# FACTORS THAT AFFECT HEALING IN CASES OF CANINE ANTEBRACHIUM FRACTURES

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**Abstract.** The aim of this work was to identify and evaluate physiological and biomechanical factors that affect healing in cases of canine antebrachium fractures.

The results and conclusions of the analysis: antebrachium fractures are most common among young canines (1–5 year of age) (56 %). Research showed that dogs' age influenced the healing of the fractures ($P<0.05$). The average of radius and ulna lengths of the examined dogs (n=25) were, respectively, 106.0.2±10.80 mm and 127±13.62 mm. The length of the antebrachium has a reliable correlation ($P<0.05$) with the healing time of the antebrachium fractures. The most common number of antebrachium fracture lines identified in an individual case was two (n=15). The amount of the fracture lines did not influence the time of healing ($P>0.05$). The average strain of the fractures (n=45) was 54.69±4.62 percent. Strain in the fracture area has a reliable correlation with duration of antebrachium fractures healing ($P<0.05$). The average width of the gap between the fractured pieces was 1.04±0.18 mm. Analysis showed that the width of the gap between the fractured antebrachium pieces has a reliable correlation with time of healing of the antebrachium fractures ($P<0.05$). Callus formations were more likely not to occur (n=14) than to occur (n=11) after being treated. The correlation between callus formations and time of healing of the antebrachium fractures is statistically relevant ($P<0.05$).

**Keywords:** Dog, antebrachium, fractures, physiological factors, biomechanical factors, healing

**Introduction.** Fractures of the radius and ulna account for up to 17 % of fractures in dogs (Saikku-Bäckström et al., 2005; Rose et al., 2009; Brown et al., 2015). Toy-breed dogs seem prone to radial/ulnar fractures even after minimal trauma (Saikku-Bäckström et al., 2005; Piras et al., 2011). Osteopenia after external coaptation or metallic implants is seen more often in toy-breeds and makes estimation of the appropriate time for implant removal difficult. Delayed union, malunion, non-union, and refracture after implant removal are also not uncommon during healing of these fractures (Saikku-Bäckström et al., 2005).

All physiologic processes occurring within bone, including repair processes during fracture healing, are dependent on an adequate blood supply (Fossum et al., 2011). Amongst others, angiogenesis occupies a central role in the whole process of bone regeneration after fracture (Keramaris et al., 2008). Blood supply is a central concern for tissue healing and it is widely recognised that medical co-morbidities leading to decreased blood flow will decrease the ability to heal fractures (Siska et al., 2008).

The outcome of fracture-healing depends on a number of factors, such as trauma severity, the quality of fracture reduction (realignment), fracture fixation technique and presence of comorbid diseases (Claes et al., 2012). Complication rates after repair are significantly higher in dogs <5 kg than in larger dogs (Saikku-Bäckström et al., 2005; Gauthier et al., 2011). Fractures of the radius and ulna in toy and small breed dogs have a higher risk for delayed union or non-union than similar fractures in large breed dogs (Piras et al., 2011). Bone-plate fixation in small dogs reportedly has an 89 % incidence of return to full function but there is an 18 % major complication rate; including plate breakage, bone screw pull-out prior to fracture stability, non-union, re-fracture of the radius, and in some cases, amputation (Baltzer et al., 2015). The reasons for impaired healing appear to be both biomechanical and vascular (Piras et al., 2011).

Up to 54 % of small-breed dogs with radial fractures treated with plate osteosynthesis develop complications. A microvascular study performed in cadaveric radii revealed that there is decreased microvascular density in the distal diaphyses of small-breed dogs, compared with large-breed dogs, which purportedly might impair bone healing in small-breed dogs. Although the definitive cause of these complications has yet to be elucidated, biomechanical and vascular characteristics unique to small-breed dogs have been identified as possible risk factors (Gauthier et al., 2011). Small-breed dogs have lower microvascular density in the distal bone diaphyses, compared to larger dogs, which may be a contributing factor to the high complication rate in small breed radial fracture repairs. In addition, small dogs may have prolonged healing times and greater incidence of delayed union due to poor soft tissue coverage of the distal antebrachium limiting the capacity of these tissues to provide an extraosseous circulation to the fractured bone (Baltzer et al., 2015).

Unlike other tissues that heal by the formation of a connective tissue scar of poor quality, bone is regenerated and the pre-fracture properties are mostly restored (Giannoudis et al., 2007). The process of fracture healing involves a sequence of several complex events that usually return a bone to an almost perfectly healed condition (Lacroix et al., 2002).

With aging the rate of bone repair is known to be progressively reduced (Mehta et al., 2010). Rigid stabilization of the fracture site, often described as absolute stability, is a key factor for successful healing. The intefragmentary strain in these cases should be <2 % (Oh et al., 2010). Factors affecting fracture healing – blood supply, location of fracture in bone, configuration of fracture, age of the animal, etc. Many factors, both local and systemic, have been associated with delayed fracture healing (Baltzer et al., 2015; Siska et al., 2008; Owens et al., 1998). Assuming adequate vascularity, the pathway of bone healing is primarily influenced by the amount of interfragmentary movement caused by the load on the fracture and modulated by the stability of the fracture fixation. The pathways of bone formation include *indirect bone union,* which is *endochondral* bone formation (bone formed on a cartilaginous precursor), *direct bone union* (bone formed without evidence of callus), or *intramembranous* bone formation (direct differentiation of mesenchymal stem cells into osteoblasts so bone forms without a cartilaginous precursor) (Fossum et al., 2013). Interfragmentary movement (IFM) is the most important mechanical parameter influencing the fracture healing process and depends on fixation stability and musculoskeletal loading. Moderate IFM leads to successful bone healing with the development of a fracture callus, whereas high IFM delays fracture healing or can even result in non-unions (Steiner et al., 2014). Fracture healing will occur only when the interfragmentary strain (IFS) (IFS = IFM (interfragmentary movements)/L (fracture gap size)) is less than the rupture strain of bone (2 %) (Claes et al., 1997). Motion at fracture sites affects the size of gaps between fragments. This motion is calculated as *strain,* which is the ratio between change in gap width to total gap width (Fossum et al., 2013).

The rigid stabilization of the fracture site and he mechanical strength of the compression bone-plate systems are principal factors determining the further course of bone healing (Oh et al., 2010). There is a correlation between the size of the fracture gap and the time to union. Time to union increases with increasing fracture gap size and is less in younger patients with less complex fractures and lesser degrees of soft tissue damage (Jagodzinski et al., 2007).

Large fracture gaps cause a delay in fracture healing. Under comparable biomechanical conditions (similar interfragmentary tissue strain), small fracture gaps heal faster than medium-sized gaps and large fracture gaps do not heal at all. Larger osteotomy gaps (5.7 mm) led to significantly more fibrocartilage and a lower number of newly formed blood vessels in the gap healing area than osteotomy gaps of medium size (2.1 mm). The amount of bone formation under a certain biomechanical environment is limited and can be enough to close medium sized gaps but is insufficient to bridge large gaps (Claes et al., 2003).

The aim of this work was to identify and evaluate physiological and biomechanical factors that affect healing in cases of canine antebrachium fractures.

**Materials and methods.** Twenty five clients owned dogs with traumatic antebrachium fractures were enrolled in the study. Sex, weight, breed, comorbid diseases or cause of trauma had no influence for the choice of objectives. Anamnesis data, complete physical and orthopedic examinations and radiographs were performed to all patients.

Radiograph examination were performed to patients under sedation. Sedation was achieved using medetomidine (Cepetor 1 mg/ml, 20 µg/kg) and butorphanol (Butomidor 10 mg/ml, 0.2 mg/kg) i.m. The doses were selected according to the summary of sedative characteristics.

Radiographic tests were performed using the X-ray machine (ECO Ray 400‘, Germany). Craniocaudal (CrCd) and mediolateral (ML) radiographic views of the antebrachium were obtained to classify the fractures and to evaluate fracture healing.

Patients age has been evaluated by the number of years, and according to that all the patients were divided into 4 groups: group I (0–1 years), group II (1–5 years), group III (5–10 years) and group IV (≥10 years).

Ulna and radius lengths were measured in radiographs after treatment. Ulna was measured from *tuber olecrani* to *processuss styloideus.* Radius was measured from *capitulum radii* to *processuss styloideus*. All measurments are shown in Figure 1. Fracture lines were also evaluated in the radiographs, counting them on both antebrachium bones.

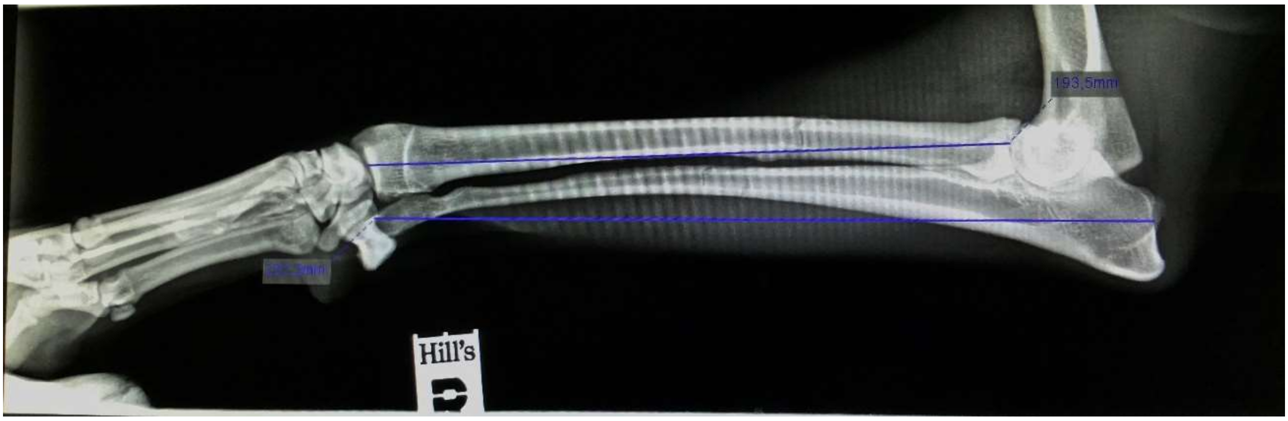


Figure 1. **Measurement of ulna and radius in radiograph.** Author: K. Ramanauskaite

Strain to each fracture line has been calculated by dividing the change in gap width from the total gap width before treatment.

Gap widths were measured in radiographs before and after the treatment (the choice of surgical or conservative treatment has not been taken into consideration). Measurements were performed in 0.01 mm accuracy, measuring from the edge of one fracture to the edge of another.

Formations of callus were evaluated in follow-up radiographs after treatment (the choice of surgical or conservative treatment has not been taken into consideration).

Fracture healing time has been evaluated by the number of weeks, and according to that all the patients were divided into 3 groups: group I (4–8 weeks), group II (≥8 weeks) and group III (failed to heal). Fractures were considered to be healed when the fractures lines and their sharp edges were not visible in radiographs, the bone density has been identified and the patients' limb function was fully regained.

Microsoft Excel 2013 was used to analyse the data. Comparisons were performed using chi-squared analysis, T-test and calculating dispersions. A P-value of <0.05 was considered significant for all comparisons.

**Results.** Antebrachium fractures were mostly diagnosed in middle aged (1–5 years old) dogs (n=14), more rarely – in young (0–1 years old) patients (n=7). Antebrachium fractures were most uncommon in elderly (5–10 years old) (n=3) and very old ((≥10 years old) dogs (n=1).

The average length of all examined ulnas was 106.02±10.80 mm and the average length of all examined radius was 127±13.62 mm.

Two was the most common number of fracture lines to be diagnosed (n=15). 3 (n=1) and 4 fracture lines (n=1) were diagnosed the most rarely.

The average power of strain to each fracture line (n=45) was 54.69±4.62 %.

The average gap width was 1.04±0.18 mm. Mode of gap widths was 0.31 mm and median was 0.63 mm.

After the treatment there were less patients who developed callus (n=11) than those who did (n=14).

According to the time it took for the fracture to heal, 11 of 25 patients (44 %) were assigned to group II, 7 (28 %) to group I and 7 (28 %) to group III.

It has been detected that the age of the patient has significant impact on antebrachium healing time (p<0.05). Most patients (40 %) from fracture healing group II were also evaluated as age group II, while the age group I mainly consisted of patients from healing group I (16 %). The age group IV only had patients (4 %) of fracture healing group III. (Figure 2).

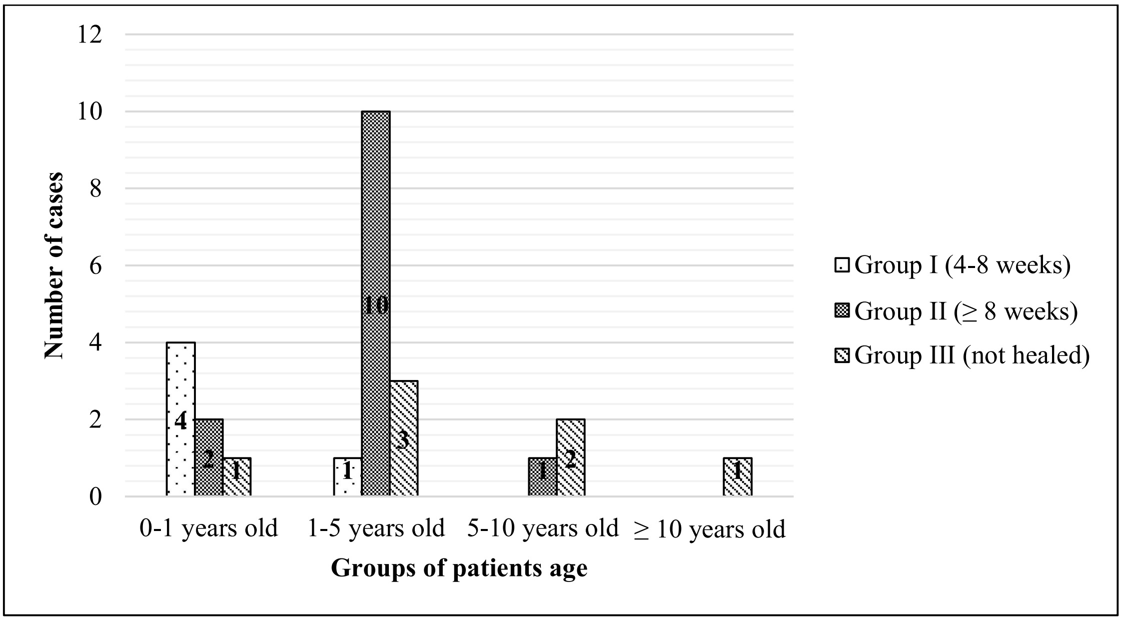


Figure 2. **The dependence of antebrachium healing on the age of the patient**

During the evaluation of the connection between bones length and fracture healing time, it has been determined that the longest radiuses and ulnas belonged to fracture healing time group I and the shortest bones belonged to fracture healing time group II. The difference between averages of antebrachium lengths in fracture healing time groups I and II was statistically significant (P<0.05).

It has been determined that antebrachium lengths has a statistically significant connection to fracture healing time groups I and II (P<0.05). (Figure 3).

In this research were determined that 2 fracture lines were the most commonly found in all fracture healing time groups (group I – 20 %, group II – 24 %, group III – 16 %), 4 fracture lines being the rarest case in all fracture healing time groups ( group I – 4 %; in groups II and III there were no patients with 4 fracture lines. It has been shown that the number of fracture lines does not have any influence on fracture healing time (P>0.05). (Figure 4).

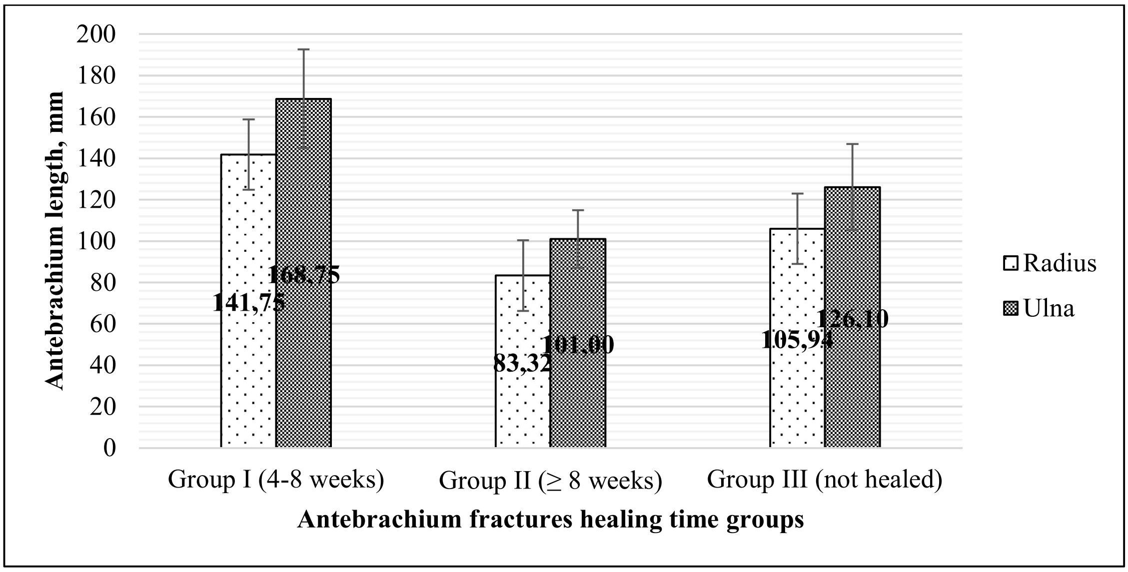


Figure 3. **Connection between antebrachium length and fracture healing time groups**

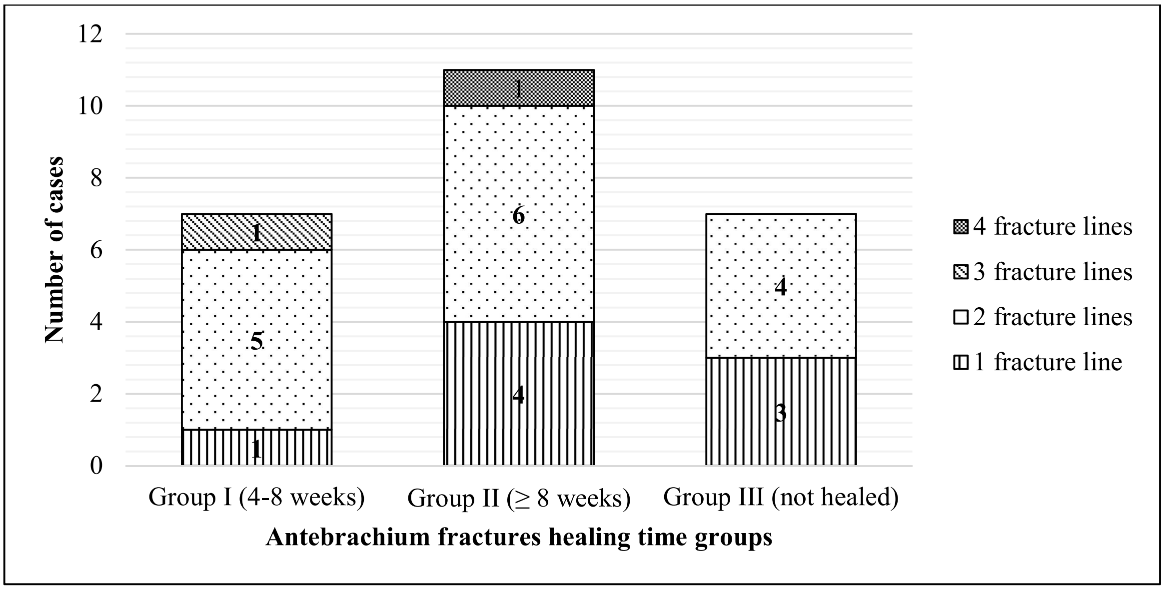


Figure 4. **The distribution of the number of lines of antebrachium fractures in the groups of healing time of antebrachium fractures**

After evaluating the connection between strain on fracture lines and antebrachium fractures healing time groups, it has been determined that the highest strain was diagnosed in fracture healing time group III and the smallest strain was found in fractures healing time group I. The difference among averages of strains in different groups were statistically significant ($P<0.05$). (Figure 5).

During this research, the widest gap widths were diagnosed in fractures healing time group III and the narrowest – in fractures healing time group I. The difference between gap widths in different fractures healing time groups was statistically significant ($p<0.05$). Also it has been established that the gap width and antebrachium fractures healing time has a statistically significant connection ($P<0.05$). (Figure 6).

During the research of the healing in canine antebrachium fractures, it has been established that calluses mostly formed in fractures healing time group II (28 %) and was the least common in fractures healing time group III (24 %). It has been determined that the connection between callus formation and antebrachium fractures healing time is statistically significant ($P<0.05$). (Figure 7).

**Discussion.** The results of this study demonstrate that biomechanical factors (gap width and strain) and 3 physiological factors (age of the patient, bone length and formation of callus) has an impact on dog antebrachium fractures healing.

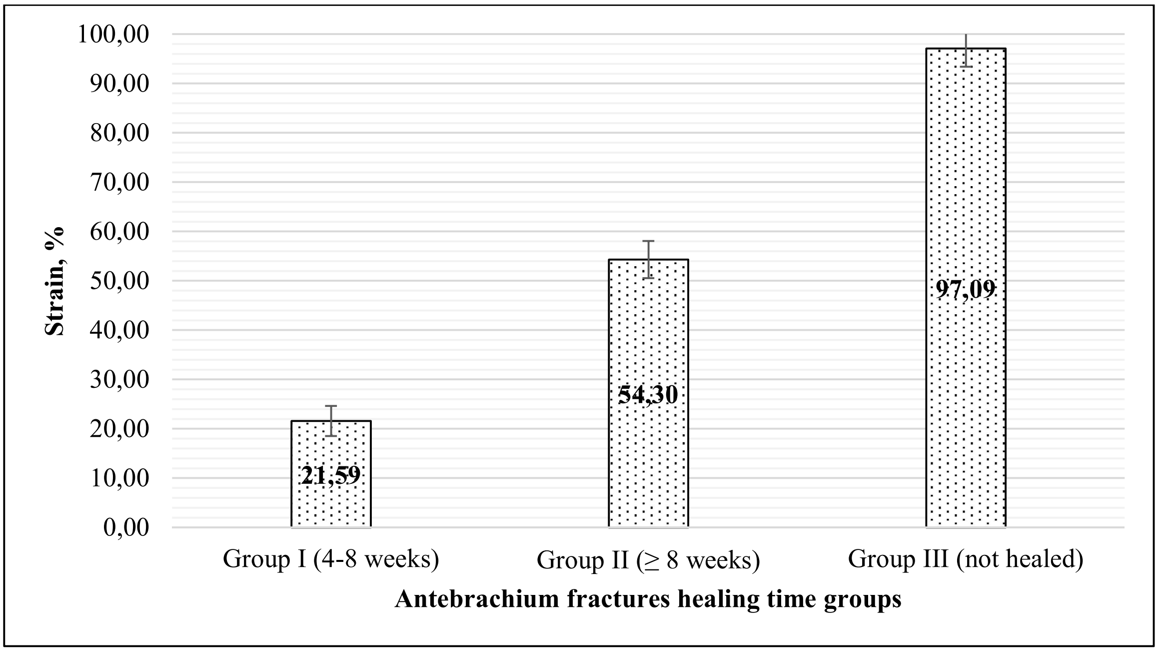


Figure 5. **The dependence of strain per area of the fracture on the time of antebrachium fractures**

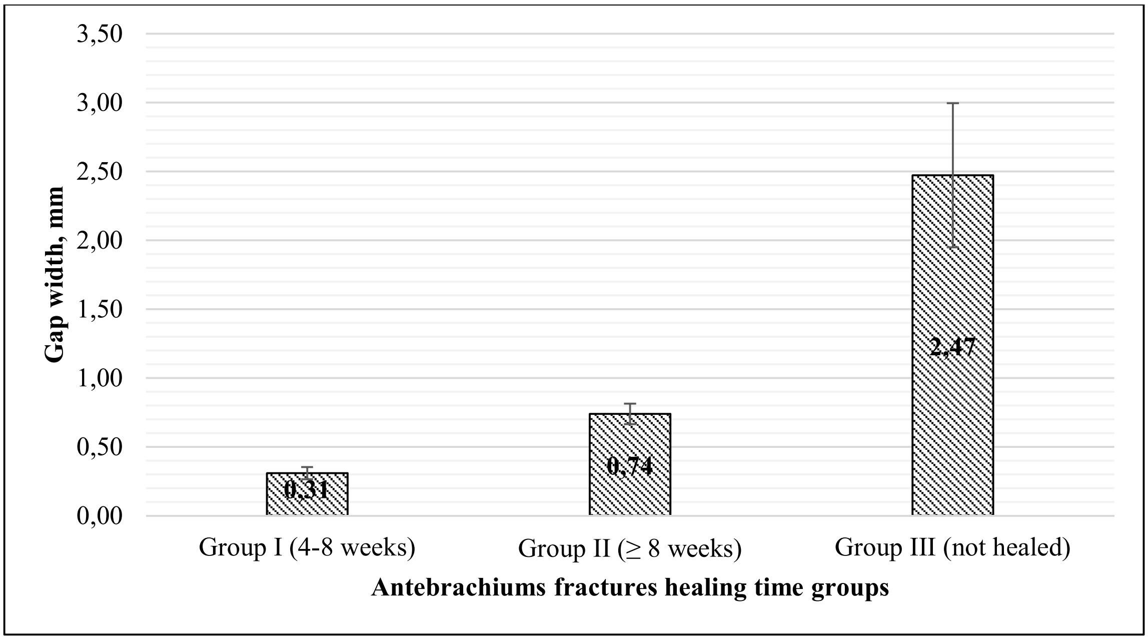


Figure 6. **The dependence of gap widths on the time of antebrachium fractures**

In our study antebrachium fractures were most common among young canines (1-5 years of age) (56 %). According to our knowledge, there is no knowing relationship between age of the dogs and frequency of antebrachium fractures. In our opinion fractures are most common among young patients because they are more active.

Also, our study showed that the patients age had an impact to antebrachium fractures healing time ($P<0.05$). According to Mehta et al., 2010, with aging the rate of bone repair is known to be progressively reduced.

In our study, the average radius length of the examined dogs was 106.02±10.80 mm and the average length of the ulna was 127±13.62 mm. Piras et al., 2011, in their study showed that toy-breeds dogs are prone to radial/ulnar fractures even after minimal traumas. According to Pozzi et al., 2012, unique morphologic, densinometric, and mechanical differences may predispose smaller dogs to radius and ulnar fractures. In our study, statistical analysis showed that the length of the antebrachium has a reliable correlation ($P<0.05$) with the healing time of the antebrachium fractures. According to Gauthier et al., 2011, small-breed dogs have a greater risk of developing certain complications, such as delayed union and nonunion, than do large-breed dogs.

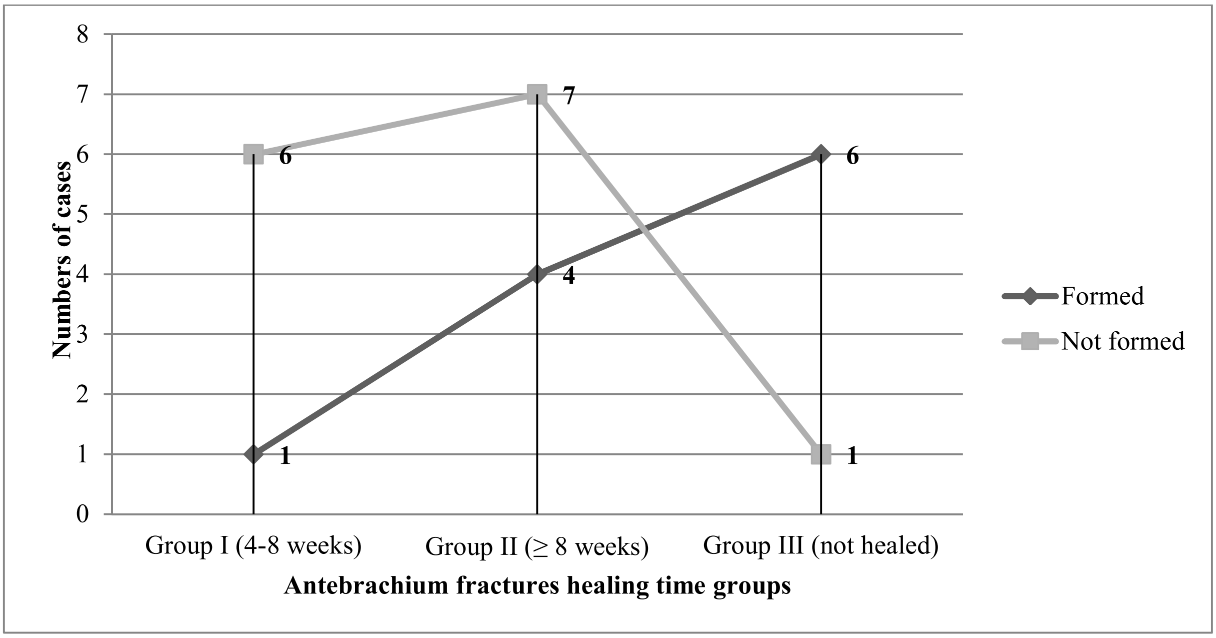


Figure 7. **Connection between callus formation and antebrachium fractures healing time**

We detected that tensile force in the fracture area has a reliable correlation with duration of antebrachium fractures healing ($P<0.05$). According to Steiner et al., 2014, interfragmentary movement (IFM) is the most important mechanical parameter influencing the fracture healing process and depends on fixation stability and musculoskeletal loading.

Our studies have shown that the width of the gap between the fractured antebrachium pieces has a reliable correlation with time of healing of the antebrachium fractures ($P<0.05$). According to Claes et al., 2013, large fracture gaps cause a delay in fracture healing. Under comparable biomechanical conditions (similar interfragmentary tissue strain), small fracture gaps heal faster than medium-sized gaps and large fracture gaps do not heal at all.

Our studies have shown that the correlation between callus formations and time of healing of the antebrachium fractures is statistically relevant ($P<0.05$). According to Oh et al., 2010, the amount of periosteal callus produces is inversely proportional to the stiffness to the construct.

**Conclusion.** Dogs antebrachium fractures healing time depends on gap width, strain, age of the patient, bone length and formation of callus. The widest gap widths (2.47±0.52 mm) and the highest strain (97.09±3.67 %) were diagnosed in fractures healing time group III, and the narrowest gap widths (0.31±0.04 mm) and the smallest strain (21.58±3.05 %) – in fractures healing time group I. Most patients from healing time group I were 0-1 years old (16 %) and most patients from healing time group III were ≥10 years old. Shorter antebrachium bones (radius 83.32±13.89 mm, ulna 101±18.54 mm) healing time was longer (≥8 weeks), and calluses mostly formed in fractures healing time group II (28 %) and was the least common in fractures healing time group III (24 %).

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