in a feline transverse patella fracture model. *J Feline Med Surg.* 2023;25(5):1098612X231172630. doi:10.1177/1098612X231172630
21. Plausinis D, Speirs AD, Masri BA, Garbuz DS, Duncan CP, Oxland TR. Fixation of trochanteric slide osteotomies: a biomechanical study. *Clin Biomech.* 2003;18(9):856–863. doi:10.1016/S0268-0033(03)00148-7
22. Schnabl E, Bockstahler B. Systematic review of ground reaction force measurements in cats. *Vet J.* 2015;206(1):83–90. doi:10.1016/j.tvjl.2015.05.017
23. Song Y, Wang M, Steven Baker J, Gu Y. The loading characteristics of landing in cats with different body weights. *Vet Med.* 2019;64(11):497–504. doi:10.17221/13/2019-VETMED
24. Natsios P, Capaul R, Kopf N, Pozzi A, Tinga S, Park B. Biomechanical evaluation of a fixation technique with a modified hemicerclage for tibial tuberosity transposition:

an ex vivo cadaveric study. *Front Vet Sci.* 2024;11: 1375380. doi:10.3389/fvets.2024.1375380

25. Calisal E, Uğur L. Olecranon fractures: a biomechanical comparison of three tension band wiring fixation methods on bone models. *J Orthop Surg.* 2023;31(3): 10225536231223109. doi:10.1177/10225536231223109
26. Friedman LGM, Quigley R, Shewman E, Kirsch J, Freehill MT, Garrigues GE. Comparison of mechanical properties between Nice knot, Modified Nice knot, and surgeon's knot. *Clin Biomech.* 2021;90:105486. doi:10.1016/j.clinbiomech.2021.105486
27. Choo Y, Kim J, Cho JS, Kim S, Kim HY. Screw with tension band wiring method is an acceptable alternative to pins with tension band wiring in a canine cadaver model of extra-articular olecranon fracture. *Am J Vet Res.* 2025;86(7):ajvr.24.12.0375. doi:10.2460/ajvr.24.12.0375