Treatment of pes varus using locking plate fixation in seven Dachshund dogs

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Keywords
Pes varus, Dachshund, open wedge, osteotomy, locking plate fixation, Fixin plates

Summary
Objectives: To describe the surgical treatment of pes varus in Dachshund dogs by medial opening wedge osteotomy of the distal tibia stabilized with a locking plate system and to retrospectively report the clinical and radiographic outcomes.

Materials and methods: Lameness in nine limbs of seven Dachshund dogs with pes varus deformity was treated with corrective osteotomy at or near the centre of rotation of angulation as defined by the intersection of the proximal and distal mechanical axes determined on caudo-cranial radiographs. Outcomes evaluated included comparison of pre- and postoperative radiographic measurements of frontal angulation and lameness assessment.

Results: Lameness resolved in eight limbs and improved in one limb. All osteotomies healed and no implant complications were detected. Mean preoperative radiographic measurements were: mechanical proximal tibial angle (mMPTA) = 91.1° (range 87.6°-95°), mechanical medial distal tibial angle (mMDTA) = 62.1° (range 51.9°-69.6°). Mean postoperative measurements were: mMPTA 92.4° (range 78°-97.5°), mMDTA 81.8° (range 76°-87°). Measurable under-correction was common, though seldom visually or functionally evident.

Clinical significance: Pes varus deformity in Dachshunds can be treated by medial opening wedge osteotomy of the distal tibia stabilized with a locking plate system. Care to preserve the lateral cortex of the osteotomy may help avoid under-correction.

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Introduction
Physeal growth disturbances of the pelvic limb are infrequently reported in the veterinary literature; only 12% of physeal injuries affected the pelvic limb and just four percent involved the tibia in one report (1). Pes varus and valgus describe skeletal deformities characterized by a medial or lateral deviation of the distal tibia in the frontal plane, respectively (2). The aetiology of this skeletal deformity is an asymmetric growth of the distal tibial physis (3–6). The cause of this premature closure may be traumatic, nutritional or developmental in origin (1, 3–5). A genetic predisposition has been proposed for pes varus in the Miniature Dachshund (2, 3).

Skeletal deformity of the distal tibia results in abnormal axial loading of the talocrural joint and may result in breakdown of periarticular structures, lameness and osteoarthritis (3–5). Patellar luxation and pes varus have been reported in combination (5, 6).

While many forms of corrective osteotomy, corrective osteotomy, and bony fixation have been reported for treatment of pes varus or valgus, the common surgical goal is to realign the stifle and tarsal joints in the frontal plane (2, 4, 7). Recent emphasis has been placed on accurate positioning of the corrective osteotomy at the centre of rotation of angulation (CORA) in order to avoid introducing iatrogenic secondary malalignment. Preoperative planning for pes varus deformity correction often reveals that the CORA is very near the talocrural joint. Fixation of such juxta-articular osteotomies is technically challenging due to the limited bone for fixation distally. This challenge can be met with use of an external skeletal fixation device, though the postoperative care and complications related to such devices can be objectionable to some pets and their owners (5). Bone plate fixation is often problematic owing to the limited bone available for distal screw purchase and the need for a thin implant profile because of the scarce soft tissue covering. The purposes of this report are to describe our methods of preoperative CORA-based planning and corrective osteotomy for treatment of pes varus in a series of Dachshunds using a thin-profile, locking bone plate, and to report the associated clinical and radiographic outcomes.

Materials and methods

Inclusion criteria
Medical records (from July 2005 to October 2010) including the results of pre- and postoperative lameness evaluations and...
Preoperative mechanical axis planning from radiographs

Preoperative mediolateral and caudocranial radiographic projection images of the affected and unaffected tibiae were obtained under general anaesthesia. The CORA-based planning for deformity correction was based on measurements made on the caudocranial view of both affected and unaffected tibiae as previously described (Fig. 1) (8–12).

We based our corrective osteotomy planning upon the mechanical axis (rather than the anatomic axis) in the frontal plane radiographic image. The mechanical axes of the angulated tibiae were divided into proximal and distal segments (13). These mechanical axes were drawn from their respective joint centres at an established angle to their respective joint orientation lines according to the principles of mechanical axis planning for CORA identification (13). These angles were defined as the mechanical medial proximal tibial angle (mMPTA) and the mechanical medial distal tibial angle (mMDTA). In dogs with unilateral pes varus, the mMPTA and mMDTA measurements from the unaffected contralateral limb were used to determine the proximal mechanical axis (PMA) and distal mechanical axis (DMA), respectively. In dogs with bilateral pes varus, reported reference values for mMPTA (93°) and mMDTA (96°) were used (9–12) (Fig. 2). The CORA was defined by the intersection between the PMA and the DMA.

The ideal osteotomy location was planned through the CORA, parallel to the distal joint orientation line (DJOL) (14). The distance from the DJOL to the CORA was recorded as the theoretical osteotomy distance (OD). The acute angle created by the intersection of the PMA and the DMA was recorded as the expected osteotomy wedge angle (eOWA). The expected OWA is the angular correction needed to fully correct the deformity by opening the medial tibial cortex of the osteotomy (Fig. 2).

Radiographic images were performed with radiodense metal spheres of known dimension to allow calibration of linear measurements for magnification.

Surgical technique

Pes varus deformity was treated in nine tibiae of the seven Dachshunds. Both limbs of bilaterally affected dogs were treated under the same anaesthetic episode. Dogs were positioned in dorsal recumbency and aseptic preparation for surgery was made under general anaesthesia. A standard medial surgical approach to the tibia was performed from the medial malleolus to the middle one-third of the tibia. 

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No temporary alignment jigs were used in seven procedures performed in five dogs. In two dogs (dogs 1 and 2), one surgeon used a temporary alignment jig\(^c\) to help maintain intra-operative alignment of the tibial segments during plate application. In preparation for jig application, two 2 mm diameter pins were placed from medial to lateral prior to performing the osteotomy. The proximal pin was positioned in the medio-lateral plane approximately parallel to the proximal tibial articular surface; an attempt was made to modify this orientation slightly by an amount equal to the mMPTA of the unaffected contralateral tibia minus 90° (example 93.2° - 90° = 3° modification) using a goniometer and the patellar tendon for visual reference. A similar method was attempted for placement of the distal jig pin relative to the tibiotarsal joint. After the osteotomy was made, orienting the pins parallel to one another would, at least theoretically, establish the same frontal plane alignment as the unaffected contralateral tibia. With the pins held in this position, a small temporary jig was locked to the pins on the medial side of the tibia until plate fixation was complete.

The CORA was identified in the surgical field by translating the radiographic theoretical OD measurement to the limb by measuring proximally from the tarsal joint. The tarsal joint was identified using intra-articular placement of a hypodermic needle and a ruler or a Castroviejo calliper\(^d\) was used for measurement. Similarly, the distance from tibial tuberosity to the radiographic CORA was measured on the limb to reconfirm the CORA position in the surgical field. A longitudinal line was etched in the medial tibial cortical surface to serve as a reference for maintenance of torsional alignment throughout the procedure (no torsional manipulations were made). The osteotomy was centred as close as possible to the CORA and performed using a sagittal saw. A medial opening wedge was created according to preoperative measurements using the same steel rule or Castroviejo calliper noted above. The jig, when used, helped maintain the osteotomy gap during bone plate application. When a jig was not used, surgeons used a Castroviejo calliper to measure the proper size of the medial gap. A spacer\(^e\) was inserted into the medial gap to help maintain the gap size. The locking bone plate was applied first to the distal segment. Next, the bone plate was provisionally fastened to the proximal segment with a pin-stopper as described elsewhere (15). Finally, the remaining screws were inserted routinely (15). This procedure was relatively simple since the locking plate did not require perfect, anatomic contouring to the medial tibial surface after angular correction.

The osteotomy was stabilized using a Fixin mini implant as described in the literature (15) (Fig. 3). Six osteotomies were stabilized using a 32 mm long, 1.5 mm thick mini T-plate\(^a\) with 2.5 mm locking head screws (dogs 1, 2, 3, 5 and 7 [bilateral]). Three osteotomies were stabilized using a 25 mm long, 1.2 mm thick mini T-plate\(^a\) with 2.5 mm locking head screws (dogs 4 [bilateral] and 6). Three osteotomy gaps were filled with autogenous cancellous bone graft (dogs 2, 3 and 5), two osteotomies were filled with a collagen sponge\(^f\) (dog 7 [bilateral]) and four osteotomies were not grafted (dogs 1, 4 [bilateral] and 6). Surgical wounds were closed routinely. In the perioperative period antibiotic, anti-inflammatory, analgesic medications were administered.

**Clinical assessment**

Medical records for all follow-up examinations were reviewed for comments regarding the appearance of limb angulation, lameness assessment and complications. Pre- and postoperative gait was reviewed for lameness assessment. Lameness was graded on a four-point scale:

- 0 = no lameness,
- 1 = mild lameness,
- 2 = obvious weight-bearing lameness,
- 3 = severe, toe-touching lameness,
- 4 = non-weight-bearing lameness.

**Results**

Seven Dachshunds ranging in age from six to 18 months (mean 10 months) and weighing 4.2 to 9.7 Kg (mean 6.6 Kg) met the inclusion criteria for the study. Three dogs were male and four were female. The right tibia was affected in three dogs, the left tibia in two dogs, and two dogs had a bilateral pes varus.
Preoperative evaluation

Clinical assessment

Each of the seven dogs was presented for grade 2 lameness secondary to pes varus. The distal varus deformity was best demonstrated with the dog in dorsal recumbency with rear legs extended. The remainder of the physical, neurological and orthopaedic examinations were normal. Patellar luxation was not detected in any of the dogs.

Radiographic assessment

Five dogs had radiographs of the unaffected tibia available for measurement of mMPTA, mMDTA. Unaffected tibiae had mean values of mMPTA = 93.4° (range: 91.9° – 94.3°) and mMDTA = 94.6° (range: 91° – 97.3°). All dogs had preoperative radiographs of the affected tibia(e) available for measurement of mMPTA, mMDTA, theoretical OD, and expected OWA. Affected tibiae prior to surgery had mean values of mMPTA = 91.1° (range: 87.6° – 95°), mMDTA = 62.1° (range: 51.9° – 69.6°), theoretical OD = 3.8 mm (range: –4 mm to +10.6 mm) and expected OWA = 35.2° (range: 24.8° – 43.6°) (Table 1)

Postoperative evaluation

Clinical assessment

Follow-up examinations were as follows: dog 1 at eight, 12, 64 and 72 weeks; dog 2 at five, 12 and 24 weeks; dog 3 at five weeks; dog 4 at three and five weeks; dog 5 at eight and 32 weeks; dog 6 at 12 weeks; and dog 7 at four and 10 weeks. Six of the seven dogs healed without any residual gait abnormality (lameness grade 0 out of 4) or visually apparent limb angulation. In dog 4, the pes varus of the left tibia was visibly undercorrected. The gait abnormality improved in dog 4, but did not completely resolve (grade 1 out of 4 lameness). No outcome differences were noted between unilaterally and bilaterally affected dogs.

Radiographic assessment

Mean postoperative values were: mMPTA = 92.4° (range: 78° – 97.5°), mMDTA = 81.8° (range 76 ° – 87°), actual OD = 10.2

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<th>Limb</th>
<th>mMPTA (°)</th>
<th>mMDTA (°)</th>
<th>tOD (mm)</th>
<th>aOD (mm)</th>
<th>eOWA (°)</th>
<th>oOWA (°)</th>
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<td>21.1</td>
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<tr>
<td></td>
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<td>76.0</td>
<td>11.4</td>
<td>15.5</td>
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<td></td>
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<td>84.5</td>
<td>10.0</td>
<td>10.2</td>
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</table>

Key: mMPTA = mechanical medial proximal tibial angle; mMDTA = mechanical medial distal tibial angle; tOD = theoretic osteotomy distance; aOD = actual osteotomy distance; eOWA = expected opening wedge angle; oOWA = obtained opening wedge angle. L = left; R = right.

Table 1: Preoperative and postoperative radiographic values in seven Dachshunds.
mm (range: 6.2 – 12.9 mm) and obtained OWA = 18.8° (range: 10.2° – 25.8°). The mean change (postoperative minus preoperative) values were: mMPTA = 2.7° (range: –12° to 7.8°) and mMDTA = 19.7° (range: 9.3 to 28.4°) (Table 1). The mean difference between the actual and the theoretical OD was 6.4 mm (range: 0.2 to 15.1). The mean difference between expected and the obtained OWA was 16.1° (range –0.2° to 25.8°) (Table 2).

Intra-operative iatrogenic fibular fracture (Fig. 4) occurred in three procedures (dogs 2, 4 [left side] and 6). A residual gap was noted on the lateral tibial cortical margin of the osteotomy in six out of nine procedures (Fig. 5). The actual OD exceeded the theoretical OD in all nine procedures, but was within 4 mm of the theoretical OD in four of the nine procedures. The obtained OWA was smaller than the expected OWA in eight of the nine procedures. Radiographic signs of healing of the osteotomies were noted at a mean of 6.2 weeks postoperatively (range: 4–12 weeks).

### Table 2

<table>
<thead>
<tr>
<th>Dog</th>
<th>mMPTA post - mMPTA pre (°)</th>
<th>mMDTA post - mMDTA pre (°)</th>
<th>aOD - tOD (mm)</th>
<th>oOWA - eOWA (°)</th>
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<td>1</td>
<td>2.2</td>
<td>12.9</td>
<td>4.0</td>
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<td>7.8</td>
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<td>25.0</td>
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</table>

Key: mMPTA = mechanical medial proximal tibial angle; mMDTA = mechanical medial distal tibial angle; aOD = actual osteotomy distance; tOD = theoretic osteotomy distance; eOWA = expected opening wedge angle; oOWA = obtained opening wedge angle; pre = preoperative; post = postoperative.

### Discussion

Ideally, corrective osteotomy is performed at the level of the CORA in order to avoid introducing iatrogenic secondary mal-alignment. In diaphyseal deformities, accurate CORA identification is relatively simple because it is the intersection of the proximal and distal anatomic axes. Accurate identification of the CORA is more challenging when the maximal deformity is juxta-articular as in pes varus because there is so little space to accurately determine the distal axis of the bone. In a previous report on pes varus correction, investigators inferred that the distal anatomic axis should be oriented at approximately 90° to the DJOL, though to the authors’ knowledge actual reference values for the anatomic MPTA and the anatomic MDTA for the dog have not been reported (4). We opted to define the CORA based on the intersection of the proximal and distal mechanical axes since these could be based on published reference values for mMPTA and mMDTA in our dogs that were bilaterally affected (10–12). In unilaterally affected dogs, we opted to use mMPTA and mMDTA values measured from the unaffected contralateral tibia. The unusual identification of the CORA distal to the tibia in both limbs of dog 7 is suggestive of multiapical deformities (Fig. 6). However, even if further subtle deformities were detected, the CORA would clearly be in close proximity to the tibio-tarsal joint such that the practical limits of osteotomy location are still pertinent. In dog 7 the actual OD was...
around 15 mm proximal to the theoretical OD in both limbs (Table 2). This induced medial translation of the distal segments as predicted by Dror Paley’s third rule of osteotomies (16).

Regardless of the method used to identify the CORA, all reports agree that the goal of centring the osteotomy at the level of the CORA creates a technical challenge of obtaining adequate fixation of the small juxta-articular segment (3–6). Successful treatment of pes varus using external skeletal fixation has been described, though the attendant postoperative care and complications can be problematic (5). In the clinical cases of this report, we elected to use internal fixation as their mode of stabilization. The Fixin system has the advantages of locking screw technology in a low-profile plate with screw hole configurations suitable for fixation of a juxta-articular osteotomy. Imperfect plate contour to the medial surface of the corrected tibia is not problematic with this system (Fig. 3).

This feature combined with the use of the system’s pin stoppers for provisional fixation can simplify bone plate application while the calculated opening wedge dimension is preserved. Medial bone plate application to the medially-based opening wedge tibial osteotomy creates an unstable environment, with no bone contact on the cis-cortex and variable bone contact on the trans-cortex. Iatrogenic fibular fracture in three dogs added further instability. A locking plate system was selected for its superior stability in the relatively unstable environment of an opening osteotomy (17). Also locking plate and screw systems better maintain the opening wedge angle since, unlike conventional plate and screw systems, they do not induce bone shifting as the screws are inserted (18). The low profile of the plate was beneficial as there is little soft tissue covering over the medial aspect of the distal tibia. The T-configuration of the distal screw holes in the plate allowed two-screw fixation of the small distal segment. The fact that the actual OD always exceeded the theoretical OD indicates that the osteotomy was always proximal to the CORA in this series. Others have reported this same finding when treating pes varus (5). However, the fact that the actual OD was within 4 mm of the theoretical OD in four out of nine of our procedures indicates that our osteotomy was often in close proximity to the determined CORA. Review of our cases suggests that the design of the bone plate would have permitted us to safely shift the osteotomy slightly distally (closer to the CORA) in most instances.

The primary goal of treatment in pes varus is accurate realignment of the stifle and tarsal joints in the frontal plane (2–7). Others have reported inconsistent realignment, though the apparent clinical significance of minor over- or under-correction is unknown (5). In our cases, some degree of under-correction was common since the obtained OWA was smaller than the expected OWA in all but one procedure. The amount of under-correction ranged from 7.1° to 25.8° (mean: 18.2°). One reason for under-correction in our cases was variable loss of cortical contact at the lateral margin.

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**Fig. 6** Dog 7: Right tibia. Preoperative caudocranial view of the tibia. The centre of rotation of angulation (CORA) is identified distal to the tibia. The same finding was noted in the contralateral limb.

**Fig. 7** A) Preoperative and B) postoperative photographs of the right pelvic limb of dog 4 positioned to evaluate the degree of pes varus. The dog is lying in dorsal recumbency with the femur, patella, patellar tendon, tibial tuberosity, and long axis of the tibia oriented parallel to the table.
of the osteotomy in six of nine procedures. During the opening wedge osteotomy, the surgeon should strive to preserve the trans-cortex so that it may act as a hinge allowing for a more accurate opening angle. In a paired bone system like the tibia and fibula, complete tibial ostectomy shifts the ‘hinge’ further laterally to the fibula such that, without fibular osteotomy or fracture, under-correction is likely. The presence of fibular fracture in our series did not appear to correlate well with accuracy of the varus angulation correction. Application of the temporary jig may have aided in our cor-rection accuracy since the two procedures in which it was used (dogs 1, 2) were the most accurate corrections (obtained OWA most similar to expected OWA). Subjectively, application of the jig allowed minimal bone shifting during plate application allowing for more accurate achievement of the expected OWA. Despite our tendency to ‘under-correct’ the pes varus, eight of nine deformities were corrected successfully based upon their cosmetic appearance and resolution of the lameness. One procedure improved but did not fully correct the deformity and the associated lameness.

In two dogs the implants were electively removed (dogs 3 and 5). The attending sur-geon in these two cases usually suggests elective implant removal after bone healing to reduce foreign material burden to the body of young dogs. Elective plate removal also reduces concerns of stress protection and secondary bone resorption that may be inherent to more stable locking systems (19, 20). Technical difficulty in the removal of some locking plate systems, owing pri-marily to a cold-welding phenomenon, has been reported (19, 21). In our case series, we did not encounter any technical difficulties with implant removal. The Fixin sys-tem used in this case series has an inter-mediary bushing-insert and the conical locking mechanism that allows for implant removal either by uncoupling the screws from the bushing-inserts or by unthread-ing the insert-screw unit from the plate (15). The authors are not aware of any re-port of cold welding or similar technical difficulties associated with removal of the Fixin locking plate system.

There are several limitations to this case series that should be recognized before extrapolating the results to clinical recom-mendations. Clinical evaluations of limb function were based on a retrospective review of subjective gait examinations. Sur-gery was performed in multiple centres by several surgeons and subtle variations among treatments were inevitable. Simi-larly, subtle variation in the radiographic positioning of the chondrodysplastic limbs may have induced varying degrees of measurement error. Since no comparison treatment groups were included, it is not our intent to claim outcome results relative to any other treatment options for pes varus.

The surgical treatment for pes varus car-ried out in this study showed successful re-sults with resolutions of lameness in eight of the nine limbs and in improvement in one limb (Fig 7, 8). Based on clinical and radiographic outcomes obtained for this study, our results support the use of the Fixin locking plate system as an appropri-ate implant to be used for fixation of acute distal tibial opening wedge osteotomies for treatment of pes varus in small dogs.

Acknowledgments
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Conflict of interest
Massimo Petazzoni is a partner of Trau-mavet, the company which owns the pat-ents for the Fixin system and which also produces and sells the Fixin system.

References