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COMPARISON OF VISUAL METHOD AND OSIRIX® SOFTWARE FOR EVALUATION OF BONE CONSOLIDATION AFTER TIBIAL TUBEROSITY ADVANCEMENT IN DOGS

COMPARAÇÃO ENTRE O MÉTODO VISUAL E O PROGRAMA OSIRIX® PARA AVALIAÇÃO DA CONSOLIDAÇÃO ÓSSEA APÓS AVANÇO DA TUBEROSIDADE DA TÍBIA EM CÃES

MARQUES, Danilo Roberto Custódio Marques[1*]; IBAÑEZ, José Fernando[2]; HESPANHA, Ana Carolina[3]; FRATINI, Paula[4]

1. Universidade de São Paulo – Doutorando
2. Universidade Federal do Paraná - Professor de Técnica e Clínica Cirúrgica de pequenos animais
3. Médica Veterinária Autonoma
4. Universidade de São Paulo – Pós-graduanda

* Autor para correspondência: **danvetmarques@gmail.com**
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RESUMO: A incidência de fraturas é muito comum na clínica cirúrgica de animais de companhia. Vários métodos são estudados para avaliar o tempo de consolidação óssea. Alguns métodos já foram bem descritos, como a avaliação visual por observadores e uso da densitometria óssea. Com o avanço da computação, programas de computador estão sendo avaliados para realizar a mesma função, mas de modo mais específico. O programa OsiriX® está sendo estudado, principalmente em exames tomográficos. Mas ainda há poucas descrições em radiografias para avaliação da consolidação óssea. O objetivo deste trabalho é comparar a avaliação da cicatrização óssea pelo método visual e com o uso do programa OsiriX® em radiografias em formato DICOM. Utilizou-se 12 radiografias de joelhos nos quais foi realizada a técnica de avanço da tuberosidade tibial (TTA) para o tratamento da ruptura do ligamento cruzado cranial. As radiografias-controle foram realizadas a cada 21 dias até a observação da consolidação óssea. Utilizou-se o teste Kappa para correlacionar o método visual com o programa OsiriX®. O valor do teste Kappa ponderado encontrado foi de 0,75, isto é, uma concordância satisfatória entre os dois métodos estudados. O uso do programa OsiriX® permitiu a avaliação da consolidação óssea nos 12 joelhos que realizaram o avanço da tuberosidade tibial, sendo encontrado o mesmo tempo de consolidação óssea com o programa e pelo método visual.

PALAVRAS-CHAVES: Cão. Cirurgia. Osso. Ortopedia. Radiologia.

ABSTRACT: Fracture repair is the most common surgery performed in small pets. Previous studies have used a variety of methods to evaluate bone healing time. Some methods, such as visual evaluation and use of bone densitometry have been well described. Developments in computing mean a number of programs are being evaluated to provide a more objective measurement of bone healing. The OsiriX® program is often used in the interpretation of CT scans, but there are few reports of its use for evaluation of bone healing on radiographs. The aim of this study was to compare evaluation of bone healing by manual visual inspection and the OsiriX® program using DICOM radiographs. Twelve stifles, in which tibial tuberosity advancement for the treatment of the cranial cruciate ligament had been performed, were evaluated. Radiographic images were obtained every 21 days until bone healing. The Kappa test was used to correlate visual examination with results from the OsiriX® program. The weighted Kappa test was 0.75, that is, there was a satisfactory agreement between the two methods. Healing in 12 stifles that had undergone tibial tuberosity advancement could be assessed using the OsiriX® program and there was no difference in estimation of bone healing time between the OsiriX program and visual assessment.

KEY WORDS: Dog. Surgery. Bone. Orthopedic. Radiology.

INTRODUCTION

Researchers studying osteometabolic diseases need accurate, non-invasive, low cost and widely available methods for the assessment of bone density. Digital radiography, and the assessment of bone denisty, is widely used to assist in the diagnosis of many local and systemic diseases (CANALI et al., 2011).

Radiographic optical densitometry (ROD) is an analytical method for measuring bone mineral content using radiographic images (VULCANO et al., 1997; LOUZADA et al., 1998; RAHAL et al., 2002; VULCANO; SANTOS, 2003). It is a non-invasive method also used to assess bone healing after surgical procedures. Optical density is measured using an image processing program that compares the gray scale of an aluminum penetrometer with the shadow of a selected bone portion. The values are given per millimeter of aluminum (mmAl) (MURAMOTO et al., 2005).

Mineral densitometry has the advantages of low cost, simplicity of execution and speed (LOUZADA, 1994). Rahal et al. (2002) used radiographic optical densitometry to assess bone changes in cats with secondary hyperparathyroidism, obtaining excellent results in the early recognition of disease on radiographic studies (compared to the most commonly used laboratory tests).

With advances in the field of Biology and Medicine, research in human diseases has considered environmental factors and eco-epidemiology. Information technology (IT) allows earlier identification of causes of disease and the production of a database of correlated factors which may not be immediately obvious to the observer (BRANSTETTER, 2007; HAUX, 2010). The use of a computer program is a highly accurate feature to assess bone consolidation (ACCORSI, 2007).

The DICOM (Digital Imaging and Communication in Medicine) model was developed to become the standard format for representation and sharing of medical images (SERIQUE, 2012). Its use was initially restricted to radiology imaging departments but, as costs have reduced, programs are now available as web applications and can be integrated with the patient's electronic records, and may contain several studies from the same patient.

Tools, such as the OsiriX®-IPad program available for Mac, have been developed to create data about radiographic images in AIM XML format (RUBIN; SHAH; NOY, 2008).

OsiriX® is a computer program for presentation and interpretation of large image sets and navigation of multidimensional DICOM images from a variety of modalities (ROSSET et al., 2004; ROSSET et al, 2005; ROSSET et al., 2006). This program is an open source and “standalone” application for the Mac OS X operating system. It contains an image database with viewing and processing tools. This program works only with the MAC OS operating system and allows identification of 2D regions of interest (ROI) for the study of images (HAGE, 2014).

Tibial tuberosity advancement (TTA) is a useful model for the study of ossification in dogs. The regular nature of the osteotomy in this surgery allows for standardization, contrasting with the bone defects created by traumatic fractures that, due to their irregularity, make it impossible to repeat bone healing conditions (LAFAVER et al., 2017). In addition, TTA occurs in a condition of surgical asepsis, eliminating the potential for adverse effects of infection on bone healing (BOUDRIEAU, 2011; SILVEIRA, 2013).

The healing of the bone defect in TTA occurs by second intention (secondary bone healing), thus, the use of bone graft does not change the type of healing, allowing more rapid healing and providing early limb support. (BOUDRIEAU, 2011).

The assessment of bone healing on mediolateral radiographs following TTA is straightforward, as the bone is not overlain by any more radiopaque structures that might interfere with the measurement of radiopacity inherent to the formation of bone callus at the osteotomy site (SILVEIRA, 2013).

The aim of this study was to compare the use of the OsiriX® program with visual assessment of consolidation of osteotomy after the TTA procedure in the stifles of 12 dogs.

MATERIAL AND METHODS

This study was granted approval by the Ethics and Animal Welfare Committee of the Federal University of Paraná (UFPR-PR) under the protocol number 018 / 2014.

Twelve adult dogs presented to the Veterinary Hospital of UFPR-PR Campus Curitiba with the diagnosis of cranial cruciate ligament rupture (CRLC) were included. Diagnosis was made by a positive cranial drawer test. The animals were sedated or anesthetized for mediolateral radiography, with the femorotibiopatellar joint positioned at an angle of 135 degrees using a goniometer, as recommended by Damur et al. (2005). The angle of the tibial plateau (APT), defined as the angle formed between the inclination of the medial tibial condyle and the line perpendicular to the tibial axis was measured as recommended by Hoffmann (2006). Cases with bone abnormalities or degenerative joint disease (DAD) were identified. Animals with a maximum tibial plateau angle of 26º were selected for the study. Animals with DAD, tibial plateau above 26º and bone abnormalities were not included in the study.

Twelve stifle surgeries were performed using advancement of the tibial tuberosity (TTA) to correct joint instability. Owners provided written informed consent for their animals to be included in the study.

Bone healing was monitored using serial radiographs every 21 days after the surgical procedure. All images were obtained with the same settings: 65kV, 200mA and time of 0.063 seconds. Bone healing was assessed on radiographic images in DICOM format using OsiriX® - DICOM Viewer and evaluated by three observers, two professors of diagnostic imaging and one professor of veterinary orthopedics.

The ROI (region of interest), option of the OsiriX® MAC system was used and two regions were demarcated on the mediolateral radiograph: the region in the center of the osteotomy and the region of the tibial diaphysis of the same limb. The value evaluation from the osteotomy site was divided by the value from the tibial shaft. Measurements were performed at the following times: preoperative (control test), immediate postoperative (Figure 1) and every 21 days until bone healing occurred. Bone healing was considerd complete when the initial (preoperative) relationship of values was similar to or the same as found in the postoperative period. The measurements found by OsiriX® were in pixels. To standardize the images using the ROI method, all images were examined at 50% zoom. Observers were asked to assess whether or not bone healing had occurred.

For statistical analysis, the Kappa test was used to compare the two assessment methods.

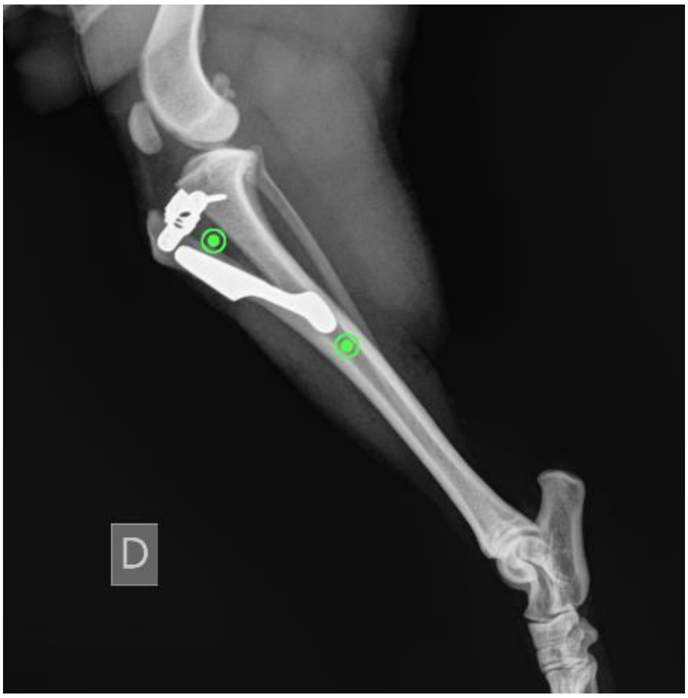

Figure 1: Use of the OziriX Program for image processing using the ROIs of osteotomy center and the tibial diaphysis on the mediolateral radiograph in DICOM format. The value found in pixels in the bone defect was divided by the value found in the tibial diaphysis.

RESULTS

Twelve animals with rupture of the cruciate ligament, in which tibial tuberosity advancement was performed, entered the study. Data on demographic characterization are shown in table 1.

Table 1: Demographic characterization of the ten stifles undergoing tibial tuberosity advancement.

Dog	Breed	Sex	Age (years)	Weight (kg)	Stifles	Cage Size
1	Labrador retreiver	Male	10	50.0	Left	9
2	Lhasa apso	Male	4	7.5	Right	6
3	Pit bull terrier	Female	8	27.0	Right	9
4	Pit bull terrier	Female	7.5	40.9	Right	9
5	Pit bull terrier	Male	9	29.3	Left	9
6	Mixed breed dog	Female	6	22.5	Right	9
7	West Highland Terrier	Male	8	9.2	Right	6
8	Mixed breed dog	Male	2	35.5	Right	9
9	Mixed breed dog	Female	13	40.2	Right	9
10	Lhasa Apso	Male	1.5	13.1	Left	6
11	Labrador retriever	Male	10	50.0	Right	9
12	Mixed breed dog	Male	11	8.5	Right	9
Total						12 Stifles

The results of the radiographic evaluation using the OsiriX® - DICOM Viewer program are shown in Table 2. Chart 1 shows the bone healing time for each patient, using visual assessment. Chart 2 shows the data used to interpret the Kappa test. Chart relates the Kappa Test to the standard test.

Table 2: Radiographic processing of the 12 stifles, using the OsiriX® - DICOM Viewer program, in ROI in pixels. Bone consolidation was considered complete when the ROI value was greater than or equal to the control (black).

	Control Group							
	Control	POI	21 days	42 days	63 days	84 days	105 days	126 days
Dog 1	0.994	0.713	0.789	0.851	0.860	0.883	**0.992**	
Dog 2	0.813	0.729	0.721	0.913	**0.922**	0.934		
Dog 3	0.757	0.759	0.788	0.643	0.677	0.721	**0.793**	
Dog 4	0.95	0.692	0.796	0.823	0.841	**0.883**	**0.976**	
Dog 5	0.727	0.875	0.732	0.635	0.597	**0.846**		
Dog 6	0.810	0.658	0.743	0.678	0.772	**0.882**		
Dog 7	0.827	0.762	0.779	0.804	0.821	**0.889**		
Dog 8	0.809	0.584	0.704	0.737	0.746	0.757	0.790	**0.817**
Dog 9	0.976	0.67	0.766	0.845	0.876	0.907	**0.981**	
Dog 10	0.884	0.611	0.764	**0.895**				
Dog 11	0.994	0.910	0.861	0.902	**0.955**			
Dog 12	0.965	0.495	0.575	0.627	0.763	0.883	**0.972**	
Total								12 stifles

*POI = Immediately postoperative

Chart 1: Time of bone healing observed by the three evaluators. The letter X represents the observed consolidation time and in parentheses how many observers recorded consolidation at that time. X (1): observation of consolidation by an observer at the end of the day (days). X (2): observation of consolidation by two observers at the end of the day (days). X (3): observation of consolidation by the three observers at the end of the day (days).

Dog	21 days	42 days	63 days	84 days	105 days	126 days
1					X(2)	X(1)
2				X(1)	X(2)	
3					X(3)	
4					X(3)	
5					X(2)	X(1)
6				X(1)	X(2)	
7				X(3)		
8						X(3)
9					X(3)	
10		X(3)				
11			X (1)	X (2)		
12					X (3)	

Chart 2. The following classification was used for the interpretation and correction of the standard test with Kappa.

Kappa values	Interpretation
<0	No correlation
0-0.19	Poor correlation
0.20-0.39	Weak correlation
0.40-0.59	Moderate correlation
0.60-0.79	Substantial correlation
0.80-1.00	Almost perfect correlation

Fonte: Landis and Koch (1977).

Chart 3: Kappa test data for the categories (days of healing) for the 3 evaluators.

	Cat. 1 **42 days**	**Cat. 2** **63 days**	**Cat. 3** **84 days**	**Cat. 4** **105 days**	**Cat. 5** **126 days**
Kappa Category	1.0	-0.029	0.518	0.554	0.535
Kappa p-value of category	< 0.001	not interpretable and significance test does not apply	0.002	0.001	0.001
Category Kappa 95% confidence interval	**sup:** 1.0 **inf:** 0.673	**sup:** 0.298 **inf:** -0.355	**sup:** 0.845 **inf:** 0.191	**sup:** 0.881 **inf:** 0.228	**sup:** 0.862 **inf:** 0.209

Chart 3 shows that the three evaluators had a statistically significant agreement (p-value <0.05) of moderate to almost perfect for healing on days 42, 84, 105 and 126. In the category healing at 63 days, the value of Kappa was -0.029 and is considered uninterpretable (we can see that the confidence interval includes zero, indicating that the Kappa value is statistically equal to zero). This is due to the fact that only one evaluator recorded that healing had occurred at 63 days. Table 3 data found by the Kappa test after evaluation of visual data.

A possible explanation for the low Kappa values for each category is that only 12 sample units were observed and there were a total of 5 categories (healing days) .

Table 3: Data found by the Total Kappa Test for the three evaluators.

General Kappa	0.569
General P-value	< 0.001
95% range **Kappa confidence**	**higher:** 0.771 **lower:** 0.368

Table 2 shows that for the 3 evaluators, the total Kappa was 0.569 (p-value <0.001), indicating a moderate agreement between the 3 evaluators. Table 4 to 5 Kappa evaluation.

Table 4: Frequency distribution of gold standard and ROI responses.

Gold standard (date when at least 2 observers agreed**)**	**ROI**						**Total**
	42 days	63 days	84 days	105 days	126 days	NA	
42 days	1						1
63 days							0
84 days			1	1			2
105 days		1	1	3		1	6
126 days			1	1	1		3
Total	**1**	**1**	**3**	**5**	**1**	**1**	**12**

Table 5: Frequency of agreement between the evaluated times.

Category	**Maximum possible**	**Expected chance**	**Observed**
42 days	1	0.09	1
63 days	0	0	0
84 days	2	0.55	1
105 days	5	2.27	3
126 days	1	0.27	1
Total	**9**	**3.18**	**6**

Table 6 shows that for the ROI and the gold standard, the weighted Kappa had a value equal to 0.750 (0.35-1.00), determining a satisfactory agreement.

Table 6: Kappa tests (unweighted and weighted) for ROI and gold standard.

	Value	**Kappa 95% confidence interval**	
		Inferior limit	Upper limit
Weighted kappa	0.750	0.35	1

DISCUSSION

The TTA technique is used as a model for osteogenesis mainly because it provides a homogeneous bone defect and secondary bone healing (BOUDRIEAU, 2011). In this case, the TTA model was used to standardize bone failure and because it is a technique frequently performed at the Veterinary Hospital of UFPR.

The size of the spacers used in TTA are pre-established at 3, 6, 9 and 12 millimeters, and cannot be modeled. These data vary according to the inclination of the tibial plateau and how far the tibial crest needs to move to form a 90º angle between the patellar ligament and the tibial plateau (KIM et al., 2008; BOUDRIEAU, 2009). With these pre-established parameters, a homogeneous bone defect can be created so the technique can be used as a model for bone consolidation and its evaluation.

Radiography for TTA planning should be performed with the femorotibiopatellar joint flexed at a 135 ° support angle (KIM et al., 2008). In this study, a goniometer was used to keep the stifle at 135 ° on all radiographs, so all stifle images were standardized for evaluation by the OsiriX® program. Animals were anesthetized for radiography to position the joint at the correct angle.

TTA healing occurs by secondary healing (BOUDRIEAU, 2011), as was observed in all operated stifles. A major advantage of this technique as a model for studying bone healing is the absence of bone overlays on the radiographs, which can confuse assessment of the bone healing process.

Joint stability and early recovery of joint function after the TTA technique is achieved due to rapid bone healing at the osteotomy site (GUERRERO et al., 2011). One of the problems for veterinary papers is ensuring owner compliance with follow-up (particulalry when repeat vists are required), so models with rapid bone consolidation are preferred.

Radiographic evaluation of bone healing is essential (SILVEIRA, 2013). In this case, visual assessment on OsiriX® was used to assess bone healing. Visual assessment is still widely used, but more accurate systems based on information technology are increasingly important. One of the major disadvantages of the visual assessment method is the inter-observer differrences in asessing bone healing.

Digital radiography is widely used in veterinary medicine. The DICOM standard was created to standardize the formation of diagnostic images such as tomography, digital radiography and magnetic resonance imaging (ALVARENGA, 2008). In this study, this image format was used for processing by the OsiriX® program.

The region of interest to be analyzed is selected by delimiting an area on the image. This region is defined by the operator and determines where the processing will be concentrated and allows measurement of the average pixel values in each ROI of the image (ALVARENGA, 2008). In this study the OsiriX® program was used to measure two ROIs, the center of the osteotomy failure and the tibial shaft just below the tibial crest. The bone gap below the cage and below the end of the TTA plate were used as reference points for the placement of the ROI in all periods monitored. Thus, the animal becomes its own control. The final value was derived from the value at the bone defect divided by the value at the diaphysis. This measurement was also performed on the preoperative radiographs, where, instead of being measured at the center of the defect, it was measured at the center of the crest. When the failure rate was close to or greater than the control value, the osteotomy was considered healed.

The OsiriX® program has been used to assess bone production or destruction, including for the influence of tomography and apical radiography on assessment of periapical bone destruction in dog's teeth (LOUZADA, 2002; ZAPATA-ORDINOLA et al., 2011) and on the assessment of bone healing in the tibia of mini pigs using cone computed tomography (KROPIL et al., 2012). This program is still little used in veterinary medicine for the evaluation of bone consolidation, but it is already being used for this purpose in human medicine and dentistry.

The two assessment methods were compared using the weighted Kappa statistical test. The value of 0.75 indicates favorable correlation between the two methods. However, our sample size was small and a larger number of cases would need to be studied to determine the real association between the evaluation methods.

The ideal position for the ROIs to assess bone healing in animals that have undergone TTA is not known. In this case, we used the TTA osteotomy center because in the cranial portion there was the "cage" and in the caudal portion the bone plate of the TTA. Preoperative radiography was used as the standard ROI and consolidation was deemed complete when the subsequent ROI was equal to or greater than the standard ROI, ie there was the same bone density before and after the surgical procedure.

In this study, we performed control radiographs every 21 days, which proved to be a satisfactory time interval for the evaluation of bone healing.

Further studies must be carried out with the OsiriX® program, mainly its standardization in pets (small animals). In addition, studies are needed to compare its use with bone densitometry which is the gold standard method for the evaluation of bone consolidation.

CONCLUSIONS

This study showed a good correlation between the evaluation models, visual assessment and OsiriX® program in 12 stifles subjected to tibial tuberosity advancement. Further studies with a larger sample size should be completed to verify these findings.

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