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Effects of Reduction Pin on Tibial Tuberosity Fractures After Tibial Tuberosity Advancement in Dogs: A Retrospective Comparative Study

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Abstract **–**Tibial Tuberosity Advancement (TTA) is commonly performed to restore stifle stability in dogs with cranial cruciate ligament rupture. Despite generally favorable outcomes, distal tibial tuberosity fracture remains a recognized complication. This study evaluated whether intraoperative placement of a reduction pin during TTA influences fracture incidence and severity. Medical records and postoperative radiographs of 62 dogs undergoing unilateral TTA were retrospectively reviewed. Dogs were divided according to intraoperative pin usage: pin group (n = 21) and no-pin group (n = 41). Follow-up radiographs were assessed for fracture presence, timing, and morphology. Fractures were categorized as nondisplaced or avulsion with displacement. Incidence and morphology were compared using Fisher's exact test. Distal tibial tuberosity fractures occurred in 4/21 dogs (19.0%) in the pin group and 9/41 dogs (22.0%) in the no-pin group, with no significant difference in overall incidence. However, fracture morphology differed significantly between groups. The pin group predominantly developed nondisplaced fractures, whereas the no-pin group showed a higher proportion of avulsion-type fractures. Use of a reduction pin was associated with an approximately 90% decrease in the probability of avulsion. In conclusion, although the placement of a reduction pin did not reduce the overall incidence of distal tibial tuberosity fractures after TTA, its use was associated with a reduction in fracture severity by limiting avulsion-type failures. These findings suggest a protective role of the reduction pin against distal tibial tuberosity avulsion following TTA.

Keywords – Tibial tuberosity advancement, cranial cruciate ligament rupture, Tibial tuberosity fracture, porous titanium cage

I. INTRODUCTION

Cranial cruciate ligament (CrCL) rupture is one of the most common causes of pelvic limb lameness and requires surgical stabilization to restore function and reduce progressive degenerative changes [4]. Some of the techniques in the management of this pathology have been the development of biomechanical procedures based on osteotomy that neutralize cranial tibial thrust by changing the geometry of the leg muscle [10],[16]. In this way, one of the surgical techniques is the advancement of the tibial tuberosity (TTA) by advancing the tibial tuberosity to reposition the angle of the patellar tendon, thus reducing or eliminating cranial tibial displacement during weight bearing [8]. Over time, the original TTA has undergone numerous improvements and variations (e.g., changes in cage/plate design and modified tuberosity advancement techniques) but all with the goal of maintaining clinical efficacy and reducing morbidity. Previous studies indicate that the TTA family of techniques generally provide favorable outcomes for CrCL insufficiency; however, complications both minor and major remain clinically important and may impact recovery, reoperation rates, and owner-perceived success [1],[2]. Among the reported complications, which is consistently recognized as a potential risk of the procedure is fracture or tear of the tibial tuberosity (including distal extension at the end of the osteotomy). Tibial tuberosity fracture after TTA has been described in several studies, sometimes requiring revision surgery depending on the displacement, implant stability, and integrity of the extensor mechanism. In a clinical study, Calvo et al characterized tibial tuberosity fracture as a complication of TTA, noting that while the prognosis may be favorable, morbidity may be significant and revision may be required in selected cases [3]. A review of the relevant literature examining tibial tuberosity fracture patterns has highlighted potential subsequent consequences for joint health and recovery in relation to clinical and radiographic outcomes, including progression of osteoarthritis [5],[18]. Thus, since tibial tuberosity failure is essentially a structural complication of an osteotomized and loaded extensor mechanism, preventive strategies have been proposed to reduce the initiation or propagation of fractures and to increase early mechanical safety until consolidation of the osteotomy. Adaptations of techniques, such as pre-drilled holes (Maquet Holes), have been discussed as potential mitigations for distal spread, although debate continues regarding their necessity and optimal execution, and robust comparative clinical data remain limited [6],[12],[18]. At the same time, concepts of prophylactic fixation have also been explored in canine stifle osteotomy procedures, where tibial tuberosity fracture is also a known complication. Ex vivo work in TPLO has shown that pin placement can measurably affect the biomechanical resistance of the tibial tuberosity under tensile loading, supporting the principle that additional pin constructs may be a modifiable variable to reduce fracture risk. While such findings cannot be assumed to translate directly to all procedures, they strengthen the mechanistic rationale for evaluating prophylactic fixation strategies in TTA cohorts in the clinical setting [9]. Given the clinical significance of tibial tuberosity fracture/tear after TTA, and the plausible mechanistic basis for prophylactic augmentation, the objective of this study was to evaluate whether prophylactic Steinmann pin placement reduces the incidence and morphology of tibial tuberosity fractures after TTA osteotomy and implant placement.

II. Materials and Method

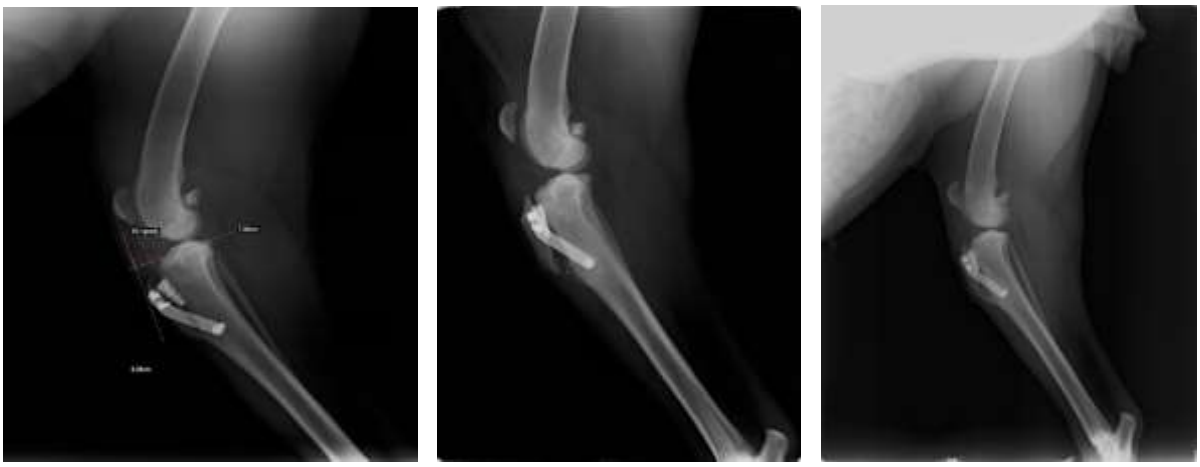
Medical records of dogs treated with TTA surgery with porous titanium scaffolds were reviewed from March 2023 to October 2025 at the Department of Surgical Clinics (DiMePRe-J) of the University of Bari Aldo Moro, Italy. Inclusion criteria for this study included dogs with complete clinical data available, availability of preoperative, postoperative, 1-month, and 2-month postoperative radiographs showing no implant failure, and no complications other than fissures or fractures of the tibial tuberosity. Dogs were excluded from the study if concomitant procedures had been performed on the tibia (tibial transposition, tibial translocation), concurrent orthopedic disease affecting the contralateral limb, other reported complications, and X-rays that were not available 2 months after surgery. Dogs were divided into two groups based on the surgeon's intraoperative decision to reduce the risk of tibial tuberosity fracture: those who received an in situ Steinmann reduction pin at the time of TTA osteotomy (group 1 with pin) and those who underwent TTA without an in situ reduction pin (group 2 No-Pin). The pin was positioned to provide additional mechanical support to the tibial tuberosity after osteotomy and implant placement. All

TTA surgical procedures were performed by board-certified surgeons with more than 5 years of experience performing TTA. For each patient enrolled in the study at the time of surgery, the breed, weight, sex, age, body condition, implants used, and complications up to the 1- and 2-month follow-up examinations were recorded.

Surgical Procedure: On the medial side of the limb, the soft tissues were carefully dissected so as not to cause damage to the patella, patellar tendon, and stifle joint ligaments. A Maquet hole was created on the medial surface of the distal tibial tuberosity. Using a dedicated guide, an osteotomy of the tibial tuberosity was performed, where the osteotomy site was then gradually distracted with a distractor to allow placement of a porous titanium cage within the osteotomy gap. Subsequently, a specially designed titanium plate was positioned on the cranial aspect of the osteotomized tibial tuberosity and fixed to the tibial shaft using three screws, thus completing the procedure. After completing this procedure in cases of suspected fissure, a 2 mm Steinmann pin was used as a reduction pin which was placed perpendicular to the tibial mechanical axis, near the Mauqet hole (Figure 1) until it was embedded in the caudal tibial cortex.

(a) (b) (c)

Fig. 1. Representative mediolateral radiographic views obtained at consecutive postoperative evaluations of a case included in the (TTA) group with pin reduction in situ . (a) immediately after surgery , b) 1 month postoperatively, and (c) 2 months after surgery



(a) (b) (c)

Fig. 2**.** Representative mediolateral radiographic views obtained in consecutive postoperative evaluations of a case included in the (TTA) group without additional pin reduction. (a) immediately postoperatively, (b) 1 month postoperatively, and (c) 2 months postoperatively. The radiographic evaluation at time points illustrates the progression of osteotomy healing and implant positioning over time

Radiographic Evaluation: Mediolateral and anteroposterior radiographs of the limbs were reviewed at four time points (preoperative, immediate postoperative, 1 and 2 months postoperative) for each patient to assess the surgical procedure, fissures or fractures, implants, and scaffold osseointegration (Fig. 2). Preoperative and immediate postoperative radiographs were evaluated for TPA. The incidence of distal tibial tuberosity fractures was compared between the Pin and No-Pin groups.

Statistical analysis: Univariate and multivariate logistic regression analysis was used to assess the binary outcome of tibial tuberosity fracture and the association between pin placement and fracture occurrence/fracture morphology. The Fisher exact test was used to assess differences in the incidence of tibial tuberosity fractures between groups. Radiographic outcomes were analyzed using non-parametric tests; with between-group comparisons performed using the Mann-Whitney U test and within-group comparisons over time using the Friedman test. The level of statistical significance was set at $p < 0.05$.

III. Results

Population: A total of 83 dogs were included in our study, of which sixteen cases met the inclusion criteria. Twenty-two cases did not reach the 2-month postoperative follow-up, did not return for radiographic recheck or did not have complete clinical examinations and X-rays. Twenty-one dogs were assigned to Group 1 (TTA with pin) and 41 dogs to Group 2 (TTA without pin). In Group 1, 6 dogs (28.6%) were male and 15 (71.4%) were female, while Group 2 consisted of 17 males (41.5%) and 24 females (58.5%). The sizes of titanium cages used during TTA ranged from 4.5 to 15 mm, with 10.5 mm cages being implanted most frequently (n = 26). A 2 mm smooth reduction pin (without thread) was used in all dogs in Group 1, regardless of cage size. The mean age at surgery was 4.9 ± 3.2 years for Group 1 and 5.3 ± 2.9 years for Group 2. The most common breeds were mixed breeds (41.4%), Labrador retriever (23%), Pitbull (8.5%), American Pit Bull Terrier (12.1%), Cane Corso (3.2%), Golden Retriever (6.4%), Turkmen Alabai (5.4%). The mean weight for Group 1 was 31.4 ± 17.9 kg and Group 2 was 35.7 ± 19.7 kg. ***Radiographic Evaluation:*** In the group treated with an in situ reduction pin (Group 1), 4 of 21 dogs (19.0%) developed a fracture of the distal tibial tuberosity, while 17 dogs (81.0%) showed no radiographic evidence of fracture. In the group treated without a pin (Group 2), fractures were detected in 9 of 41 dogs (22.0%), with 32 dogs (78.0%) having no fractures (Figure 3). None of the fractures in this group required reoperation, and they were treated conservatively. No statistically significant difference in the incidence of distal tibial tuberosity fractures was detected between the groups. Univariate logistic regression analysis showed that in situ reduction pin placement was not significantly associated with fracture occurrence ($p > 0.05$). In contrast, in the no-pin group (n = 9 fractures), 8/9 fractures (88.9%) were displaced avulsion fractures, while 1/9 (11.1%) were nondisplaced (Fig. 4). No avulsion events were observed in dogs treated with a reduction pin (0/21), whereas avulsions occurred in 9 of 41 dogs (22.0%) without pin placement (Fig. 5). Fisher's exact test showed a statistically significant association between the absence of a pin and the occurrence of avulsion ($p = 0.0223$). Firth's logistic regression yielded an odds ratio of 0.08 (95% CI: 0.004–1.44), indicating a significant reduction in the odds of avulsion in dogs treated with a reduction pin. This confirms a statistically significant association between the absence of an in situ reduction pin and the occurrence of tibial tuberosity avulsion, with dogs treated with a pin having approximately 90% less odds of avulsion compared to dogs without a pin.

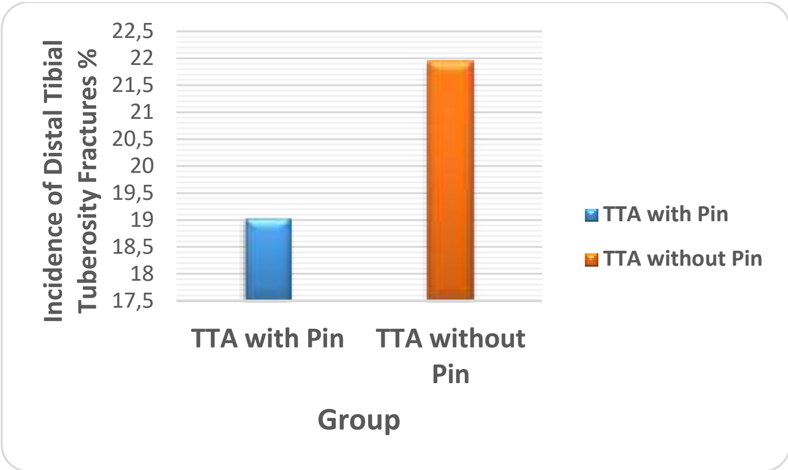


Fig. 3. Graphical representation of the incidence of distal tibial tuberosity fractures after tibial tuberosity advancement (TTA) with and without the placement of a 2 mm Steinmann reduction pin. Fractures were identified in 4/21 dogs (19.0%) in the pin group and 9/41 dogs (22.0%) in the no-pin group. Univariate logistic regression analysis showed no statistically significant association between reduction pin placement and overall fracture incidence ($p > 0.05$)

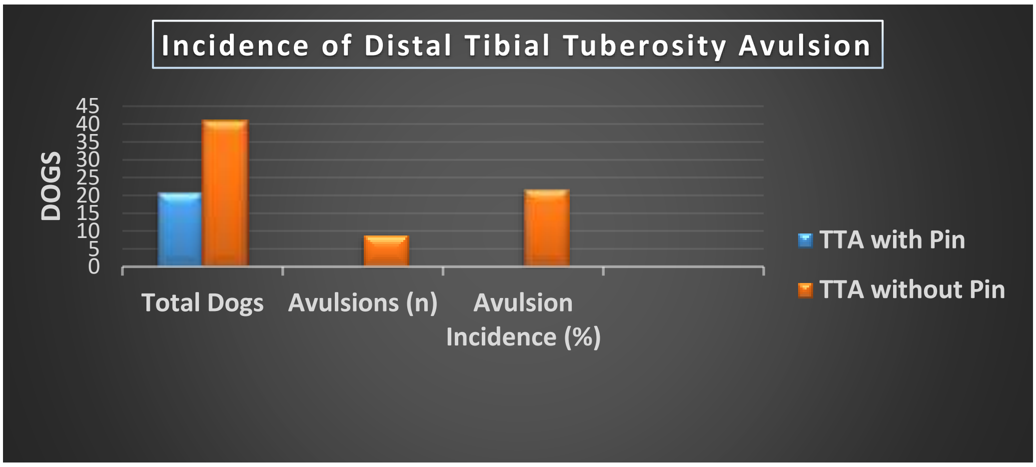


Fig. 4. Graphical representation of the incidence of avulsion fractures of the distal tibial tuberosity adjacent to the Maquet hole in dogs undergoing TTA. No avulsion events were observed in the needle group (0/21; 0%), whereas avulsions occurred in 9/41 dogs (22.0%) without needle placement. Fisher's exact test revealed a statistically significant association between the absence of a reduction pin and the occurrence of avulsion ($p = 0.0223$). Firth's logistic regression yielded an odds ratio of 0.08 (95% CI: 0.004–1.44), indicating significantly lower odds of avulsion in dogs treated with a reduction pin

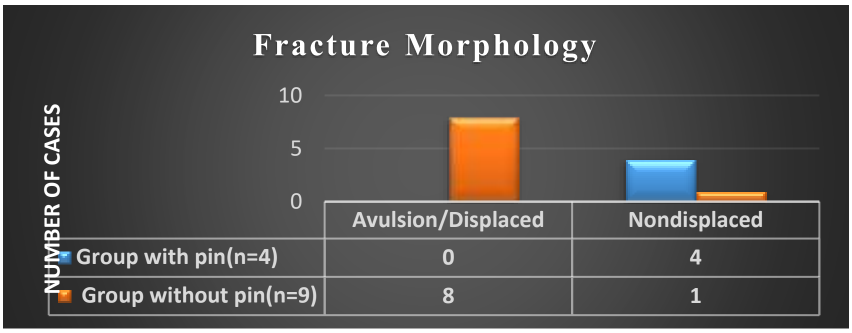


Fig. 5. Graphical representation of the distribution of fracture morphology among dogs that developed distal tibial tuberosity fractures. These findings suggest that pin placement may affect the severity of the fracture pattern rather than the overall incidence of fractures

Descriptive data, including body weight, failure modes, preoperative tibial plateau angle, and postoperative plateau angle are described in Tab.1. Values are presented as mean± standard deviation. No significant difference was detected any gropups at any measurement time point P>0.05.

Table 1**.** Comparison of baseline demographic and radiographic parameters between dogs treated with tibial tuberosity advancement (TTA) with in situ reduction pin placement (Group 1) and without pin placement (Group 2)

	Group 1 with pin	**Group 2 without pin**	***p* value**
Body wheight	31.4±17.9	35.7±19.7	0.39
Preoperative TPA	23.34±3.27	23.41±3.46	0.94
Postoperative TPA	5.33±3.43	5.31±3.23	0.98
Post /pre angle difference	18.01	18.10	0.91
Failure mode	n=4 distal tibial tuberosity fracture without avulsion	n=8 distal tibial tuberosity fracture with avulsion n=1 distal tibial tuberosity fracture without avulsion	

Statistical analysis of these data indicates that pin placement did not affect surgical extension outcomes, but was associated with a change in fracture morphology, potentially reflecting altered load transmission to the distal tibial tuberosity during weight-bearing in the early postoperative phases.

IV.DISCUSSION

In this retrospective comparative study of dogs undergoing tibial tuberosity advancement (TTA) with a porous titanium implant, the overall incidence of distal tibial tuberosity fracture after tibial tuberosity advancement (TTA) with a porous titanium cage did not differ significantly between dogs treated with or without a Steinmann reduction pin in situ . Tibial tuberosity fracture is a known complication of TTA and previous retrospective studies have demonstrated variable incidences of tibial tuberosity fractures depending on surgical technique in approximately 1-4% of dogs following TTA procedures. Although higher rates have been observed, with Crovace et al. describing a 20% incidence of tibial tuberosity tear or fracture through the Maquet hole [3],[5]. In particular, the Maquet hole has been consistently identified as a preferential site for limiting the spread of distal osteotomy to the target site, suggesting that it functions as a local stress concentrator within the proximal tibia [11],[17]. After TTA, redistribution of load along the tibial crest alters native biomechanics, and disruption of the distal cortex may increase strain within the tibial tuberosity, predisposing to avulsion or fracture if distal support is inadequate. Surgical variables—including the width of the distal osteotomy, implant positioning—have been identified as important contributors to fracture risk, with previous work demonstrating an association between osteotomy configuration and the occurrence of tibial tuberosity fracture [13]. Thus, the potential protective effect of a pin may help to alleviate peak stresses at the terminal osteotomy. This interpretation is consistent with broader orthopaedic principles, where supplemental fixation (e.g., tension band wiring or bicortical pin constructs) has been shown to increase resistance to tensile forces at osteotomy sites and reduce the incidence of fracture propagation [13]. However, detailed radiographic evaluation in our study revealed that fractures were present in both groups, but most of the fractures in the pin group were incomplete and non displaced, whereas the fractures in the non pin group were mostly true avulsion fractures with displacement. This observation is very important, as displacement and avulsion of the tibial tuberosity are generally considered to be the clinical sequelae of this complication. Calvo et al. noted that although tibial tuberosity fractures after TTA often have a favourable prognosis. However, current results suggest that even when cortical failure occurs, the presence of a reduction pin may mitigate progression to avulsion. Experimental and cadaveric studies evaluating tibial tuberosity advancement and associated osteotomy techniques have shown that adjunctive fixation such as Kirschner or Steinmann pins, tension band constructs, or combined fixation systems can increase construct stiffness, reduce micro motion, and increase load thresholds to failure before biologic healing [7],[14],[20]. In the present group, the reduction pin was placed distally within the tibial tuberosity, engaging the region most susceptible to tensile loading. Radiographically, this configuration appeared to provide sufficient mechanical restraint to limit fragment displacement. This interpretation is consistent with experimental findings in a study from the TPLO literature, where it was demonstrated that protective benefit depends on proper pin placement intersecting the predicted plane of failure in traction, which significantly increases resistance to tibial tuberosity avulsion [9],[15]. All fractures in this study were identified on radiographic evaluation at 1 month postoperatively, with no new fractures detected at 2 months. This time pattern is consistent with large clinical series reporting that complications related to the tibial tuberosity occur early, before significant healing of the osteotomy occurs [11],[19].

IV. CONCLUSION

Based on the results of our study, we can conclude that in situ reduction pin placement does not necessarily prevent fracture occurrence, but it may reduce the incidence of clinically significant avulsion fractures by limiting displacement of the distal tibial tuberosity. It is worth noting that this is a retrospective study, the current analysis remains limited by its sample size, standard radiographic assessment may have underestimated subclinical cortical damage in the Maquet foramen, and biomechanical testing was not performed to directly assess the stabilizing effect of the reduction pin during early postoperative loading. Future prospective studies with larger cohorts, standardized postoperative protocols, and multivariable analyses may more accurately characterize how the pin affects stress distribution across the distal tuberosity.

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