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Comparative holding strength between partially threaded tipped and nonthreaded tipped pins for fracture fixation in the canine femur: biomechanical results

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Abstract:
The objective of this study was to compare the holding power of partially threaded and nonthreaded tipped intramedullary (IM) pins by measuring the minimum amount of force necessary for initiation of pin removal from the bone. A comparison of the holding strength of partially threaded tipped IM pins between fractured femurs and intact femurs at 0 vs 8 and 4 vs 8 weeks revealed no statistical significance. Similar results were also obtained with nonthreaded tipped IM pins of fractured and intact femurs at 0 vs 8, 4 vs 8 and 0 vs 4 weeks. There was a significant difference between the holding strength of partially threaded tipped IM pins of the fractured femurs and that of the intact femurs at 0 as vs 4 weeks. It was concluded that, partially threaded tipped IM pins provided a comparably higher holding strength than nonthreaded tipped IM pins.

Keywords: IM pin, femur, holding strength, dog.

Köpeklerde ucu yivli ve ucu yivsiz intramedullar pinlerin aksiyel ekstraksiyon güçlerinin deneysel olarak araştırılması: biyomekanik bulgular

Özet: Bu çalışmanın amacı ucu yivli ve yivsiz intramedullar (IM) pin uygulamalarında kemikten IM pinin çekilmesi için gerekli olan minimum güç ölçümüyle IM pinlerin aksiyel ekstraksiyon güçlerinin belirlenmesidir. Ucu yivli IM pinlerin tutma gücünün kırık ve kırık oluşturulmayan femurlar arasında 0-8 ve 4-8 haftalar arasında istatistiksel bir fark oluşturmadığı tespit edildi. Benzeri sonuçlar 0-8, 4-8 ve 0-4 haftalar arasında ucu yivsiz pinlerin uygulandığı kırık ve kırık oluşturulmayan femurlar arasında da gözlendi. Kırık ve kırık oluşturulmayan femurlara uygulanan ucu yivli IM pinlerin tutma güçleri arasındaki fark 0-4 haftalar arasında istatiksel olarak önemli bulundu. Sonuç olarak ucu yivli IM pinlerin ucu yivsiz IM pinlerden daha fazla tutma gücüne sahip olduğu kanısına varıldı.

Anahtar Kelimeler: IM pin, femur, tutma gücü, köpek.

INTRODUCTION

Considerable dispute has arisen over the fundamental issue of the efficacy of the partially threaded tipped versus nonthreaded tipped pins in the treatment of fractures. The ineffectiveness of the threaded pins in fracture fixation was reported (1, 2). However, (3) stated that the use of threaded pins give a more secure hold in the cancellous bone of especially at the distal extremity fractures. It was reported that as bone proliferation occurs at the site of pin insertion, it will grow into the grooves between the threads (4). Proof of this is seen at the time of pin removal as the pin must be unscrewed from the distal metaphysis before it can be extracted from the bone. Fully threaded or partially threaded pins provide better holding power than nonthreaded pins with external skeletal fixation (1, 4).

In an in-vitro experimental study comparing the holding strength of the partially threaded tipped and nonthreaded tipped intramedullary (IM) pins, no statistical difference could be found between two groups (5).

The objective of this study was to compare the holding power of partially threaded and nonthreaded tipped IM pins by measuring the minimum amount of force necessary for pin removal from the bone. In addition, histology of the distal femurs was also provided to correlate with the biomechanical results.

MATERIALS AND METHODS

Thirty adult mixed breed dogs weighing 20-25 kg, were used in this comparative study. Thirty dogs were divided into 3 experimental groups as follows, group 1 for 0 week (immediately after surgery), group 2 for 4 and group 3 for 8 weeks. In all dogs of all groups, the left femur (fractured) and right femur (intact or control) were implanted with the same type of either partially threaded tipped or nonthreaded tipped IM pins. Three sixteenths inch both partially threaded tipped and nonthreaded tipped IM pins were used in this experiment. The dogs were premedicated with atropine sulfate (1 ml/10 kg) and acepromazine maleate (0.1 mg/kg) administered subcutaneously, and thiamylal sodium was administered intravenously to induce anesthesia, maintained with halothane and oxygen on a semi-closed system. A standard lateral approach to the femoral middiaphysis was performed. Only left femurs on all dogs were subjected to fracture and IM pinning, whereas the contralateral-right femurs (intact or control) were subjected to IM pinning only. Retrograde and normograde IM pinning techniques were used for the fractured and intact femurs, respectively. At the required time of 0, 4, and 8 weeks, each individual was destroyed. Lateral and anteroposterior radiographic views of all dogs were provided following surgery and at the end of 4 and 8 weeks periods. The right intact femur and both femurs of (dog 1-partially threaded tipped pin) were illustrated in Figures 1 and 2. Following euthanasia, femurs were dissected; freed of soft tissues, wrapped in airtight plastic bags, and stored in a freezer at 20 C until the time of biomechanical testing. A universal material testing system (MTS) was used to determine the minimum force required for axial extraction of the pins from the bones at a rate of 5.0 mm/min. Each distal femur was anchored with Die stone (femur mixing medium) in a square shaped aluminum mount consisted of two blocks, linked to the MTS servohydraulic test machine (Fig. 3). The distal part of the femurs was properly placed between the proximal holding unit and the multi-position table top of the MTS apparatus. Four screws were then used to fasten the smaller to the large block, with the rubber-like cushioning foam pads between the moving parts. The protruding part of the pin above the greater trochanter was connected to the proximal holding unit of the MTS apparatus with 2 screws. Comparative statistical analysis were made using Student's t test, with $P < 0.05$ considered to be statistically significant.

BIOMECHANICAL RESULTS

Group 1 - 0 Week

Partially Threaded Tipped IM Pins and Nonthreaded Tipped IM Pins

No statistical difference ($P<0.2$) was present between fractured and intact femurs for the partially threaded tipped pins, while nonthreaded tipped pins (intact femur) had greater holding strength than for nonthreaded tipped pins (fractured femur) ($P<0.01$). Partially threaded tipped pins with fractured femurs required a greater force for

axial extraction than nonthreaded tipped pins with fractured femurs. The same was true for partially threaded tipped pins with intact femurs compared to nonthreaded tipped pins with intact femurs ($P<0.001$) for both comparisons.

Group 2 - 4 Week

Partially Threaded Tipped IM Pins and Nonthreaded Tipped IM Pins

No statistical difference ($P>0.2$) was found between fractured and intact femurs for the partially threaded tipped pins. Nonthreaded tipped pins (intact femur) had greater holding strength than nonthreaded tipped pins (fractured femur) ($P<0.01$). Partially threaded tipped pins (fractured femur) required greater holding strength than nonthreaded tipped pins (fractured femur) ($P<0.001$). Partially threaded tipped pins with intact femurs were also more resistant to axial extraction of nonthreaded tipped pins with intact femurs ($P<0.001$).

Group 3 - 8 Weeks

Partially Threaded Tipped IM Pins and Nonthreaded Tipped IM Pins

No statistical difference ($P>0.2$) existed between fractured and intact femurs for the partially threaded tipped pins as well as between the fractured and intact femurs for the nonthreaded tipped pins. Partially threaded tipped pins with fractured femurs required more force to be extracted than nonthreaded tipped pins with fractured femurs ($P<0.01$). The force required for axial extraction of partially threaded tipped pins with intact femur was greater than the force required for axial extraction of nonthreaded tipped pins with intact femur ($P<0.01$). The holding strength of partially threaded and nonthreaded tipped pins at 0, 4 and 8 weeks was presented in Tables 1, 2 and 3. Figure 4 illustrates the mean holding strengths of partially threaded and nonthreaded tipped pins as a function of time at 0, 4 and 8 weeks following surgery.

DISCUSSION

Mechanical factors other than biological factors affect the holding strength of IM pins at 0 time. At the time of pullout tests, regardless of the type of the IM pins, the proximal part of the femurs above the fracture line remained attached to the IM pins, indicating that the proximal femur had also a certain amount of holding strength. This was a contributing factor to the increased holding strength in the intact femurs along with the friction of the IM pin with the entire proximal femur. The difference of holding strength of nonthreaded tipped pins between the fractured and intact femurs was significantly higher ($p<0.001$), but no statistical significance ($p<0.2$) in the holding strength was present between the fractured and intact femurs of partially threaded tipped pins. This is also an indication of better engagement of pin threads into the surrounding trabecular bone with intact femurs in terms of being less affected by friction and holding strength of the proximal femur. By this criterion, the holding strength of partially threaded tipped pin relies on the distal femur, where in the threads are surrounded by the trabecular bone. However, it appears that both distal and proximal femurs are effective on the holding strength of nonthreaded tipped IM pins.

In an in vitro experimental study comparing the holding strength of partially threaded tipped and nonthreaded tipped IM pins, no statistical difference could be found between two groups (5). However, since radiographs were not obtained, IM pins may not have been inserted in the same location in the distal femur of each dog, resulting in pin variation (within the cancellous bone or under the patella having been wedged against the inner surface of the cortical bone) with relative to the curvature of the femur (5). It was reported that the holding strength of partially threaded tipped pins relies on the threads seated into the cancellous bone or wedged against the inner surface of the cortical bone (5). However in the current experimental model, partially threaded tipped and nonthreaded tipped IM pins were seated into the soft trabecular bone with no attachment against the inner surface of the cortex.

At 4 weeks, the mean holding strength of partially threaded tipped pins of fractured and intact femurs was superior to that of partially threaded tipped pins of fractured and intact femurs at 0 week. However, at 4 weeks, the mean holding strength of nonthreaded tipped pins of fractured and intact femurs was lower than that of nonthreaded tipped pins of fractured intact femurs at 0 week. No statistical difference ($p>0.2$) was found between fractured and intact femurs for the partially threaded tipped pins. Nonthreaded tipped pins of intact femur had significantly greater

holding power ($p<0.01$) than the nonthreaded tipped pins in fractured femur. Partially threaded tipped pins in fractured femur required a significantly greater holding strength ($p<0.001$) than nonthreaded tipped pins in fractured femur. Partially threaded tipped pins in intact femur were also ($p<0.001$) superior in holding strength to nonthreaded tipped pins in intact femur. At 4 weeks, the holding strength of nonthreaded tipped pins in fractured and intact femurs declined to a level below the holding power at 0 week. A radiographic and clinical evaluation of the femurs revealed that the fracture was healing, although there was no evidence of clinical union. At the time of biomechanical testing, it was also evident that, after the peak level was reached for the minimum holding strength of the IM pin, another peak level was observed due to separation of the proximal femur remaining attached to the IM pins from the distal femur at the level of the fracture line where extraosseous soft tissue had been started to be pulled out. Because clinical union was not evident, micro-motion beyond undoubtedly contributed to more fibrous tissue formation with nonthreaded tipped pins in fractured femurs than nonthreaded tipped pin in intact femurs.

The mean values for the holding strength of partially threaded tipped pins in fractured or intact femurs increased to 150 % and 193 %, respectively of the 0 week values at the end of 4 weeks, and returned to 132 % and 140 % of the 0 week values at the end of 8 week period. The mean percentage of holding strength values of partially threaded tipped pins with fractured versus intact femurs at 8 weeks was 68 % and 93 % of 4 week values, respectively. The mean values for the holding strength of nonthreaded tipped IM pins in fractured femurs decreased to 24 % of the 0 week values at 4 weeks, and returned to 98 % of the initial values at the 8 week period. The mean holding strength of the nonthreaded tipped IM pins in intact femurs decreased to 74 % of initial values at 4 weeks and returned to 58 % of 0 week values at the end of 8 weeks. The mean holding strength of nonthreaded tipped IM pins in fractured femurs increased 4.14 times (414 %) of 4 week values by 8 weeks. However, the mean holding strength of nonthreaded tipped IM pins with intact femurs decreased to 78 % of the 4 week values at the end of 8 weeks. Eventhough the holding strength of nonthreaded tipped pins of fractured femurs increased by 8 weeks to a level above the 4 week values, it was still below the initial value at 0 week. The increase observed with nonthreaded tipped pins of fractured femur was attributed to more solid consolidation of fracture healing, which was still progressing. A typical second peak curve displacement was less pronounced at 8 weeks than at the end of 4 weeks.

No statistical difference was found between the holding strength of partially threaded tipped pins in fractured femurs when comparing 0 to 8 ($P<0.2$) and 4 to 8 weeks ($P<0.01$). The same was true for partially threaded tipped pins of intact femurs at 0 week versus 8 weeks ($P<0.2$), and P was more than 0.1 at 4 weeks versus 8 weeks. Similar results were obtained with nonthreaded tipped pins in fractured and intact femurs at the intervals of 0 to 8, 4 to 8 and 0 to 4 weeks. The holding strength of the partially threaded tipped pin of fractured femurs was significant ($P<0.001$) between the 0 week and 4 week periods. At 4 weeks, the holding strength of partially threaded tipped pin with intact femurs was superior ($P<0.05$) to the 0 week values in the partially threaded tipped pins with intact femurs. Comparative studies evaluating the holding strength of partially threaded tipped pins and nonthreaded tipped pins with external skeletal fixation have been conducted. The holding strength for dog tibias pinned transversaly with either a 1/8 inch nonthreaded Steinmann pin or partially threaded tipped pin in two cortices or partially threaded tipped IM pin with the threads in only one cortex was reported in 1987 (6). Threaded pins engaging two cortices had a significantly greater force of extraction ($P<0.0001$) compared to nonthreaded or threaded tipped pins engaging only one cortex, as well as the superiority of one cortex partially threaded tipped pins to nonthreaded tipped pins immediately after insertion and at 8 weeks. The mean axial force required for pin extraction decreased to 94 %, 67 % and 52 % of the 0 week values for two cortices partially threaded tipped IM pin; one cortex partially threaded tipped IM pin; and nonthreaded tipped IM pin respectively, at the end of 8 weeks. The decrease in the holding strength for nonthreaded and one cortex partially threaded tipped pin was statistically significant after 8 weeks. However no difference could be found for the two cortices partially threaded tipped

pins due to interdigitation of the threads into cortical bone (6).

Comparison of the effect of various factors such as IM pin length within the femur, total IM pin length above the greater trochanter, femur length, body weight and medullary canal diameter on the holding strength of the IM pins were not evaluated in this study. The lack of relationship of holding strength to bone length, length of pin within the bone and body weight was reported (5).

It was concluded that at no time was the mean holding strength of partially threaded tipped pins with either fractured or intact femurs below the initial values. The mean values of nonthreaded tipped IM pins with either fractured or intact femurs were below the initial values at 4 and 8 weeks.

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Table 1. Holding strengths (kg) of IM pins. (0 Week Group)

	Partially Threaded Tipped IM Pins		Nonthreaded Tipped IM pins	
	Fractured Femur	Intact Femur	Fractured Femur	Intact Femur
Mean±SD	64.682±7.4	74.44±10.2	8.960±6.7	30.202±10.4

SD: Standard Deviation

Table 2. Holding strengths (kg) of IM pins. (4 Week Group)

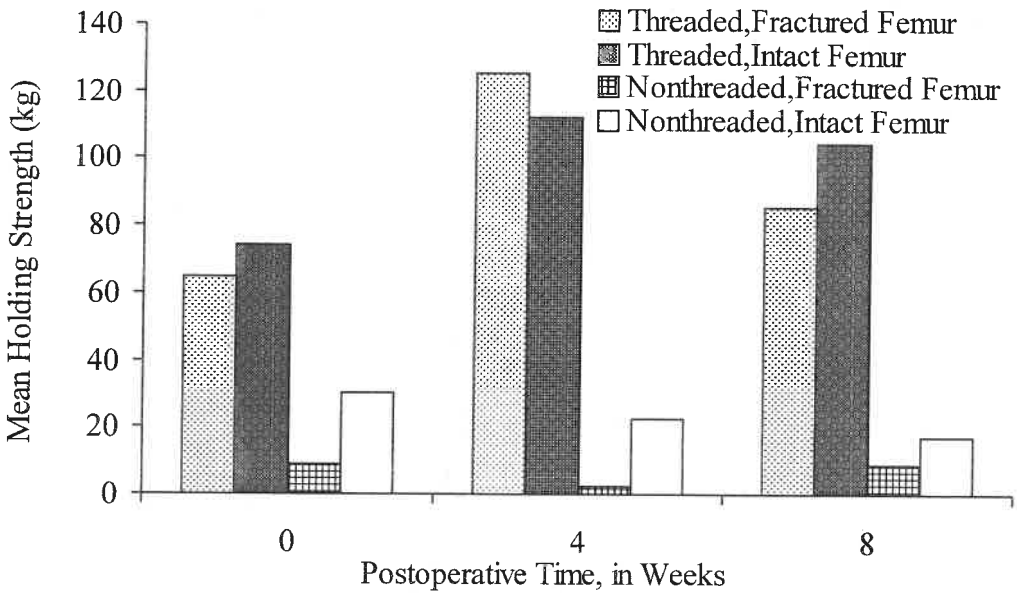
	Partially Threaded Tipped IM Pins		Nonthreaded Tipped IM pins	
	Fractured Femur	Intact Femur	Fractured Femur	Intact Femur
Mean±SD	125.106±24.2	112.042±29.8	2.118±1.5	22.290±10.3

SD: Standard Deviation

Table 3. Holding strengths (kg) of IM pins. (8 Week Group)

	Partially Threaded Tipped IM Pins		Nonthreaded Tipped IM pins	
	Fractured Femur	Intact Femur	Fractured Femur	Intact Femur
Mean±SD	85.626±39.1	104.64±37.9	8.780±8.8	17.462±19.3

Fig.3. Mean holding strength of partially threaded tipped and nonthreaded tipped IM pins as a function of time.



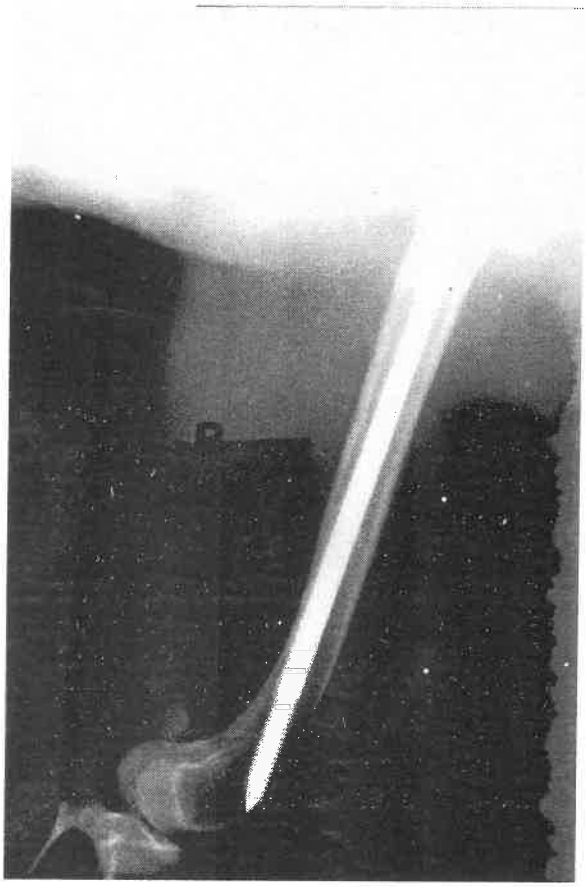


Fig. 1. Immediate postoperative lateral radiographic view of the right femur of dog 1 (partially threaded tipped pin), 8 weeks, group 3.

Fig. 2. Immediate postoperative ventrodorsal radiographic view of the right and left femurs of dog 1 (partially threaded tipped pin), 8 weeks, group 3.

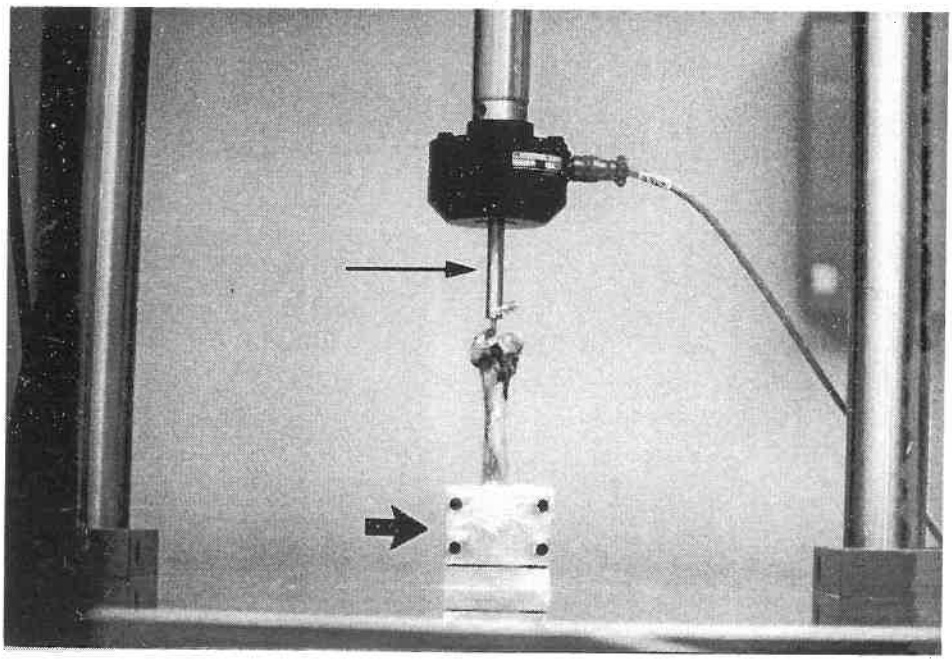


Fig. 3. Representation of the pin extraction. Proximal holding unit (long arrow) of the MTS apparatus to which the protruding part of the IM pin was secured with two screws, and the stationary adjustable mount (short arrow) was secured to the MTS post.