1844RN

OUTCOME OF TRIPLE PELVIC OSTEOTOMY IN DOGS IS ESTABLISHED WITHIN A MONTH AFTER THE SURGERY

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Received : February 7, 2011 *Accepted*

Abstract

The purpose of our study was to evaluate the temporal aspect of the onset of the outcome of a triple pelvic osteotomy (TPO) in a group of 34 dogs younger (but one) than 12 months of age with a homogenous longer follow-up. In each case, lameness and positive Ortolani sign were detected. In some cases, bilateral TPO or denervation of the contralateral hip was performed. Clinical and radiological re-checks were performed in a uniform way for all dogs one and three months after surgery. The mean angle of reduction and subluxation for the operated joints decreased substantially by 17.3 ±1.58 degrees one month after the surgery, without any further statistically significant reduction at three months. Additionally, in 71% of the operated joints, the outcome of the TPO, defined in terms of the absence of the angle of reduction and subluxation, was already established at one month post-surgery and did not change at three months post-surgery. These results indicate that the outcome of the TPO in dogs is established within a month after the surgery and is basically maintained afterwards.

Key words: dogs, triple pelvic osteotomy, angle of reduction, Norberg angle, femoral head coverage.

Hip dysplasia is a developmental joint disease manifested by laxity, instability, and malformation of the hip joint. The disease occurs most commonly in large breed dogs and rarely in dogs with a body weight less than 11-12 kg (4). Several methods of treating hip dysplasia in dogs have been described in literature. The choice of the method depends on several factors, such as age, body weight, and severity of clinical and radiological signs. The methods can be divided into two groups: non-surgical and surgical.

One of the surgical treatments is the triple pelvic osteotomy (TPO). The procedure was introduced in the 1980s by Slocum and Schrader (9). The TPO is reported to improve hip stability and reduce progression of hip degeneration by rotation of the acetabular segment to increase dorsal coverage of the femoral head. The procedure is generally indicated for young growing dogs (4-8 months of age) with signs of joint instability, but without or with only a minimal radiographic evidence of degenerative joint changes (4, 10). However, this does not preclude the possibility of applying the procedure to older dogs. Tomlinson and Cook (12) suggest that the maximum of the effectiveness of the TPO, in terms of the improvement in the Norberg angle and in the percentage coverage of the femoral head, is achieved during the first three weeks post-surgery and does not substantially change at six weeks. However, in their study, only a subgroup (57%) of 56 dogs had the results for the second post-surgery examination. Moreover, the timing of the examinations was not uniform across the dogs.

For these reasons, our study aimed at the evaluation of this temporal aspect of the effectiveness of the procedure in a group of dogs with a uniform follow-up. In particular, we aimed at evaluating the results of the TPO at one and three months post-surgery with respect to the following parameters: the change of the angle of reduction, change of the femoral head coverage, change of the Norberg angle, presence of lameness and pain, and dog's activity level.

Material and Methods

The medical records and imaging examinations of 37 dogs with bilateral hip dysplasia, which were treated with the use of the TPO between 2001 and 2007, were reviewed. The following information was collected for each of the animals: breed, sex, age, weight, the presence of hip pain during hip palpation, values of the angle of reduction (AR) and subluxation (AS), femoral head coverage (FHC) by the acetabulum in the ventrodorsal (VD) radiographic view, value of the Norberg angle (NA), and the follow-up examination results. The AR and AS were measured by using a non-digital goniometer. The FHC was measured as the distance (in mm) of the center of the femoral head from the dorso-lateral acetabular rim (14), with negative and positive values indicating a medial and lateral location of the center with respect to the rim, respectively.

All dogs were examined before and immediately after the surgery, and then one month and three months post-surgery. The pre-surgery examination and the post-surgery follow-up at months 1 and 3 included the degree of weight bearing, severity of lameness, presence of hip pain during palpation, and the measurements of the NA, AR, AS, and FHC. Note that the immediate post-surgery measurements of NA, AR, and AS could not be retrieved from medical records and are not included in the analyses presented in this report. Additionally, for many dogs, the AS, while detectable, could not be precisely measured, either because it was too subtle or because it passed the sagittal plane of the hip. For this reason, the AS measurements were not analysed.

The dogs were selected for surgery based on clinical and radiological examinations. The surgery was performed on the animals that had painful hips, experienced difficulties during activities, had a positive AR, and did not have any visible evidence of damage of the acetabular rim in the DAR view. Dogs with an evidence of degenerative joint disease were excluded from the TPO treatment. Ventral denervation (1) of the hip contralateral to the one subjected to the TPO was performed on some of the dogs. The procedure was applied when, based on radiological and clinical evidence, the hip could not be subjected to the TPO. Six dogs underwent the simultaneous bilateral TPO procedure when the condition of both joints was similar and when using separate procedures might exacerbate the other joint.

The animals were prepared for surgery according to a routine protocol. The surgical procedure (11) consisted of three osteotomies of the pelvis-pubic, ischial, and ilial, including the removal of a fragment of the pubic bone. None of the animals underwent wire tightening of the ischial bone. The ischial soft tissue and skin incision were closed before iliac osteotomy. The appropriate eight hole canine pelvic osteotomy plate (20^{o} or 30^{o}; MEDGAL™; see Fig. 1) with a left- or right-sided configuration was chosen for each patient according to the value of the AR. In particular, for dogs with a pre-surgery AR value equal to 30⁰ or larger, the 30⁰-plate was used. For all other dogs, the 20⁰-plate was used. All plates were secured with 3.5-mm self-tapping cortical screws. After the surgery, when the dog was anaesthesised, a measurement of the AR/AS was made, and the radiographic examination of the pelvis was performed in the VD view.

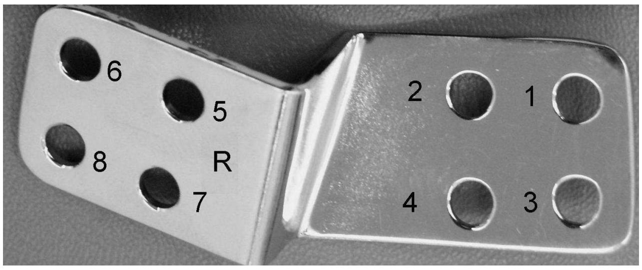

Fig. 1. The eight hole canine pelvic osteotomy plate (right) used in the study, with the indication of the numbering of the screws.

After the surgery, the dogs received nonsteroidal anti-inflammatory drugs for seven days, antibiotic therapy for five days, and were subjected to restricted activity, *i.e.*, short walks on a leash for four weeks. The follow-up orthopedic examinations and radiographs were taken one and three months after the surgery. The VD view radiographs, as well as the evaluation of the AR/AS, were taken under heavy sedation. All identified complications were recorded.

Statistical analysis methods. For each dog, measurements of the AR were obtained for both rear legs before the surgery and one and three months post-surgery, what yielded six measurements for each animal. For all operated dogs, a non-zero value of the AR at baseline, *i.e.*, immediately before surgery, was detected.

Due to incomplete database records, repeated measurements of the FHC and NA were available only for a subset of dogs. In particular, six repeated measurements (for both rear legs before the surgery and one and three months pos-surgery) of the FHC were available. Additionally, for the same subset, measurements of the NA for joints in both rear legs before and one month after the surgery were obtained. Thus, four NA measurements were available for each animal.

Two analyses of the AR measurements were performed. In the first one, the measured values of the angle were analysed with the use of a general linear model for correlated data (13). The model was adjusted for the possible correlation between the measurements obtained for the same animal by using a Kronecker product of an autoregressive correlation structure (for the within-joint measurements) and of an unstructured variance-covariance matrix (for the two joints) (8). Additionally, the association between the changes of the AR *versus* baseline, observed at the post-surgery assessments, was presented graphically and summarised by using Pearson’s correlation coefficient.

In the second analysis, the percentage of TPO-treated joints at one and three months post-surgery, for which the AR was equal to 0 degrees (*i.e*., was absent), was compared by McNemar’s test (7). Additionally, the agreement between the outcomes at the two follow-up assessments was analysed by using Cohen’s κ (7).

Analyses similar to those used for the AR were applied to the FHC measurements. The NA measurements were analysed by using a general linear model for correlated data, similar to the one used in the analysis of the AR data.

The influence of sex, age, and mass on the AR, FHC, and NA measurements was checked by including the corresponding covariates in the applied models. The influence of the plate type (20^{o}-plate or 30^{o}-plate) was investigated by including an appropriate covariate in a general linear model applied to the TPO-operated joints.

All analyses were performed in SAS v9.1.3. Graphs were produced by using STATA v.9. All statistical significance tests were performed at the 5% significance level (two-sided).

Results

Statistical analysis. The data contained information for 37 dogs. Three of them had a luxation of the joint contralateral to the one treated by the TPO, with no angle measurements available for the former. Those three dogs were excluded from the analysis. Thus, in total, the data for 34 operated animals were analysed.

All dogs were operated between September 2, 2001 and April 11, 2007. In the analysed group, there were 23 (67.7%) intact females and 11 (32.3%) males. The distribution of dog age was as follows: two (5.9%)

5-month-old, eight (23.5%) 6-month-old, 14 (41.2%) 7-month-old, seven (20.6%) 8-month-old, two (5.9%) 10-month-old, and one (2.9%) 12-month-old. The mean weight was 29 ±7.16 kg. Table 1 presents the breeds.

Six (17.6%) dogs had the simultaneous bilateral TPO. Nineteen (55.9%) dogs had the unilateral TPO, without an intervention in the other hip. Nine (26.4%) dogs underwent the unilateral TPO and the denervation of the contralateral hip.

Table 1

The distribution of breeds in the analysed material

Breed	Count (%)	Breed	Count (%)
Akita-inu	1 (2.9%)	Golden Retriever	6 (17.7%)
Saint Bernard Dog	1 (2.9%)	Labrador Retriever	6 (17.7%)
Bernese Mountain Dog	3 (8.8%)	Mastino Napoletano	3 (8.8%)
Cane Corso	2 (5.9%)	Bernese Cross-bred	1 (2.9%)
Dogo Argentino	2 (5.9%)	German Shepherd Dog	2 (5.9%)
Perro de Pressa Canario	1 (2.9%)	Irish Setter	3 (8.8%)
Fila Brasiliero	1 (2.9%)	Tosa-inu	2 (5.9%)

Table 2 presents the mean and SD of the AR at baseline (pre-surgery), one and three months post-surgery. The summary statistics are presented for five groups of joints, which were formed by considering the status of a particular joint and its counterpart.

Table 2

Summary statistics of the measurements of the angle of reduction at baseline, one and three months post-surgery for the five groups of joints formed by considering the status of a particular joint and its counterpart

Treatment status of the joint	Baseline		Month 1		Month 3	
	N	Mean ±SD	N	Mean ±SD	N	Mean ±SD
Both TPO-treated	12	33.7 ±6.4	12	7.5 ±8.9	11	5.0 ±8.1
TPO-treated, the other denervated	9	28.9 ±9.3	9	8.9 ±13.6	8	6.3 ±14.1
TPO-treated, the other not operated	19	22.6 ±8.6	19	7.9 ±9.6	19	4.5 ±5.7
Denervated, the other TPO-treated	9	21.1 ±14.3	9	12.2 ±12.8	9	10.0 ±11.2
Not operated, the other TPO-treated	19	14.2 ±10.7	18	12.8 ±10.3	18	10.6 ±12.0

Given the similar pattern of the observed results, the denervated and non-operated joints were treated as a single group in the general linear model applied to the AR measurements. Similarly, the three sets of TPO-operated joints were treated as one group.

Based on the model, the mean values of the AR for the TPO-treated joints at baseline, one and three months post-surgery can be estimated to equal 27.25 ±1.65, 8.13 ±1.65, and 5.45 ±1.68 degrees, respectively. The difference between the first two estimated mean values is equal to 19.12 ±1.59, while the difference between the two last two values is equal to 2.68 ±1.63. The former is statistically significant (P<0.0001), while the latter is not (P=0.10). These results imply that, while the substantial observed decrease in the AR induced by the TPO one month after the surgery can be assumed to reflect a systematic effect, the additional observed decrease after two additional months of follow-up is most likely due to chance.

For the denervated and non-operated joints, the estimated mean values of the AR at baseline, one and three months post-surgery are: 16.84 ±1.94, 12.71 ±1.96, and 10.36 ±1.97 degrees, respectively. The difference between the first two estimated mean values is equal to 4.12 ±1.89 and is statistically significant (P=0.03), while the difference between the last two values is equal to 2.36 ±1.90 and is statistically not significant (P=0.22). As for the TPO-operated joints, these results constitute an evidence for a systematic effect on the AR one month after the surgery and no significant evidence of any additional effect after two additional months of follow-up.

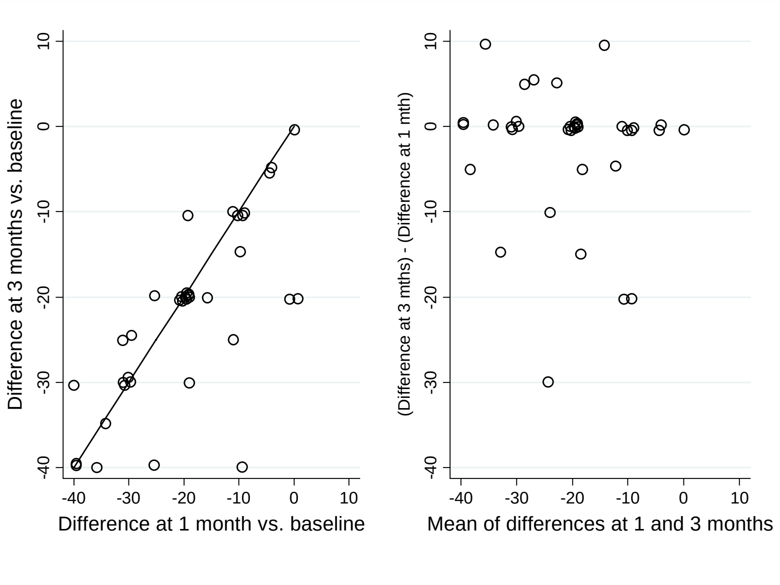

Fig. 2. Left panel: scatterplot of changes of the angle of reduction versus baseline at one and three months for the operated joints (solid line: the 45-degrees line; a small amount of random noise was added to several groups of points to break their overlap). Right panel: scatterplot of the difference between the two changes *versus* their mean value.

The conclusions based on the model are also supported by Fig. 2. The left panel of the figure presents the scatterplot of change of the AR *versus* baseline at one and three months for the TPO-treated joints. Note that the values of all of the changes are non-positive, which indicates a decrease in the angle. To enhance interpretability of the plot, the 45-degrees line has been included in it. It can be seen that the points tend to cluster around the diagonal line. This indicates that they are substantially positively correlated. In fact, the estimated Pearson's correlation coefficient is equal to 0.73. The right panel of Fig. 2 shows the plot of the difference between the two changes *versus* their mean value (2). It can be seen that in the majority of the cases, the change of the AR observed at three months does not deviate by more than 10 degrees from the change observed at one month. In fact, in most cases, the two changes are identical, with their difference equal to 0.

In the group of the TPO-operated joints, the AR values at months 1 and 3 were higher, on average by 6 ±3.1 and 5.2 ±2.7 degrees, respectively, for the joints operated with the use of the 30°-plate. These differences are jointly statistically not significant (P=0.11).

For the TPO-treated joints, the relative frequency of joints with the AR of 0° at months 1 and 3 post-operation was similar and was equal to 52.5% and 60.5%, respectively. The difference was statistically not significant (P=0.55 for McNemar's test), suggesting that the main effect of the TPO was established one month after the surgery. For the denervated and non-operated joints, the relative frequencies were lower and equal to 33.3% and 40.7%, respectively.

There was a strong agreement between the outcomes, in terms of achieving the AR of 0°, at one and three months: if there was improvement in the AR at one month, there was most likely also improvement at three months; and if there was no improvement in the AR at one month, there was most likely no improvement at three months. In fact, in 27 (71%) of the 38 TPO-treated joints, for which data were available at one and three months of follow-up, the results of both post-surgery assessments were concordant. The strength of agreement can be expressed in terms of Cohen's κ (7). For the operated joints, κ was equal to 0.41 (95% confidence interval, CI: (0.13, 0.70)). It indicates that the observed agreement was higher by 41% than the agreement that would be expected by chance. Thus, a fair agreement between the outcomes observed at the two follow-up assessments can be inferred (7). For the 27 denervated or non-operated joints, for which data are available at one and three months of follow-up, the results of both assessments were concordant for 23 (85%) joints. The corresponding value of κ was equal to 0.68 (95% CI: (0.40, 0.97)), indicating, not unexpectedly, a stronger agreement.

Repeated measurements of the FHC were available for 19 dogs. Among these dogs, there were six (31.6%) intact females and 13 (68.4%) males. The distribution of their age was as follows: one (5.3%) 5-month-old, 5 (26.3%) 6-month-old, seven (36.8%) 7-month-old, four (21.1%) 8-month-old, 1 (5.3%) 10-month-old, and one (5.3%) 12-month-old. The mean weight was 29.6 ±7.47 kg.

Table 3 presents the mean and SD of the FCH at baseline (pre-surgery), one and three months post-surgery. The summary statistics are presented for five groups of joints, which were formed by considering the status of a particular joint and its counterpart.

Table 3

Summary statistics of the measurements of the position of the center of the femoral head from the dorso-lateral acetabular rim at baseline, one and three months post-surgery for the five groups of joints formed by considering the status of a particular joint and its counterpart

Treatment status of the joint	Baseline		Month 1		Month 3	
	N	Mean ±SD	N	Mean ±SD	N	Mean ±SD
Both TPO-treated	8	8.4 ±1.5	8	1.9 ±3.0	8	1.6 ± 4.1
TPO-treated, the other denervated	4	6.0 ±3.4	4	0.5 ±5.3	4	-1.3 ±6.7
TPO-treated, the other not operated	11	6.3 ±2.4	1	-0.5 ±2.7	1	-1.9 ±2.5
Denervated, the other TPO-treated	4	7.5 ±3.9	4	7.8 ± 2.1	4	8.8 ±4.7
Not operated, the other TPO-treated	11	4.1 ±3.8	1	3.6 ±3.4	1	3.0 ±3.1

The FHC measurements were analysed by a general linear model. In the model, the denervated and non-operated joints were treated as a single group. Similarly, the three sets of TPO-operated joints were grouped together.

The model-estimated mean values of the FHC for the TPO-treated joints at baseline, one and three months post-surgery are equal to 6.98, 0.54, and -0.56 mm, respectively, with SD=0.76. The difference between the first two estimated mean values is equal to 6.44 ±0.52, while the difference between the two last values is equal to 1.11 ±0.52. Both are statistically significant (P<0.0001 and P=0.04, respectively).

In the group of the TPO-operated joints, the FHC measurements at months 1 and 3 were higher on average by 3.6 ±1.2 and 4.7 ±1.5 mm, respectively, for the joints operated with the use of the 30°-plate. These differences are jointly statistically significant (P=0.01).

For the denervated and non-operated joints, the estimated mean values of the FHC at baseline, one and three months post-surgery, are as follows: 4.97, 4.75, and 4.53 mm, respectively, with SD=0.94. The difference between the first two estimated mean values is equal to 0.21 ±0.64, while the difference between the last two values is equal to 0.22 ±0.64. None of the differences is statistically significant (P=0.74 and P=0.73, respectively).

For the TPO-treated joints, the relative frequency of joints with the FHC≤0° , *i.e.*, for which the center of the femoral head was located medial to or at the dorso-lateral acetabular rim, at months 1 and 3 post-surgery was equal to 52.2% and 60.9%, respectively. The difference was statistically not significant (P=0.50 for McNemar's test). For the denervated and non-operated joints, the relative frequencies were lower and equal to 6.7% and 13.3%, respectively.

There was a strong agreement between the outcomes, in terms of achieving the FHC≤0°, at one and three months: if the center of the femoral head was located medial to or at the dorso-lateral acetabular rim at one month, it was likely to be similarly located at three months; and if it was located lateral to the rim at one month, it was likely to be lateral also at three months. In fact, in 21 (91.3%) of the 23 TPO-treated joints, for which data were available at one and three months of follow-up, the results of both post-surgery assessments were concordant. The estimated value of Cohen's κ was equal to 0.82 (95% confidence interval, CI: (0.60, 1.00)), indicating a substantial agreement between the outcomes observed at the two follow-up assessments (7). For the 15 denervated or non-operated joints, the results of both assessments were concordant for 14 (93.3%) joints. The corresponding value of κ was equal to 0.63 (95% CI: (-0.01, 1.00)).

Table 4

Summary statistics of the measurements of the Norberg angle at baseline and one month, and for the post-pre difference for the five groups of joints formed by considering the status of a particular joint and its counterpart

Treatment status of the joint	N	Baseline Mean ±SD	Month 1 Mean ±SD	Month 1 Mean ±SD
Both TPO-treated	8	78.1 ±3.7	96.9 ±20.7	18.8 ±20.8
TPO-treated, the other denervated	4	88.8 ±11.8	106.3 ±20.2	17.5 ±15.0
TPO-treated, the other not operated	11	89.1 ±10.7	100.9 ±14.8	11.8 ±12.7
Denervated, the other TPO-treated	4	81.3 ±14.4	92.5 ±15.6	11.2 ±30.0
Not operated, the other TPO-treated	11	95.0 ±11.0	90.5 ±17.0	-4.5 ±10.6

Table 4 presents the mean and SD of the NA measured pre- and post-surgery for the group of 19 dogs, for which the FHC measurements were analysed. The Table also displays the mean and SD of the post-pre differences.

The values of the NA measurements were analysed by a general linear model. The TPO-treated or denervated joints were treated together as a single group of operated joints, because there was no statistically significant difference between the mean baseline values and between the changes for the four groups of those joints (P=0.52). For the operated joints, the model suggested that the NA increased on average by 14.2 ±2.9 degrees after the surgical intervention. This increase was statistically significant (P<0.0001) and indicates a positive effect of the surgical intervention. For the non-operated joints, the estimated coefficient suggested a slight decrease in the angle (5.2 ±4.5), but the decrease was not statistically significant (P=0.26).

In the group of the TPO-operated joints, the pos-surgery NA values were lower on average by 9.8 ±7.2 degrees for the joints operated with the use of the 30°-plate. The difference was statistically not significant (P=0.18).

Clinical results. There were 37 dogs operated on, of which 34 were evaluated statistically. The three dogs excluded from the analysis suffered, before the performance of the TPO, from luxation of the hip contralateral to the leg that was ultimately operated. The results of the operated side were satisfactory and comparable to those obtained for the other dogs. In particular, within four weeks after the surgery, the AR for the operated leg decreased to 0º for all of the three excluded dogs.

The TPO was performed without any important operative or postoperative clinical complications. Three dogs (Mastino Napoletano, Labrador Retriever, and German Shepherd) suffered from haematoma in the lateral post-operative wound. In Mastino Napoletano, it was necessary to make drainage after removing 2-3 skin sutures. The other two dogs (one treated bilaterally) recovered without any medical treatment, but only with the use of a local thermotherapy.

In all cases, an eight-hole canine pelvic osteotomy plate was used. In 23 cases it was difficult to place screws 1 or 6 (for the numbering, see Fig. 1). However, in those cases there was no evidence of any problems due to the fact that the screws were not used.

Two dogs had radiographic evidence of screw loosening. Both were operated bilaterally. In one of them, a Dogo Argentino, a dislocation of screw 1 was detected in the left joint during the first re-check, four weeks after the surgery. In the second dog, a Fila Brasiliero, three broken screws (no. 2, 3, and 4) were identified in the cranial part of the plate in left joint. In both cases, the loosening of the screws had no important influence on the reduction of the AR values measured one and three months after the surgery. Initially, the right and left AR for the Dogo Argentino were equal to 20º and 30º, respectively, while for the Fila Brasiliero both values were equal to 30º. At the first postoperative examination at four weeks, all the values of the AR decreased to 0º. At the second postoperative examination at three months, the AR values remained at 0º, except for the left AR for the Dogo Argentino, which was measured at 5º. The loosening of the screws did influence the FHC values measured one and three months after the surgery. Before the surgery, the FHC for both dogs was equal to 8 mm and 10 mm for the right and left joint, respectively. For the Dogo Argentino, the corresponding values at one and three months post-surgery were equal to -3 and 5 mm and to -6 mm and 3 mm, respectively, hile for the Fila Brasiliero they were equal to -2 mm and 4 mm and to -2 mm and 5 mm, respectively. The pre-surgery values of the NA for the Dogo Argentino were equal to 75º and 80º for the right and left joint, respectively, while for the Fila Brasiliero they were equal to 80º and 85º, respectively. One month post-surgery the corresponding values were equal to 115º and 90º for the Dogo Argentino and to 140º and 85º for the Fila Brasiliero. Overall, however, the final clinical outcome of the TPO was satisfactory for both dogs.

Discussion

The results of the statistical analysis confirm the expected positive effect of the TPO. On average, in about 53% and 60% of the operated joints, the measured AR was equal to 0º (*i.e.*, disappeared) at one and three months after the surgery, respectively. The measured values of the AR decreased with time, indicating the improvement in the function of the joints. The effect of the treatment was clearly observed already at one month post-surgery and, in principle, was maintained at the same level two months later. This conclusion was supported by the analysis of the agreement between the changes of the AR observed for the individual animals at the two post-surgery follow-up visits. There was no statistically significant effect of the plate type on the mean post-surgery AR of the TPO-operated joints.

The analysis also indicates that, in cases when the other joint was not operated or only denervated, the performance of the non-operated joint also improved. In particular, in about 33% and 41% of the non-operated joints, the measured AR was equal to 0^{o} at one and three months post-surgery, respectively.

The results of the analysis of the coverage of the femoral head, conducted for a subset of dogs with available measurements, are in agreement with the results of the AR analysis. The measured values of the FHC decreased with time for the TPO-operated joints, indicating the improvement in the function of the joints. On average, in about 52% and 61% of the operated joints, the center of the femoral head was located at or medially to the dorso-lateral acetabular rim. There was also a strong agreement between the location of the center of the femoral head observed for the individual animals at the two post-surgery follow-up visits.

The analysis also indicates that in cases when the other joint was not operated or only denervated, in about 6.7% and 13.3% of the non-operated joints, the center of the femoral head was located at or medially to the dorsolateral acetabular rim at one and three months post-surgery, respectively.

Tomlinson and Cook (12) measured the FHC by the percentage coverage of the area of the femoral head by the acetabulum. They reported the mean percentage coverage of 24.4%, 72.6%, and 82.8% at baseline, 3 and 6 weeks post-surgery, respectively, for the 20°-plates, and 19.9%, 73.2%, and 71.6% for the 30°-plates. The corresponding weighted (by the number of joints) means are 22.5%, 73%, and 77% at baseline, 3 and 6 weeks post-surgery, respectively. Thus, the results imply a large increase in the coverage of at 3 weeks, with a slight increase afterwards. In our analysis, we see a similar pattern in the FHC measurements expressed as the distance between the center of the femoral head and the dorso-lateral acetabular rim (see Table 4; note that a decrease in the distance implies an increase in the percentage coverage). In our data, the mean post-surgery FHC measurements were higher for the joints operated with the use of the 30°-plate. A similar trend towards higher percentage coverage for the 20°-plate can also be observed in the results of Tomlinson and Cook (12). However, in their data, it does not reach statistical significance. This discrepancy between their and our results may be due to the difference in the measures used to capture the femoral head coverage and the related variability.

For the NA, the results of our analysis indicate a statistically significant increase in the angle after the surgical intervention for operated and denervated joints at one month post-surgery. On average, the angle increased by about 14 degrees. There was no statistically significant effect of the plate type on the mean post-surgery NA of the TPO-operated joints. Similar observations were made by Tomlinson and Cook (12); they reported a mean increase in the NA of about 35-40 degrees at 3 weeks after the TPO, without a plate effect. For the non-operated joints, our results suggest no change in the mean value of the NA.

We have observed a decrease in the AR and an improvement of the NA in denervated joints. This agrees with the conclusions regarding the efficacy of the denervation drawn by Ballinari *et al.* (1). It is difficult to provide an unambiguous reason for this effect. It may be due to the disappearance of pain and the re-gained ability to use the hip joint, with all positive consequences for the tendons, capsule joint, and muscles. Additionally, the improvement in the contralateral, TPO-operated joint, may have also a positive influence on the ability to use the pelvic limbs.

In our analyses, none of the other clinical factors under consideration (sex, age, body weight) influenced the outcome of the operation. Note, however, that the available sample size was limited and one cannot exclude the possibility of a false negative finding.

In our study, a screw migration was observed in two cases. It occurred in two heavy active dogs, which were operated bilaterally. The problem was detected during the first postoperative examination and, what is worth stressing, did not affect the positive post-operative results. The problem of the screw loosening after the TPO procedures is well known. It is the most common post-operative complication with respect to the cranial part of the plate (3, 5, 6, 10). Bogoni and Rovesti (3) reported that it is likely to occur in the first 10 d after the surgery. They consider that fibrous callus, which is present during that time, allows keeping the postoperative acetabular rotation without any changes, despite the problem with the screws. Simmons *et al.* (10) reported that migration of screw 1 was significantly higher in dogs treated bilaterally. They recommended securing the cranial screws within the sacrum bone to avoid implant migration. Fitch *et al.* (6) indicated that screw loosening leads to reduced weight bearing and gait abnormalities of the operated leg, which are observed 4-12 months after surgery. They suggest that a more rigid fixation by using the second ventral plate could help to limit the loosening of screws. Additional factors, which may influence the loosening of screws, are low bone ilium density of young dogs, high activity level, screw type, and screw positioning (5).

Retrospective studies often encounter problems related to, *e.g.*, unavailability of data. In our case, the immediate post-surgery measurements for the NA, AR, and AS could not be retrieved. As indicated in the Introduction, precise measurements of the AS were not available for many dogs due to problems with measuring the angle. For these reasons, we cannot, for instance, evaluate whether the outcome of the TPO, observed four weeks after surgery, is established immediately after the operation, or somewhere later during the first month. However, this does not preclude drawing the conclusion that the results of our study indicate that the positive outcome of the TPO in joint congruity, evaluated by using the AR, FHC, and NA is achieved already during the first month after the surgery and does not substantially change at three months post-surgery. This is in agreement with the conclusions reported by Tomlinson and Cook (12). Our findings confirm the usefulness of the TPO for treatment of hip dysplasia in dogs.

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