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Osteotomy Gap Consolidation in Dogs after Tibial Tuberosity Advancement with and without Cancellous Bone Graft

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ABSTRACT

***Background*:** Cranial cruciate ligament disease is the leading cause of lameness in dogs. The application of autogenous cancellous bone graft within the osteotomy gap has been indicated to accelerate bone healing, but prospective clinical studies evaluating the effects of autogenous cancellous bone graft on osteotomy gap healing after TTA have produced mixed results. The aim of this study was evaluate bone healing time in dogs with cranial cruciate ligament disease that underwent osteotomy for tibial tuberosity advancement with or without autogenous cancellous bone graft. We hypothesized that an autogenous cancellous bone graft would accelerate bone consolidation after tibial tuberosity advancement.

***Materials, Methods & Results*:** A total of 30 dogs (8 male; 22 female) of various breeds with unilateral or bilateral cranial cruciate ligament disease (CCLD), a minimum weight of 20 kg (44 lbs), and a tibial plateau angle up to 25º were randomly assigned to Group A [15 dogs; graft] or B [15 dogs; control]. Dogs underwent tibial tuberosity advancement (TTA) with [Group A] or without [Group B] autogenous cancellous bone graft harvested from their tibia. All surgical procedures were performed by the same experienced orthopedic surgeon. They were assessed through monthly radiographs (at postoperative [PO] day 30, 60, 90, and, as required to cover complete healing, 120, 150, 180, and 210 days). Radiographic evaluation was conducted by an experienced veterinarian who was familiar with the TTA procedure and was blinded to the treatment group (images without identification - name/group). Significantly more dogs in Group A achieved 100% osteotomy gap consolidation at 30 days PO (P = 0.0002) and 60 days PO (P = 0.0016) than Group B. The average time to 100% bone consolidation was 56 days (± 15.4) for Group A and 108 days (± 46.47) for Group B, and was significantly shorter for group A (P < 0.0001).

***Discussion*:** Our results have showed bone consolidation time in dogs with CCLD undergoing the surgical technique of TTA is significantly faster when aided by an autogenous cancellous bone graft at 30 and 60 days PO. Therefore, we accept our hypothesis that autogenous cancellous bone graft accelerates bone consolidation. These results support the findings of another study, that noted that the use of autograft resulted in significantly higher osteotomy healing scores at 6 and 10 weeks postoperatively. The divergence of results between studies evaluating osteotomy gap consolidation following TTA may be partly explained by the subjective and different methods of bone consolidation evaluation used in these investigations. This is a standard limitation when using radiographic evaluation, however, the selection of this method is justified by the fact that this imaging modality is commonly used in routine clinical practice to evaluate bone consolidation – it is, therefore, clinically representative. The present study is subject to certain limitations. Firstly, variables other than bone graft treatment may have influenced bone consolidation time, such as age, weight, and cage size. However, these variables were not significantly different between the evaluated groups (P > 0.05), thus eliminating the effects of these potentially confounding variables. Secondly, the investigator evaluating radiographic bone consolidation could not be completely blinded to the treatment group, as some degree of radiation attenuation was associated with the cancellous bone graft. In conclusion, one consolidation time in dogs with CCLD undergoing the surgical technique of TTA is significantly faster when aided by an autogenous cancellous bone graft.

Keywords: stifle, knee, TTA, cranial cruciate ligament, rupture.

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INTRODUCTION

Cranial cruciate ligament disease (CCLD) is the leading cause of lameness in dogs [16]. Surgical treatment should be performed as soon as possible to delay secondary osteoarthritis and prevent meniscal injury [14] and tibial tuberosity advancement (TTA) is an option to neutralized femorotibial shear force during weight-bearing [22]. Complication rates associated with TTA range from 10% to 59% [2,3,12,13,15,23].

The application of autogenous cancellous bone graft (ACBG) within the osteotomy gap has been indicated to accelerate bone healing and reduce the risk of implant failure and tibial tuberosity fracture [2,19]. Studies evaluating the effects of ACBG on osteotomy gap healing after TTA have produced mixed results. Bone consolidation resulting from TTA occurs at a similar rate regardless of whether an ACBG is used [1,10]. Conversely, cancellous bone graft accelerated consolidation in the gap caused by TTA in 30 dogs [2]. Limitations of these 2 studies include that initial evaluation of osteotomy gap healing did not occur until 6 weeks post-operatively (PO) and that only a few dogs were followed up until complete bone consolidation occurred. Since metaphyseal bone is expected to undergo fast healing, differences in early osteotomy gap healing could have been lost by performing the initial evaluation of gap healing at 6 weeks [2,10] instead of 4 weeks PO [20].

The objective of the present study was to compare osteotomy gap consolidation in dogs after TTA with and without the use of autogenous cancellous bone graft. We hypothesized that bone consolidation in the gap caused by TTA would be accelerated by the use of ACBG.

MATERIALS & METHODS

The research was approved by the ethical commission of the University of São Paulo (USP), São Paulo, SP, Brazil. In all cases, informed consent was obtained from the owners. Furthermore, all surgeries were performed in accordance with the ethical guidelines. The only difference between the 2 groups was the harvest of a bone graft on the osteotomy of the Tibia. Furthermore, the evaluation was done purely through X-rays at appropriate times. No other invasive procedures were conducted in any group. The period of x-ray re-checks followed the normal time for dogs that undergo stifle surgery.

Study design and grouping

A total of 30 dogs that were presented to the Veterinary Hospital of the Faculty of Veterinary Medicine and Animal Science - USP, with uni- or bilateral CCLD were included in the present study. Further inclusion criteria encompassed a minimum weight of 20 kg and a tibial plateau angle of less than or equal to 25°. Dogs were randomly (by coin toss) assigned to undergo TTA with (15 dogs; Group A) or without (15 dogs; Group B) the use of autogenous cancellous bone graft. Data on the following variables were collected: Breed, age, weight, gender, affected limb, time since onset of lameness, and TTA cage size.

Surgical procedures

All surgical procedures were performed by the same experienced orthopedic surgeon. A medial mini-arthrotomy was performed to inspect and, if necessary, treat the menisci. The TTA procedure was performed as previously described [15]. For the 15 dogs in Group A, the plate was secured to the tibia with cortical screws to stabilize the osteotomy prior to harvesting the bone graft. Autologous cancellous bone graft was harvested from the proximal methaphysis of the tibia, just caudal to the osteotomy, with a Volkman curette and placed in the gap until it fills completely. For the remaining 15 dogs in Group B, no bone graft was acquired or utilized. This was the only difference in procedure between the 2 groups.

Postoperative medications consisted of carprofen[1] [Rimadyl® - 2.2 mg/kg every 12 h, BID] 10 days, hydrochloride tramadol[2] [Cronidor® - 2 mg/kg every 8 h, TID] for 5 days, and cephalexin[3] [Ceftrat® - 30 mg/kg every 12 h, BID] for 10 days in all dogs.

Radiologic evaluation

All dogs were assessed by radiographic examination (craniocaudal and mediolateral projections - CC and ML) immediately postoperative and monthly thereafter until complete consolidation was achieved. Radiographic evaluation was conducted by an experienced veterinarian who was familiar with the TTA procedure and was blinded to the treatment group (images without identification - name/group). At each examination point, the degree of consolidation was rated as 0, 25, 50, 75, or 100%, same has used in others researches [12] using both projections and compared among the 2 groups. In addition, we compare the time needed to achieve 100% of consolidation.

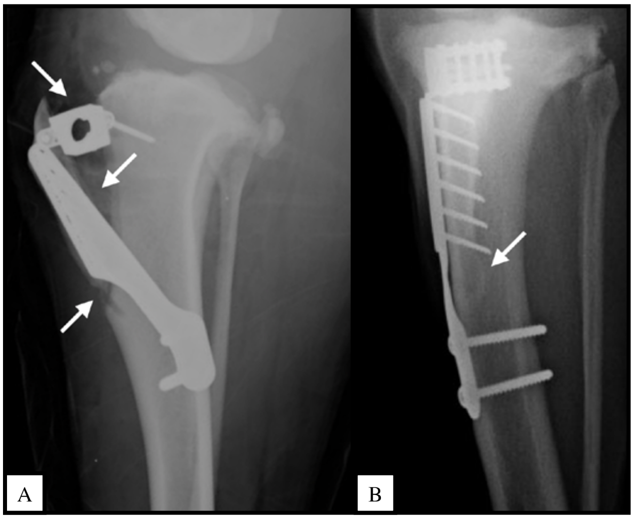

Figure 1. X-ray of a case of TTA in a dog showing areas of consolidation evaluation (white arrows). A- Mediolateral view. B- Craniocaudal view.

Consolidation had been evaluated in 3 locals in the ML x-ray view (above the cage, between tibial crest and tibial metaphysis and below the plate) and by the opacification of the medullar canal of proximal tibia in the CC x-ray view, which is superimposed with tibial crest (Figures 1 & 2).

Descriptive analytics

Quantitative variables, such as animal age and weight, spacer size, and consolidation time (75% minimal at 90 days and 100% at any time of evaluation), were expressed as mean, standard deviation and range. Differences between groups were compared using the Kolmogorv-Smirnov test for parametric data and the Mann-Whitney test for non-parametric data. Statistical significance was defined as $P < 0.05$. All statistical analysis were performed using InStat[3]. A post-hoc power analysis was performed using the following formulas:

RESULTS

In Group A the mean age was 5.06 ± 2.68 years (range = 1-9 years) and the mean weight was 34.50 ± 7.53 kg (range = 20.0- 47.9 kg). Dogs in Group A consisted of 5 males and 10 females and comprised of the following breeds: Labrador Retriever (n=3), Rottweiler (n=3), Mixed Breed (n=3), Pitbull (n=2), Golden Retriever (n=2), Dogue de Bordeaux (n=1), and Beagle (n=1). In Group B, the mean age was 5.26 ± 2.28 years (range = 1-9 years), and the mean weight was 35.25 ± 8.53 kg (range = 20.00 - 45.50 kg). Dogs in group B consisted of 3 males and 12 females and comprised of the following breeds: Labrador Retriever (n=4), Rottweiler (n=3), Pitbull (n=3), Golden Retriever (n=2), Boxer (n=1), German Shepherd (n=1), and Mixed Breed (n=1).

In Group A, 9 dogs had CCLD in the right and 6 in the left, with an average time between CCLD onset and surgery of 5.56 ± 4.47 months (range = 0.5-15 months). A cage size of 12 mm was used in 9 dogs, while a 9 mm cage was used in the remaining 6 dogs. In Group B, 7 dogs had CCLD in the right and 8 in the left, with an average time between CCLD onset and surgery of 5.67 ± 4.42 months (range = 1-18 months). A cage size of 12 mm was used in 8 dogs, while a 9 mm cage was used in the remaining 7 dogs. No statistically significant differences in age, weight, time of surgery, or cage size were observed between groups (Table 1).

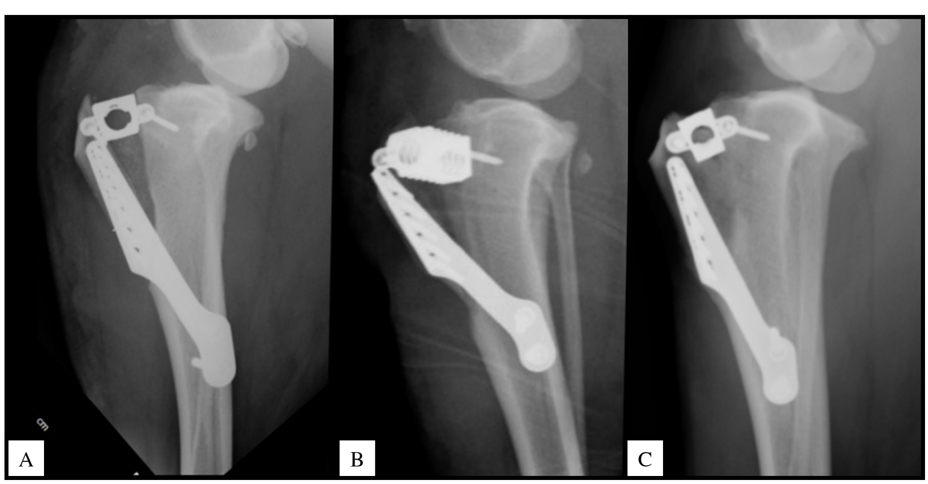

Figure 2. X-ray of 3 cases of TTA in dogs. A- Immediate post operative mediolateral view of grafted TTA. B- Immediate post operative mediolateral view of non-grafted TTA. C- 60 days post operative mediolateral view of non-grafted TTA showing complete consolidation.

In Group A, 100 % bone consolidation of the osteotomy gap was achieved for 3 animals at 30 days PO; 14 animals at 60 days PO; and all 15 animals at 90 days PO. In Group B, 100% consolidation was not achieved for any animals at 30 days PO, but was achieved for 4 animals at 60 days PO; 9 animals at 90 days PO; 11 animals at 120 days PO; 12 animals at 150 days PO; 13 animals at 180 days PO; and all 15 animals 210 days PO.

Significantly more dogs in Group A achieved 100% consolidation at 30 days PO ($P = 0.0002$) and 60 days PO ($P = 0.0016$) than Group B (Table 2). There was no statistically significant difference between the 2 groups in the number of dogs that achieved 100% consolidation at 90 days PO ($P = 0.051$). The average time to 100% consolidation was 56 days (± 15.4) for Group A and 108 days (± 46.47) for Group B. Time to complete consolidation was significantly lower in Group A ($P < 0.0001$), which received the autogenous cancellous bone graft treatment, than Group B, which received no such treatment (Table 3). The average time to achieve 75% osteotomy gap consolidation was 32 ± 7.74 PO days for Group A and 57 ± 21.01 PO days for Group B and was significantly shorter for Group A ($P < 0.004$). Post-hoc power analysis revealed an 86.59% chance of detecting a difference in 100% consolidation between groups and a 94.28% chance of detecting a difference in 75% consolidation between groups.

DISCUSSION

Findings of the present study indicate that the use of autogenous cancellous bone graft resulted in increased osteotomy gap consolidation at 30 and 60 days PO. No statistically significant difference in bone consolidation was identified between groups at 90

Table 1. Mean and standard deviation of age, time between rupture and surgery (CCLD time), weight, and cage size of dogs that underwent TTA with and without cancellous bone graft.

Variable	With graft	Without graft	*P**
Age (years)	5.14 (± 2.77)	5.07 (± 2.23)	0.89
CCLD time (months)	5.56 (± 4.47)	5.67 (± 4.42)	0.82
Weight (kg)	34.5 (± 7.53)	35.25 (± 8.53)	0.80
Cage width (mm)	10.80 (± 1.52)	10.60 (± 1.54)	0.77

CCLD = cranial cruciate ligament disease; kg = kilogram. $P < 0.05$.

Table 2. Mean and standard deviation of the percentage of dogs that underwent TTA with or without cancellous bone graft that achieved 100% bone consolidation of the osteotomy gap at 30, 60, and 90 days PO.

Postoperative day	With graft	Without graft	*P**
30 (%)	75.3% (± 17.3)	33.1% (± 28.3)	0.0002
60 (%)	95.9% (± 11.4)	64.6% (± 30.0)	0.0016
90 (%)	99.3% (± 2.5)	82.2% (± 26.6)	0.051

TTA = tibial tuberosity advancement; PO = post operative; $P > 0.05$.

Table 3. Mean and standard deviation of the time between surgery at 100% bone consolidation and at 75% of consolidation (maximum 90 days post operative) of the osteotomy gap of dogs that underwent TTA surgery with (15 animals) and without (15 animals) cancellous bone graft.

Variable	With graft		Without graft		*P**
Consolidation	100%	75%/90d	100%	75%/90d	
Mean of days (SD)	56.00 (± 15.40)	32.00 (± 7.74)	108.00 (± 46.47)	57.27 (± 21.01)	= 0.0040
Number of animals	15	15	15	11	

*$P < 0.0001$.

days PO, likely because the majority of dogs in Group A (93%) were already healed before this time point compared to dogs in Group B (n=27%). Therefore, we accept our hypothesis that autogenous cancellous bone graft accelerates bone consolidation.

The signalment of dogs affected by CCLD in this study was consistent with prior reports, as the majority of animals were adult, medium to large breed dogs (such as Labrador Retriever, Rottweiler, Golden Retriever [10], American Pit Bull Terrier, and Mixed Breed dogs [4,7,8,11]. The difference observed in the present study between the number of affected males (26.66%) versus females (73.33%) corroborates the findings that CCLD is most frequent in spayed bitches [6,9]. That being said, there is no evidence of a hormonal factor in this condition [11].

The average time to complete consolidation was almost halved by the use of autogenous cancellous bone graft in this study. These results support the findings of Bisgard *et al.* [2], who noted that the use of autograft resulted in significantly higher osteotomy healing scores at 6 and 10 weeks postoperatively [2]. These results and our present study are disputed by Guerrero *et al.* [10], however, who reported no difference in osteotomy healing with and without autogenous cancellous bone graft at 6 weeks and 4 months following TTA surgery [2,10]. It was reported difference just proximal to the cage, but no on overall evaluation [10].

The divergence of results between studies evaluating osteotomy gap consolidation following TTA may be partly explained by the subjective and different methods of bone consolidation evaluation used in these investigations [2,10,12]. This is a standard limitation, when using radiographic evaluation [2,3,10], however, the selection of this method is justified by the fact that this imaging modality is commonly used in routine clinical practice to evaluate bone consolidation - it is, therefore, clinically representative [9].

An advantage of the present study design includes that the initial evaluation of osteotomy gap consolidation was performed at an earlier time point than in previous reports (4 weeks rather than 6 weeks PO) [2,10]. As a result, we were able to demonstrate that the use of autogenous cancellous bone graft allowed for complete osteotomy consolidation at 4 weeks in 20% of dogs, compared to 0% of dogs that did not receive graft material. Healing diagnosed at an earlier stage is clinically relevant as it could allow for an earlier return to full function without exercise restriction [5]. Implant failure has been observed in several studies [12,17,18] and We postulated after consolidation the risk of implant failure doesn't exist. It is another reason to graft TTA, since our study and Bisgard *et al.* [2] has showed faster consolidation [2].

The present study is subject to certain limitations. Firstly, variables other than bone graft treatment may have influenced bone consolidation time, such as age, weight, and cage size [21]. However, these variables were not significantly different between the evaluated groups ($P > 0.05$), thus eliminating the effects of these potentially confounding variables. Secondly, the investigator evaluating radiographic bone consolidation could not be completely blinded to the treatment group, as some degree of radiation attenuation was associated with the cancellous bone graft. Another limitation of this study is the small sample size, although these are similar to those of recent investigations evaluating the same treatment [2,10]. In addition, our post-hoc power analysis suggests that our sample size is sufficient to detect significant differences between groups at two comparisons (75% and 100% healing). Furthermore, the small number of animals included in Group B is justifiable on ethical grounds, since the use of bone graft is currently considered standard of care for the TTA procedure [15].

CONCLUSIONS

Bone consolidation time in dogs with CCLD undergoing the surgical technique of TTA is significantly faster when aided by an autogenous cancellous bone graft.

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Ethical approval. The research was approved by the Ethical Commission of the University of São Paulo (USP), College of Veterinary Medicine under the CEUA number 937808091. São Paulo, SP, Brazil.

Declaration of interest. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

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