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Acetabular ventroversion using the sacroiliac wedge, with or without pelvic osteotomies in dogs: an *ex vivo* study[1]

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ABSTRACT.- Ikenaga F.M, Rocha J.R., Carvalho L.L., Honsho C.S., Dias F.G.G., Costa R.C., Rocha T.A.S.S. & Dias L.G.G.G. 2019. **Acetabular ventroversion using the sacroiliac wedge, with or without pelvic osteotomies in dogs: an *ex vivo* study.** *Pesquisa Veterinária Brasileira 39(8):643-648*. Universidade de Franca, Avenida Dr. Armando Salles de Oliveira 201, Parque Universitário, Franca, SP 14404-600, Brazil. E-mail: gustavogosuen@gmail.com

Canine hip dysplasia (CHD) is a common condition observed in the surgical clinics for small animals. Among the surgical techniques for management of CHD, triple pelvic osteotomy and sacroiliac wedge promote acetabular lateral axial rotation (ventroversion), increasing acetabular coverage and joint stability. The present study aimed to evaluate radiographically, by measuring the Norberg angle (NA) and the acetabular coverage percentage (ACP), the acetabular ventroversion induced by the sacroiliac wedge technique, with or without pelvic osteotomies; we also checked the feasibility of wedges made of polyamide with an angulation of 20° and 30°. The software used to measure NA and ACP was AutoCAD® 2009. Pelves from 10 canine corpses were evaluated radiographically at four time-points: M0 (Control Group), M1 (wedges of 20° and 30°), M2 and M3 (wedges associated with bilateral pubis and ischium osteotomies, respectively). There was no significant increase in the acetabular ventroversion at M1, M2, and M3. The polyamide sacroiliac wedge technique proved to be feasible, stable, and easy to apply. Further, the software proved to be efficient and easy to use for NA and ACP measurements. In the present study, even in the cases of non-dysplasic adult canine corpses, it was concluded that the sacroiliac wedge technique does not require to be accompanied by pubis and ischial osteotomies because they did not significantly increase the NA and ACP.

INDEX TERMS: Acetabular ventroversion, canine hip dysplasia, sacroiliac wedge, pelvic osteotomies, *ex vivo*, dogs, surgery, clinics.

RESUMO.- [Ventroversão acetabular associada ou não a osteotomias pélvicas por meio da utilização de cunha sacroilíaca em cães: estudo ex-vivo.] A displasia coxofemoral (DCF) é afecção comum na clínica cirúrgica de pequenos animais. Entre as técnicas cirúrgicas para controle da DCF, a osteotomia pélvica tripla (OPT) e a cunha sacroilíaca (CSI), promovem rotação lateral acetabular no eixo axial (ventroversão), aumentando a cobertura acetabular e a estabilidade da articulação. Desta forma, o presente estudo objetivou avaliar radiograficamente, por meio da aferição do ângulo de Norberg (NA) e da porcentagem de cobertura acetabular (PCA), a ventroversão acetabular induzida pela técnica da cunha sacroilíaca, associada ou não às osteotomias pélvicas, além de verificar a exequibilidade das cunhas confeccionadas de poliamida com angulação de 20º e 30º. O software utilizado para aferir o AN e o PCA foi o AutoCAD® 2009. Dez pelves de cadáveres caninos foram avaliadas radiograficamente em quatro momentos: MO (Grupo Controle), M1 (cunhas de 20º e 30º), M2 e M3 (cunhas associadas à osteotomia bilateral do púbis e ísquio, respectivamente). Não houve aumento significativo da ventroversão em M1, M2 e M3. A técnica de cunha sacroilíaca de poliamida mostrou-se exequível, estável e de fácil aplicação. Não obstante, o software utilizado mostrou-se eficiente e de fácil utilização nas aferições do AN e PCA. Neste estudo, mesmo tratando-se de cadáveres

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de cães adultos e de maioria não displásicos, concluiu-se que a utilização da técnica de cunha sacroilíaca não necessita de associação à ostectomia púbica e a osteotomia do ísquio por não promoverem aumento significativo do AN e da PCA.

TERMOS DE INDEXAÇÃO: Cunha sacroilíaca, displasia coxofemoral canina, osteotomias pélvicas, ventroversão acetabular, cães, *ex vivo*, caninos, cirurgia, clínica.

INTRODUCTION

Canine hip dysplasia (CHD) is frequent in dogs, especially in the fast-growing large breeds (Minto et al. 2012, Rocha et al. 2013); CHD occurs due to joint incongruence between the femoral head and the acetabulum, causing soft tissue looseness and instability, as well as degenerative joint disease (Rocha et al. 2013).

The diagnosis of CHD is based on the review, history, clinical signs, and orthopedic and radiographic examination (Piermattei et al. 2015, Rocha et al. 2013). The measurement of Norberg angle (NA) and acetabular coverage percentage (ACP) are effective methods for the detection of CHD in dogs, which can be calculated using specific software (Lopez et al. 2008, Regonato et al. 2009). Both assess the structural and functional conditions that influence the hip joint, such as joint laxity, hip joint subluxation, and acetabular configuration, but they are not evaluated by the same method since the craniolateral acetabular border influences the NA and the dorsal acetabular border the ACP measurement (Ohlerth et al. 2001).

Treatment of CHD may involve conservative or surgical techniques; however, it is recommended that it be instituted as early as possible, regardless of the technique chosen. Surgical techniques for treating CHD aim to relieve the pain during ambulation and reduce the increased acetabular coverage, improving joint stability (Schachner & Lopez 2015). In this context, Slocum & Slocum (1992) reported triple pelvic osteotomy (TPO), and Conzemius et al. (1999) and Regonato et al. (2009) reported the sacroiliac wedge (SW), as techniques to increase the surface contact between the femoral head and acetabulum, by increasing the acetabular ventroversion, indicated in 5–12-month-old animals of large and giant breeds, restoring the joint function (David & Kasper 1992, Vezzoni 2007).

There is no consensus in the scientific literature regarding the degree of optimal rotation of the pelvis to allow greater acetabular coverage, although rotation from 20° to 30° is accepted for dogs without hip joint subluxation (Slocum & Devine 1986, Tomlinson & Cook 2002). It is known that a lower degree of rotation does not lead to improvement, and excessive rotations may compromise the extension and abduction of the hip joint due to collision of the femoral neck with the acetabular border (Schrader 1981, Slocum & Devine 1986).

In a study with canine corpse pelves, Conzemius et al. (1999) proposed the use of SW, producing an effect similar to that of TPO. Regonato et al. (2009) demonstrated the surgical approach, and proved its efficiency for acetabular ventroversion, using castor bean (*Ricinus communis*) polyurethane wedges in canine corpses. This technique, besides promoting acetabular ventroversion, overcame the disadvantages of TPO, reducing surgical time, risks, and costs. The SW technique involves the application of a wedge between the sacroiliac junction, promoting rotation of the acetabular segment, being associated with ischial and pubis osteotomies (Regonato et al. 2009). The wedge stabilization at the sacroiliac junction is achieved using orthopedic screws applied to the lateral side of the ilium, passing through the wedge, and penetrating the sacral body (Conzemius et al. 1999, Regonato et al. 2009).

The aim of this study was to radiographically evaluate NA and ACP in order to compare the effectiveness of the acetabular ventroversion achieved by the polyamide SW technique with angulations of 20° and 30°, with or without pelvic osteotomies. In addition, we sought to assess the feasibility and possible advantages of the polyamide wedge and the actual need for pelvic osteotomies, with a view to minimizing the surgical time and possible post-operative complications.

MATERIALS AND METHODS

Ethics statement. The present study was carried out under the agreement and surveillance of the Ethics Committee on the Use of Animals of the "Universidade de Franca" (Unifran), under protocol number 027/12.

Animals. The use of corpses is advocated for ethical considerations as the well-being of animals. Such specimens were donated by the animal tutors for the Veterinary Hospital. No preliminary screening was performed for the presence of hip dysplasia.

For this study, the hip joints from 10 canine corpses of medium to large size (body weight above 15kg) were used.

Radiographic evaluation. The hip joints were radiographically evaluated (ventrodorsal and laterolateral projections) at four time-points. In the first time-point, M0 (control), no surgical intervention was performed in order to obtain the NA and ACP. The second time-point (M1) was after the implantation of SW, right and left, with 20° and 30° angulation, respectively, without any pelvic osteotomy. In the third time-point (M2), after SW removal and bilateral pubis ostectomy (Fig.1B,C), the SW were reassigned, fixed, and the radiographic examination was performed sequentially. In the fourth time-point (M3), the SW were removed again, and ischial osteotomy was performed bilaterally (Fig.1D). Simultaneously, the SW were relocated and fixed to perform the last radiographic examination. For all four time-points (M0 to M3), 10 right and 10 left hip joints were assessed (Fig.2).

Implants. The wedges were made using nylon (polyamide), angled at 20° and 30°, 2.5cm high, 3cm long, and 1cm wide. The stainless steel orthopedic screws used for stabilizing the wedges at the sacroiliac joint were 3.5-mm thick, and of appropriate length, as required.

Surgical technique. The operative procedures were performed in M1 to M3, in both hemipelves, for the implantation of the wedges with 20° and 30° angulation in the left and right sacroiliac junctions, respectively. Initially, a wide trichotomy was performed from the second lumbar vertebra to the beginning of the coccygeal vertebrae, and enlarged in both lateral directions.

The corpses were positioned in the ventral decubitus, and the sacral bones were technically approached, as proposed by Piermattei (1993). For placement of the wedge at the sacroiliac junction, the dorsal sacroiliac ligament was sectioned, and the access/removal of the synchondrosis (sacroiliac joint) was performed using a periosteal elevator, osteotome, and hammer lift.

Once the sacroiliac joint was sectioned, a 2.5-mm bore was made on the lateral surface of the sacrum using a surgical drill, with the depth being 50% to 60% of that of the sacral body. Simultaneously, the wedge was positioned at the sacroiliac junction, with its base level with the dorsal plane of the sacrum, as described by Regonato et al. (2009) (Fig.1A).

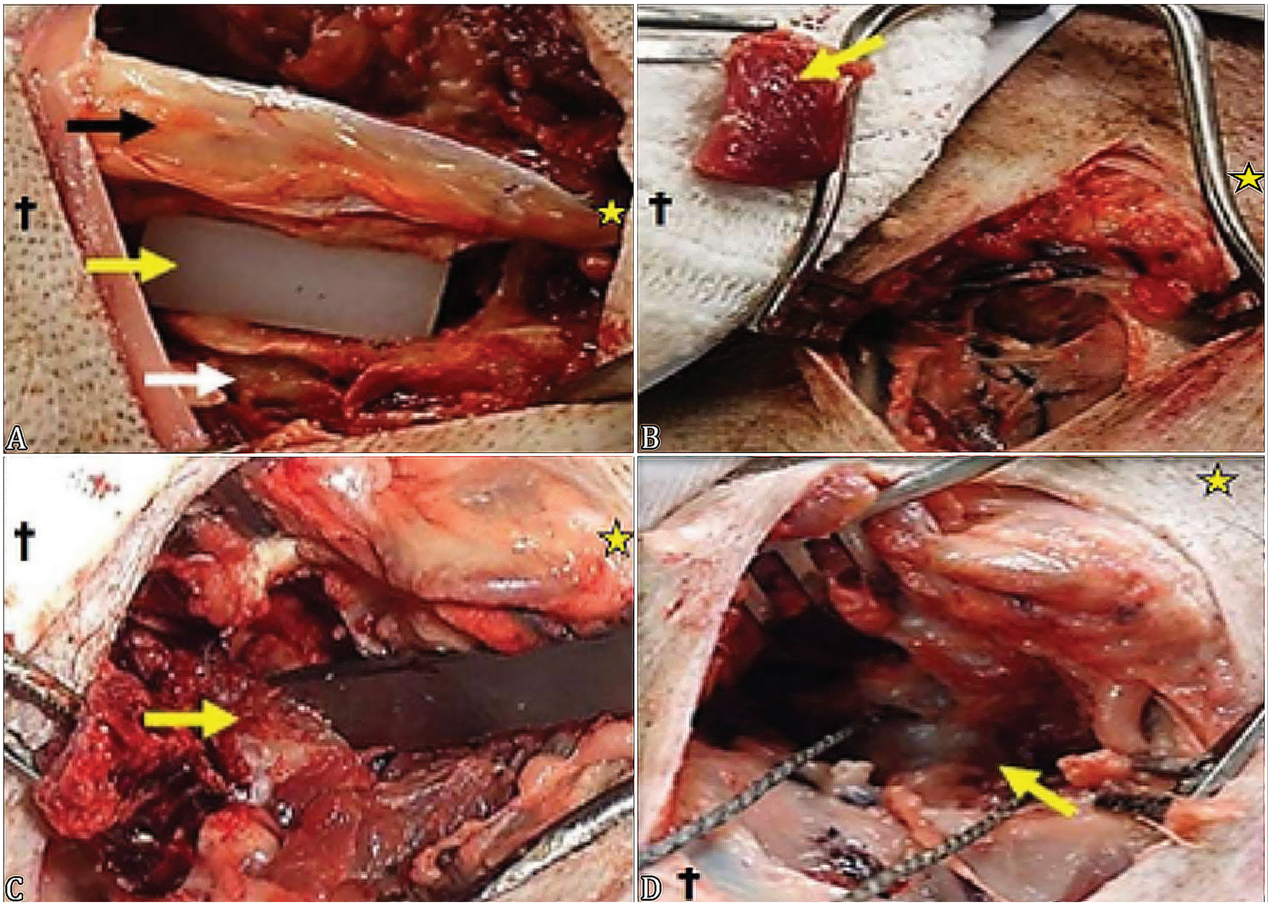

Fig.1. Surgical time-points studied. (**A**) Placement of the 20° polyamide wedge implant (yellow arrow) with its base level with the dorsal plane of the sacrum (white arrow) on the medial aspect of the right ilium wing (black arrow). (**B**) Ventral incision on the pubis, with removal of a fragment of the pectineus muscle (yellow arrow). (**C**) Performing ostectomy of the pubis (yellow arrow) using hammer and osteotome. (**D**) Passage of the Gigli saw for osteotomy of the ischium (yellow arrow).

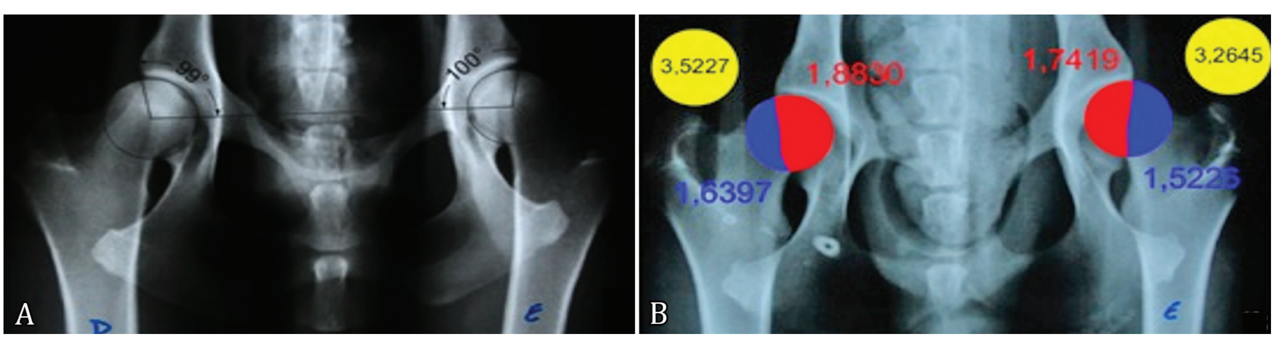

Fig.2. Radiographic images of the canine cadaver pelvis in the ventrodorsal projection. (**A**) Norberg angle gauging. (**B**) Measurement of the area of the femoral head covered by the acetabulum (red semicircle) and not covered by the acetabulum (blue semicircle), used to calculate the ACP (acetabular coverage percentage). The yellow circle represents the total area of the femoral head.

The iliac crest and wedge were then drilled using a pneumatic surgical drill, with an attempt to combine this opening with the one previously made in the sacrum. A stainless steel screw of 3.5mm diameter with compatible length was used for stabilization. This procedure was performed on both hemipelves. After radiographic evaluation (M1), the wedges were removed, and the pubis was osteotomized bilaterally using an osteotome and orthopedic hammer. To facilitate this, the cadaver was positioned in dorsal decubitus, the pectin muscle was removed, and then, using the osteotome, a 1-cm area of the pubis was removed (Fig.1B,C). Thereafter, the SW were reassigned and fixed, as previously described.

After a new radiographic evaluation (M2), the wedges were removed again, and the animal was positioned in lateral decubitus (right and left) to perform ischial osteotomy using the lateral approach. After elevation and removal of the musculature, the Gigli saw was used for the ischial osteotomy (right and left) (Fig.1D). Subsequently, the SW was reassigned and stabilized (M3).

Radiographic positioning and evaluation of acetabular ventroversion. The ventrodorsal (VD) position of the corpses was adopted, as recommended by the Orthopedic Foundation for Animals. Right and left laterolateral (LL) projections were also performed to validate the correct positioning of the screws in the sacral body.

Radiography was performed at all time-points (M0 to M3) to verify which angulation of SW (20° or 30°), with or without pelvic osteotomies, provided adequate acetabular ventroversion, and consequently, increased acetabular coverage. Two parameters, NA and ACP, were measured. To achieve this, the radiographs were photographed using a digital camera (Sony Cyber-shot, 16.1 megapixels) and the images were exported to AutoCAD® 2009 software - Autodesk. Measurement of NA was performed as described by Brass et al. (1978) (Fig.2A), and the ACP was measured based on the formula (a/b)x100=ACP, as described by Tomlinson & Johnson (2000), where: "a" represents the area of the femoral head covered by the acetabulum (red area, Fig.2B) and "b" represents the total area of the same femoral head (yellow circumference, Fig.2B).

Statistical analysis. The variables were tested for normality using the Shapiro-Wilk test. For the normally distributed data, a single-variance analysis with multiple replications was performed, followed by the Tukey test, and the data were reported as mean ± standard deviation. The means of the tested groups (M1, M2, and M3) were compared to the means of the Control Group (M0) for the same side of the limb (hemipelvis). The means for the right and left sides of each group were also compared. The level of statistical significance was set at $P \leq 0.05$.

RESULTS

Ten canine corpses (7 males, 70% and 3 females, 30%) unidentified breed were used, with the weight ranging from 17.4kg to 42.8kg (mean 27.32kg). Regarding the presence of hip dysplasia, 3 (30%) and 5 (50%) of the cadavers included in this experiment were diagnosed with dysplasia (based on NA) in the right and left hips, respectively.

After radiographic evaluations (M0, M1, M2, and M3) and NA and ACP measurements for each time-point, we observed in both groups an increase in the NA values at M1 and a decrease at M2 and M3, but without statistically significance (Table 1).

Table 1. Values (in degrees) and standard deviations of the NA (Norberg angle) and ACP (acetabular coverage percentage) of the hip joints of the 10 dogs at the time-points studied

Surgical technique/ Measurement method	SW	M0	M1	M2	M3
NA (º)	Right 20°	106 ± 4^{aA}	111 ± 6^{aA}	112 ± 5^{aA}	110 ± 8^{aA}
	Left 30°	103 ± 5^{aA}	109 ± 3^{aA}	108 ± 5^{aA}	108 ± 7^{aA}
ACP (%)	Right 20°	56 ± 3^{aA}	57 ± 2^{aA}	58 ± 4^{aA}	56 ± 2^{aA}
	Left 30°	54 ± 8^{aA}	57 ± 2^{aA}	57 ± 1^{aA}	56 ± 2^{aA}

M0 = corresponds to the preoperative time-point, M1 = corresponds to the time-point after placement of polyamide sacroiliac wedge (SW) with an angulation of 20° and 30° in the right and left sacroiliac junctions, respectively, M2 = corresponds to the time-point after bilateral pubis ostectomy and repositioning and stabilization of SW, M3 = corresponds to the time-point after bilateral ischial osteotomy and repeated stabilization of SW; ^{a} similar lower case letters indicate that there is no statistical difference in the data between the time-points, ^{A} similar capital letters indicate that there is no statistical difference between the data for each hemipelvis at each time-point studied.

DISCUSSION

The proportion of males and females in the experimental animals studied (70:30, respectively) corroborate the findings of Minto et al. (2012), who mentioned that there is no sexual predisposition to hip dysplasia. The dysplastic animals observed in the study included 3 (30%) and 5 (50%) corpses affected in the right and left hips, respectively. This non-uniformity between the groups may be due to the absence of preliminary screening, since the animals cadavers were donated to the institution; moreover, these animals were adults and some were non-dysplastic, which, in clinical practice, would not be considered candidates for the technique.

In this study, at one of the time-points, no osteotomy was performed for the wedge placement (M1), as proposed by Conzemius et al. (1999), the developer of this technique, who believed that SW technique without osteotomy was feasible. We performed an osteotomy at M2 and two osteotomies at M3, avoiding the third osteotomy of the ilium performed in the TPO technique, based on the study by Regonato et al. (2009), who cited the advantages of SW over TPO.

The ventral rotation of the acetabulum between 20° and 30° is, according to Slocum & Devine (1987), sufficient for most patients. The authors produced polyamide wedges with an angulation of 20° and 30° in order to test whether there is a difference in the resulting ventroversion, since the 30° angulation, according to Slocum & Devine (1986) and Regonato et al. (2009) can impair pelvic limb abduction, adversely affecting the patient's ambulation. Polyamide was selected due to its easy acquisition, low cost, ease of sterilization, and ability to be modeled; it allows the drilling and allocation of orthopedic screws and is biocompatible (Spadeto-Junior et al. 2010).

The placement of the wedges at the right and left sacroiliac junctions was performed as described by Conzemius et al. (1999), and reproduced by Regonato et al. (2009). In this study, no intercurrences were found in the surgical technique between the groups. However, the most difficult part of the procedure, requiring the greatest attention, also cited by the aforementioned authors, was the correct placement of the screw in the sacral body.

The polyamide wedges could not be seen on radiographic examination because they were radiolucent, as shown in the study by Regonato et al. (2009), who used castor bean wedges. The VD and LL projections were essential for the verification of the correct placement of the implants in the sacrum; in particular, the DV projection was essential for verification of NA and ACP measurements.

Both ACP and NA were measured at all the time-points studied, since, according to Lopez et al. (2008), such combined assessments can correctly classify pelvic conformation in up to 98% of the cases, thus increasing the accuracy of the results.

Using the same methodology proposed by Lopez et al. (2008), the radiographic images obtained were photographed and exported to AutoCAD® 2009 software, and sequentially, NA was measured in accordance with the method proposed by Regonato et al. (2009), and ACP was measured according to the method described by Tomlinson & Johnson (2000) and Regonato et al. (2009).

Rasmussen et al. (1998) reported that in the immediate postoperative period of TPO, there was an increase in the NA and ACP values, and that in the majority of animals, the values increased by an average of 20° in the case of NA. In the present study, there was an increase in M1 in relation to M2 and M3, but the difference was not significant (Table 1). This was probably due to the fact that some of the animals were non-dysplasic; moreover, according to Regonato (2010), there may be a gradual increase in the acetabular coverage in the first 6 weeks following the surgical procedure. The changes that occur in the pelvic structure during the postoperative period, such as healing and soft tissue remodeling, cannot be observed using this type of experimental paradigm.

There was an increase in the NA at M1 (SW only) and a decrease at M2 and M3, but the differences were not statistically significant. This is possibly due to ostectomy of the pubis and ischium, which may have reduced the pressure caused by the wedge placement at the sacroiliac junction, which, in turn, increases the acetabular coverage. The same observation was made with respect to ACP, which was higher at M1 than at the other time-points, corroborating the findings of Lopez et al. (2008) and Regonato (2010), who mentioned that with the increase or decrease in NA, the ACP increases or decreases proportionally. It is believed that the reasoning used to explain the changes in the NA can also be used to explain the changes in ACP for this experimental model.

Another factor possibly contributing to the small increases in NA and ACP is the methodology used: the removal and replacement of the wedges at each time-point may have impaired the correct positioning and ideal stabilization of the wedges, but could not be observed in the intraoperative examination and in the radiographic images of the groups.

Assessment of differences in the values obtained at the different time-points revealed a 4.7%, 5.6%, and 3.7% increase at M1, M2, and M3, respectively, for the use of the 20° wedge, compared with the value at M0. For the wedge of 30°, there was an increase of 5.8% at M1 and 4.8% at M2 and M3 compared with M0. Subjectively, since there was no statistical significance, the performance of both osteotomies seems to have impaired the increase of NA, except at M2 for the wedge of 20°.

Regarding ACP, when we evaluated the percentage difference in the values, we observed the same trend as that for NA, with an increase of 1%, 2%, and 0% at M1, M2, and M3 for the 20° wedge, compared with the value at M0. When using a 30° wedge, a 3% increase was observed in the ACP at M1 and M2 and 2% at M3, compared with M0. Therefore, SW technique performed with osteotomies reduced the ACP.

CONCLUSIONS

From the surgical point of view, the placement of the polyamide wedge at the sacroiliac junction of dogs proved to be feasible, easy to apply, and stable, with the application of the compressive screw, at the different time-points studied.

The scanning of the radiographic images and the use of AutoCAD® 2009 software for measuring the NA and ACP of the studied groups at the desired time-points proved to be efficient and easy to use.

In the present study, in the case of cadavers of adult and mostly non-dysplasic dogs, it was concluded that the SW technique modified the acetabular coverage without osteotomies, but not significantly, as shown by the measured NA and ACP, mainly for the wedges with a 20° angle than those with 30° angle. The osteotomies did not enhance the operative technique studied, and a small reduction in ACP was detected.

Conflict of interest statement.- The authors declare no conflict of interest.

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