



ORIGINAL ARTICLE

Intramedullary Pining versus Tape Splinting for Fixation of Tibiotarsal Fractures in Small Cage Birds: An Experimental Study

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Abstract

Objective- Tibiotarsal bone is the most commonly fractured long bone in small companion birds. The treatment options are basically limited to tape splinting the leg due to anatomical limitations. The goal of this study was to investigate intramedullary pinning (IM pin) as an alternative treatment option.

Design- Experimental study

Animals- Thirty mature budgerigars with an average weight of 30 g.

Procedures- The birds underwent mid shaft tibiotarsus osteotomy and the fractures were managed by tape splinting or IM pinning in each group. The IM pins and splints were removed on the 21st day after surgery. Radiographs were taken on 0, 7, 14, 21, and 28 days after surgery. Histopathological and biomechanical evaluations were performed on specimens by day 28. Stability on palpation, lameness scores, and mortality rate were recorded.

Results- Radiography showed perfect bone healing in the IM pin group versus the presence of malunion and deformity in the splint group. Histopathology demonstrated a more advanced bone healing in the IM pin group, characterized by the dominance of new bone trabeculae and new cortex formation with very little fibrous tissue. Biomechanical tests revealed significantly higher yield load, ultimate load, stiffness and absorbed energy in the IM pin group ($p < 0.05$). Lameness scores were significantly better in the tape splint group ($p < 0.05$) and the mortality rate was 0 in the splint group versus 33% in the IM pin group.

Conclusion and Clinical Relevance- Although IM pinning showed a more advanced level of bone healing radiographically, histopathologically, and biomechanically, the higher mortality rate and higher lameness scores make it a less desirable choice for pet birds. IM pinning technique did not prove to be as safe as the tape splintage technique. Tape splinting remains the gold standard in managing the fractures of the tibiotarsal bone in budgerigars as it offers low risk and high acceptability.

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1. Introduction

Fracture is a frequent challenge in all bird species.^{1,2} Wing and leg fractures in birds are the most common problems.³ The tibiotarsus is among the most commonly fractured bone in small companion birds seen in practice.⁴ Small psittacine and passerine species are commonly kept as pets. Indeed, cockatiels and budgerigars make up the most referrals of small companion birds in practice. It has been reported that in canaries over 95% of the fractures are of tibiotarsus bone.⁵ Several factors predispose the bones of captive birds to fracture. Anatomical characteristics such as scarce subdermal tissue, little soft tissue coverage, centralized body musculature, thin and brittle long bone cortex and thin skin exist in birds.⁶ Also, poor quality diet, poor ultraviolet exposure, low activity levels, osteomyelitis, neoplasia and finally trauma can weaken and break the bones.⁶⁻⁸ The goals that must be pursued in the management of fractures in birds are the same as those applied in mammals including effective stabilization of the fracture fragments, early ambulation, return to function and possibility of using as many joints as possible.⁹ Different methods have been successfully performed in birds. Some include splint and cage rest,¹⁰ intramedullary (IM) pin,^{11,12} intramedullary pin with splint,¹³ external skeletal fixation,^{2,14-18} interlocking nail,¹⁹ "Tie-in" which is the combination of external skeletal fixation with IM pinning²⁰ and plates.²¹⁻²³ Currently, all of the aforementioned methods could be considered as an option in the fracture management of birds.^{6,24,25} However, considering all of the limitations named for birds plus small size, management of small companion bird fractures has its unique problems regarding the choice of a suitable method for fracture repair, pre- and postoperative care and anesthesia. Currently the method of choice for fixing the fractures of tibiotarsus of small companion birds is the conservative approach using tape slintage.^{26,27} Although this method has proven to have satisfactory outcomes in small birds, there are huge demands for internal fixation of the tibiotarsus fractures which could offer immediate

fracture stabilization with potentially shorter recovery time. This study aimed to examine whether the IM pinning method could be considered as a practical alternative for tape slintage in the management of tibiotarsus fractures of small companion birds.

2. Materials and Methods

Animals and Surgical Procedures

The study was approved by the local ethics committee of Regulations for Using Animals in Scientific Procedures in the Veterinary School of Shiraz University.

Thirty healthy mature budgerigars bought from 5 different bird shops with an average weight of 30 g were kept in the study lab for one week to adapt to the environment. The animals had full access to food (*ad libitum*) and water throughout the study. Birds were randomly divided into two groups regardless of their gender. Birds were transferred to the operation room with covered cages to reduce the transfer stress. After proper restraint, general anesthesia was provided with isoflurane (AErrane®, Baxter, USA), giving 5% for the induction and 3% for the maintenance in 1 liter/min oxygen flow via a mask. The body was kept warm by avoiding excessive plucking, using cotton swabs for scrubbing, and using a water-circulating heat pad. After routine preparations, tibiotarsus bone was exposed through a craniomedial approach. Transverse mid-shaft tibiotarsal osteotomies were created in both groups using an oscillating saw under irrigation by normal saline. Fractures of one group were left without any attempt to fix and the surgical sites were closed routinely by PGA 4-0 suture material (Ethicon, USA) for muscles and Nylon 4-0 suture material (Ethicon, USA) for the skin in a simple continuous pattern. A primary layer of sterile gauze followed by tape splint (Altman's method) were put on the limb in this group. The Altman's tape splint technique consists of putting adhesive tape around the fractured limb and being reinforced with glue to increase rigidity.²⁶ After fracture reduction, the strips of tape are placed around the

limb in the normal perching position, with the knee and tarsus-metatarsus joints slightly flexed. Adhesive strips are placed across the whole length of the affected bone and should include the proximal and distal joints, both laterally and medially. Using a hemostatic forceps, sheets are adhered to each other and fixed around the leg using glue.⁷ Fractures of the other group were fixed internally by K-wire in a retrograde fashion using a needle holding forceps. By flexion of the leg during IM pin advancement, the cranio-proximal region of the tibiotarsus was aimed as the protrusion point of the IM pin so that the stifle joint was avoided. Surgical sites were closed routinely as previously described. During surgery, all birds received subcutaneous warm lactated ringer 0.5 ml per site into the pre-crural area and 50 mg/kg clindamycin (Zahravi, Iran) and 1 mg/kg meloxicam (Meloxivet®, Razak, Iran) both of which were injected into the pectoral muscle. Recovery of the patients took place under a heating lamp while the bird was wrapped in a towel and fed diluted dextrose as soon as possible.⁵ All of the birds were transferred into individual cages. Cage bars were all removed while the cage floor was loaded with shredded paper to provide softer padding. Post-operation medications included oral 50 mg/kg clindamycin (Zahravi, Iran) and 1 mg/kg meloxicam (Meloxivet®, Razak, Iran) for three days. The IM pins and splints were removed on day 21 after surgery. Sedation for radiography was performed by administrating of 13 mg/kg intranasal midazolam,²⁸ (Midazolox®, Exir, Iran). Birds were monitored for 28 days of the study period.

Radiological Evaluation

To evaluate bone formation, union and remodeling, radiography of each hind limb was performed postoperatively on the surgery day 0 and then at the 7, 14, 21, and 28 days post-surgery using a DR X-ray machine (E7k252x, Toshiba, Japan). Two expert radiologists, who were blinded to the experiments and groups, evaluated the radiographs and reported the observed results.

Histopathological Evaluation

Euthanasia was performed on three birds from each group on day 28. The protocol included deep sedation by intramuscular injection of ketamine (Rotexmedica, Germany) and intracardiac injection of Potassium Bromide (Merck, USA). Three bone specimens from each group were taken and fixed in 10% neutral buffered formalin. The formalin-fixed bone samples were rinsed with water and then decalcified in 10% nitric acid solution and processed for routine histological examination. Two sections of 5µm thick were cut in a longitudinal direction from the center of each specimen and stained with hematoxylin and eosin for analysis by a light microscope (CX-41, Olympus, Japan). Finally, an expert radiologist, who was blinded to the experiments and groups, evaluated the sections and reported the observed results. The sections were blindly evaluated and described by a pathologist. Images of the histologic sections were captured by a digital camera (E-P1, Olympus, Japan) connected to the light microscope.

Biomechanical Testing

Six birds were euthanized from each group on day 28. Then, the tibiotarsus from each case was dissected, wrapped in a saline-soaked gauze bandage to prevent dehydration and stored at -18° C in small, sealed freezer bags. On the day of testing (1 week after euthanasia) the bones were slowly thawed at room temperature and kept wrapped in the saline-soaked gauzes except during testing. The three-point bending test was performed, using a universal tensile testing machine (DPPB/20, Bongshin, Korea) to determine the mechanical properties of bones. The distance between the jaws of the device was 8 mm. Probe width and thickness were 9.9 mm and 1.5 mm, respectively. The bones were loaded at a rate of 10 mm/min until fracturing occurred. Ultimate load, yield load, absorbed energy and strain were recorded and stiffness was calculated from the curves.

Clinical Evaluations

The stability of the fracture site was assessed by palpation on radiographic time points of 7, 14, 21, and 28 days post-surgery. Weight-bearing was evaluated visually when the bird was in the cage by giving lameness scores based on a modified lameness grading used by Hatt *et al.*²⁹ on days 7, 14, and 28 post-surgery (Table 1). The mortality rate was also documented throughout the study.

Table 1. Modified lameness grading according to Hatt *et al.*²⁹

Score	Description
0	Normal wing or leg function
1	Subtle, intermittent weight-bearing lameness or wing droop
2	Subtle, consistent weight-bearing lameness or wing droop
3	Obvious weight-bearing lameness or wing droop
4	Intermittent non-weight-bearing lameness or wing droop
5	Consistent non-weight-bearing lameness or wing droop

Statistical Analysis

Statistical analyses of data were done using GraphPad Prism software (version 8.2.0 GraphPad Software, Inc. San Diego, USA). Lameness scores were compared by the Mann-Whitney test. Biomechanical evaluation results were compared using independent t-test. The data derived from the load-deformation curves were expressed as mean \pm standard error of the mean (SEM) for each group. The level of significance was set at $p < 0.05$.

3. Results

Radiology Evaluations

On radiographs of day 0 of the splint group, fracture ends were not in complete alignment with the adjacent joints, and displacement of the fracture ends was present. This group showed collapsed overriding fracture ends and soft tissue inflammation on day 7 post-surgery. On day 14 post-surgery, less soft tissue inflammation around the overriding fracture ends was observed. On day 21 post-surgery, the

overriding fracture ends were less sharp. Finally, on day 28 post-surgery, the overriding fracture ends showed blunting, and there was no soft tissue inflammation present. The IM pin group showed consistent radiographic appearance on days 0, 7, and 14 post-surgery, which included perfect reduction and alignment of the fracture ends. Throughout this period (days 0 to 14), radiographs showed stable IM pins in the medullary cavity of the tibiotarsus bones with superimposition of the IM pins on diaphysis of the bones. Signs of callus formation existed in neither of the mentioned time points. On day 21 after the IM pins were removed, bones showed primary bone healing, including cortical continuity with no periosteal callus present. Despite some irregularities on the cortex, no fracture line was present in the area of osteotomy at this time. On day 28 endosteal callus had filled the bone medulla, and a smooth cortical surface at the fracture site was present (Figure 1).

Overall, alignment and apposition were not achieved in the splint group resulting in angular deformity while, perfect alignment and apposition were present in the IM pin group throughout the study period.

Histopathological Findings

In the IM pin group, new cortical bone provided complete continuity at the fracture site. The medullary cavity was filled with interconnected new bone trabeculae, and little fibrous tissue was present at the fracture site. In the splint group, the malalignment of the bone ends at the fracture site was evident. The fracture site was mainly comprised of the old cortex remnants and woven bone islands. In addition, fibrocartilage and a considerable amount of fibrous tissue were also present in these groups. Figure 2 provides pictures of the two groups on day 28 of the study.

Biomechanical Assessments

The failure mechanism of the bones was consistent; it took place at the defected area with the fracture line being perpendicular to the long axis of the bone. On day 28 of

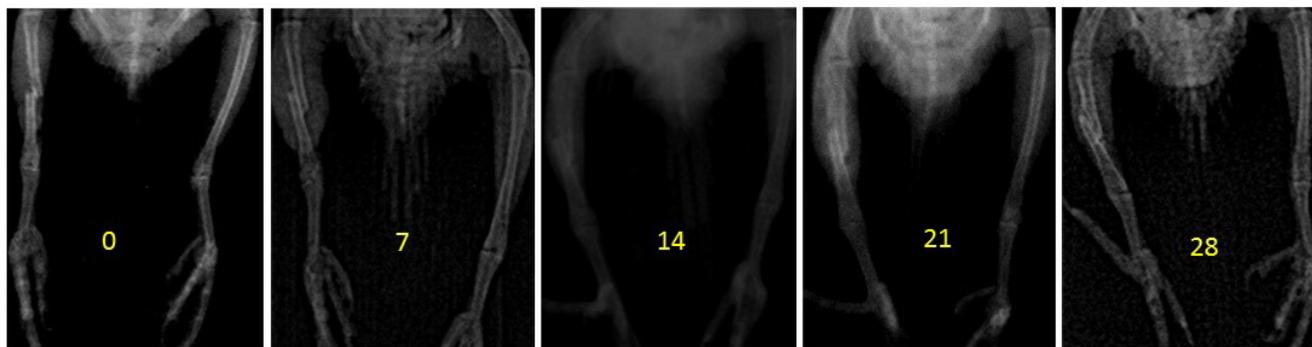
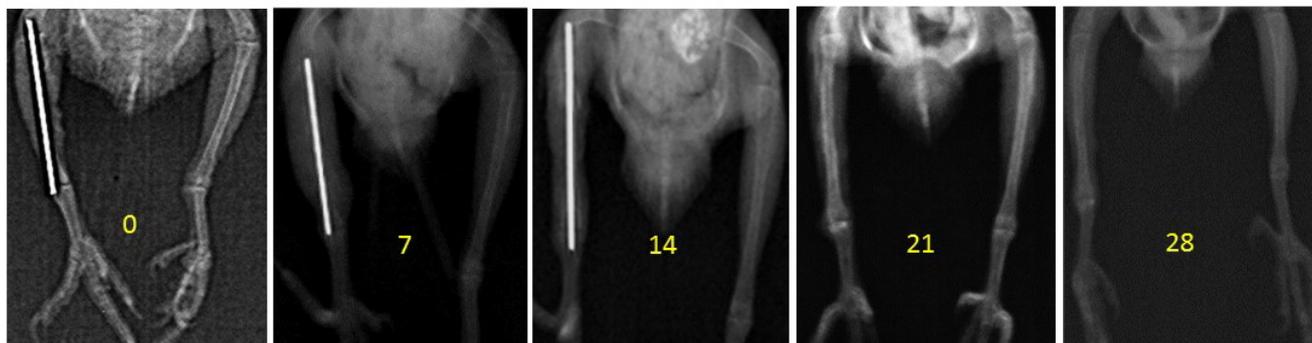
Splint group:**Pin group:**

Figure 1. Radiographs of days 0, 7, 14, 21, and 28 after surgery. The splint group shows the displacement of the fracture ends on day 0. On the 7th day this group shows collapsed fracture ends and significant soft tissue swelling in the area. At 14th day the soft tissue swelling has subsided and there is no change in the overriding fracture ends. At day 21 less sharp bone ends are the main feature. At 28th day overriding fracture ends are blunt and there is no soft tissue inflammation. The IM pin group at day 0, 7 and 14 just show the stable IM pin filling the medullary cavity of the tibiotarsus. The diaphysis of the bones is superimposed by the metal radio-opacity thus no bone changes in the cortex and medullary cavity could be witnessed. At day 21 after IM pin removal, signs of bone healing including almost complete cortical continuity with a rough surface and absence of fracture line were present. At day 28 the bones showed normal radiographic characteristics including cortical and medullary integrity with a smooth surface at the fracture site.

the study, the IM pin group showed a significantly higher yield load (9.83 ± 0.60) compared to the splint group (5.32 ± 0.73), ($p < 0.05$). The ultimate load was also significantly higher in the IM pin group (11.32 ± 0.78) compared to the splint group (6.56 ± 0.78), ($p < 0.05$). Stiffness showed significantly higher numbers in the IM pin group (4.99 ± 40) compared to the splint group (2.75 ± 0.36), ($p < 0.05$) and absorbed energy was also significantly higher in the IM pin group (35.66 ± 6.04) in comparison with the splint group (13.60 ± 2.64), ($p < 0.05$). Strain values, however, did not show any significant difference between the two groups being 2.56 ± 0.61 in the IM pin group and 2.36 ± 0.49 in the splint group. Further details are provided in Table 2.

Clinical Evaluation Results

The stability of the fracture site by healing tissue was palpable on 21 and 14 day after fixation in the splint and IM pin groups, respectively. On day 7, the median of the lameness scores in the splint group was 3.00 (3.00-4.00) compared to 4.00 (3.75-4) in the IM pin group. On day 14, the median of the lameness scores in the splint group was 2.00 (2.00-3.00) while it was 3.00 (3.00-3.25) in the IM pin group. On day 28, figures included 1.00 (1.00-2.00) in the splint group and 2.00 (2.00-3.00) in the IM pin group. Statistical results showed significantly better lameness scores in the splint group compared to the IM pin group in

all evaluated time points ($p < 0.05$). Percentiles are provided in Table 3.

The mortality rate was 0 in the splint group and 33% in the IM pin group. These mortalities included two deaths during surgery and three deaths within 48 hours after surgery and these birds were replaced.

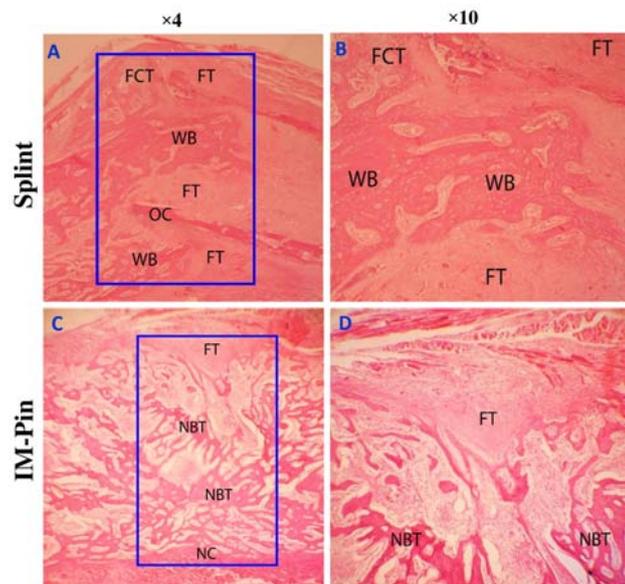


Figure 2. Histopathological sections of the healing process of osteotomized tibiotarsus bones after 28 days of injury; longitudinal view. The blue boxes in $\times 4$ column are the regions that are magnified in the $\times 10$ column. A and B: The fracture line in the splint group has overriding cortical ends of the old cortex (OC) and is filled mostly with fibrous tissue (FT), Fibrocartilage tissue (FCT) and woven bone (WB). C and D: The fracture line in the IM pin group shows cortical and medullary continuity comprising of new cortex (NC) and new bone trabeculae (NBT) plus a small amount of fibrous tissue (FT).

Table 2. Results of three-points bending biomechanical test at 28 days after injury.

Variable	Splint group (mean \pm SEM)	IM pin group (mean \pm SEM)
Yield Load (N)	5.32 \pm 0.73	9.83 \pm 0.60*
Ultimate Load (N)	6.56 \pm 0.78	11.32 \pm 0.78*
Stiffness (N/mm)	2.75 \pm 0.36	4.99 \pm 0.40*
Strain (%)	2.36 \pm 0.49	2.56 \pm 0.61
Absorbed Energy (J)	13.60 \pm 2.64	35.66 \pm 6.04*

* indicates significant difference in each row.

Table 3. Percentiles of lameness scores at different time points.

Group	Day 7 percentiles			Day 14 percentiles			Day 28 percentiles		
	25%	50%	75%	25%	50%	75%	25%	50%	75%
Splint	3.00	3.00	4.00	2.00	2.00	3.00	1.00	1.00	2.00
IM-pin	3.75	4.00	4.00	3.00	3.00	3.25	2.00	2.00	3.00

4. Discussion

This study aimed to examine the use of intramedullary pin fixation as an alternative to tape splinting in the management of tibiotarsus fractures in budgerigars. We intended to evaluate the method as a new way for managing fractures of the tibiotarsus that are among the most frequent presentations in pet birds.^{30,31} A PubMed search on literature showed no previous prospective randomized study on tibiotarsus fractures of small cage birds. All the birds that finished the 28-day period of this study experienced fracture healing. The IM pin group had a more advanced level of bone healing radiographically, histopathologically, and biomechanically at the end of the study. However, mortality rate and lameness scores were significantly better in the splint group.

From a radiological standpoint, primary bone healing provided perfect alignment and apposition thus complete clinical union in the IM pin group documented by day 21 post-operatively. However, the splint group experienced a secondary bone healing process with mal-positioned bones and angulated limbs throughout the healing period. This difference actually proves the rigid fixation provided by IM pin compared to tape splint. In a study by Tunio *et al.*, the ulnar fractures repaired by external fixation in pigeons showed complete bone union by callus formation (secondary bone healing) and 50% clinical union (invisible fracture line) at week three post operation.²

From a histopathological perspective, comparison of the samples of 28th day post-surgery revealed a more advanced level of bone healing in the IM pin group. The presence of a more mature tissue composition including, new bone trabeculae and new cortex in the IM pin group showed a superior stage of bone healing compared to the splint group, which presented woven bone, excessive fibrous tissue and chondroplasia. These findings suggest that fracture site has been experiencing some levels of motion in the splint group, and confirms the findings of Helmer and Redig, and Rubin *et al.*, who stated that excessive

motion at the fracture site and poor apposition of fracture ends are the main drawbacks of external coaptation.^{26,27} Moreover, biomechanical superiority of the IM pin group at day 28 post-operatively interprets as being stronger and more resistant to potential trauma at this time point. This can suggest that the splint group needs more time to experience mineralization and remodeling to become stronger and more resistant to potential trauma.

In present study, the fracture site was palpably stable by day 21 and 14 post-surgery in the splint and IM pin groups, respectively. Wright *et al.* also have reported a median time of fracture stabilization by palpation as 19 days after fixation in the tibiotarsal fractures treated with tape splint.⁴ Stejskal *et al.* have found that tibiotarsal fracture in a black swan repaired by interlocking nail showed clinical stability on 14 days after fracture stabilization.¹⁹ A study conducted by Wander *et al.* on pigeon humeral fracture stabilization by xenograft showed fracture stability was achieved by day 21 after fixation.¹² Finally, delayed weight-bearing by the IM pin group is contrary to one important primary goal of fracture management, which is an early return to function.⁹ This issue might be addressed by earlier removal of the IM pins in possible future studies.

Limitations of this study were the hardship of handling birds of such small size including, restraint, medication administration, surgery, and stress management. Future studies for evaluating other possible choices of fixation and performing the study on a larger scale are also suggested. Although in this study, the intramedullary pin showed a better stabilization and faster bone healing, high mortality rate and poor weight-bearing outcomes make it a less desirable choice for the pet birds. Consequently, we still suggest tape splint as a low risk and acceptable treatment for tibiotarsal fractures of budgerigars. These results might be also applied to similar small cage birds. Also, it is worth mentioning that the anesthesia and recovery of small birds are reputed to be hard but we found it almost smooth as long as we followed the designed protocol and used the trained team members and prepared everything before the procedure.

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Conflict of Interest

The authors have no conflict of interest.

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