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A Retrospective Study of Risk Factors Associated with Refracture after Repair of Radial–Ulnar Fractures in Small-Breed Dogs

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Abstract

Objective The aim of this study was to identify risk factors for refracture after radial union in small-breed dogs.

Study Design In our retrospective study, medical records of radial–ulnar fracture cases in small dogs treated with plates and screws were reviewed. General information and postoperative course (days until confirmed radial fracture healing, with or without ulnar union, time to final follow-up, with or without plate removal and refracture) were recorded. The fracture line location, screw positions, radial thickness and width, and pixel values throughout the postoperative periods were obtained from the radiographs. The affected limbs were classified into non-plate removal (P) and plate removal (R) groups.

Results Refracture occurred in 5 of the 141 limbs at the most distal screw in the P group and 5 of the 40 limbs at the same site as the initial fracture in the R group. Multivariate analysis indicated that refracture was linked to the amount of relative change with growth in the position of the most distal screw in the P group, with pixel value and radial thickness ratios at the same site as the initial fracture in the R group.

Conclusion Reducing the screw diameter relative to the radial width to the appropriate extent may be considered in cases where the screw positioned at the most distal end of the radius is expected to be relatively proximal as the distal radius grows; not removing the plate may be considered in cases with a decreased radial thickness or bone mineral density beneath the plate during plate removal.

Keywords
- implant-induced osteoporosis
- radial–ulnar fractures
- small-breed dogs
- refracture
- risk factor

Introduction

Radial–ulnar fractures in small dogs are common; 14% of long bone fractures occur in the distal one-third region of the radius.[1] A higher complication rate is reported in treating distal radial–ulnar fractures in small-breed dogs than in large-breed dogs.[2] The treatment success rate with internal fixation using plates and screws is high, and bone union was achieved in all cases without the development of nonunion.[3]

In recent reports, the major postoperative complications requiring revision surgery for fracture treatment using conventional and locking plate systems were 3%[4] and 9%,[5] respectively. However, no reports included refracture after radial union as a complication for consideration. In human medicine, refracture is "a fracture caused by a load that the normal bone can bear after bone union occurred. The fracture line coincides with the initial fracture line or within the bone area that has changed due to the fracture and its

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treatment."[6] Refracture of the long bone diaphysis after bone union is a major postoperative complication,[7] which can occur with and without plate removal. Plate removal may be a risk factor for refracture. However, as no studies in small animal orthopaedics have investigated the relationship between refracture after radial–ulnar union and plate removal, no consensus exists that retaining the plate can reduce the refracture rate.

Structural changes (cortical bone necrosis and thinning of the cortical bone beneath the plate) have been reported to be induced in the cortical bone where the plates and screws are placed[8] and are termed implant-induced osteoporosis (IIO). Clinically, IIO is a cause of refracture that occurs after implant removal.[9] A previous study reported that small-breed dogs with radial–ulnar fractures treated with plates and screws developed IIO during the healing process.[10] However, no studies have investigated the association between refracture and IIO after plate removal in treating radial–ulnar fractures in small-breed dogs. Therefore, the aim of this study was to identify the risk factors for refracture after radial union in small-breed dogs with and without plate removal.

Materials and Methods

Case Selection Criteria

This study included radial–ulnar fractures in small-breed dogs (weighing $\leq$5 kg) treated with plates and screws from January 2010 to December 2016 at 10 hospitals (Asakadai Animal Hospital, Hiro Animal Hospital, YPC Tokyo Animal Orthopedic Surgery Hospital, Japan Animal Medical Centre, Mizuno Animal Clinic, Nippon Veterinary and Life Science University Animal Medical Centre, Pet Clinic Anihos, Senkawa Dog and Cat Hospital, Tanoue Animal Hospital, and Zephyr Animal Hospital). The inclusion criteria for this study were as follows: the radial fracture was the first fracture; the radius fracture was treated with a single plate and screws; no postoperative findings of bone and implant infection; the radial union was achieved; no other orthopaedic injuries; and no neurological, endocrine, digestive, or urological disorders.

Groups

All fractured limbs were classified into two groups based on plate removal during the treatment period: non-plate removal group (plate group; P group) and plate removal group (removal group; R group). In the R group, plate removal was not caused by structural bone changes (osteopenia and decreased bone diameter) but rather by the owner's choice to avoid implant-related complications. Implant-related complications (including skin irritation, cold conduction, and implant loosening) were informed by veterinarians based on previous reports.[11]

Medical Records Review

General information was extracted from the medical records in all cases regarding the state of fractures, method of repair, and postoperative course, including general information (dog breeds, age in months, weight at surgery, and sex), the state of the fracture, method of repair (affected limb, method of fixation, and method of application), and postoperative course (days until confirmed radial fracture healing, with or without ulnar union, time to final follow-up or refracture after surgery, and age at the time of the last follow-up).

In the P group, the final follow-up time was defined as the time at the last radiograph for the non-refractured limb and the time at the refracture of the limb. The follow-up period was the time between the fracture reduction surgery and the final follow-up.

In the R group, the period of plate fixation and the presence and duration of cast splinting after plate removal were also recorded. The final follow-up time was the time at the last radiograph for the non-refractured limb and the time at the refracture of the limb. The follow-up period was the time between plate removal and the final follow-up.

Radiography

Radiography was performed using digital radiography devices (VPX-40A, VPX-40B1, VPX-100A, VPX-120A, VPX-200, VPX-500A; TOSHIBA, Tokyo, Japan), and the images of the forearm were acquired in orthogonal orientation (kV and mAs as per the device). The X-ray recording devices were XG-1V (Computed Radiography system, 10-bit grayscale resolution; FUJIFILM, Tokyo, Japan), Capsula 2 (Computed Radiography system, 10-bit grayscale resolution; FUJIFILM), Capsula V (Computed Radiography system, 10-bit grayscale resolution; FUJIFILM), DR-ID300 (indirect flat panel detector, 10-bit grayscale resolution; FUJIFILM), and Aero DR (indirect flat panel detector, 12-bit grayscale resolution; KONICA MINOLTA, Tokyo, Japan).

Measurement Parameters for Radiographic Examination

Commercially available software (OsiriX MD ver. 10.0.2; Pixmeo, Bernex, Switzerland) was used to measure the location of the fracture line, plate and screw positions, radial morphology, and pixel values for the affected limb of each fracture from the radiographs. Radial healing was evaluated using orthogonal radiographs with callus formation and fracture line barely visible (stage of early clinical union) or fracture line not visible, defined as a bone union.[12]

In the P group, the location of the fracture line at the initial and final follow-up, the position and amount of relative change in the position of the most distal and proximal screws at the time of fracture reduction surgery and final follow-up, working length (WL), plate screw density, screw-to-bone diameter ratio (SBDR), radial thickness (most distal and most proximal to the plate and at the site of the initial fracture), and bone growth distal and proximal to the plate were measured. Working length, plate screw density, and SBDR were measured as in the previous report.[5] Specifically, the number of empty holes between screws in bone fragments closest to the fracture line was defined as WL. Plate screw density was defined as the percentage of the number of screws to the total number of holes in the plate (number of fixed screws/total number of holes in the plate $\times$ 100 [%]). Screw-to-bone diameter ratio was calculated by dividing screw diameter (actual screw values) by radial width at non-fracture limbs (screw diameter/radial width $\times$ 100 [%]). In the craniocaudal view of the radiograph,

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as the presence of the plate renders it difficult to measure the radial width, the radial width was measured at the narrowest point of the radius of the non-fracture limbs when SBDR was calculated. In the R group, the location of the fracture line at the initial and final follow-up and radial thickness and width (most distal and most proximal to the plate, initial fracture site) were measured.

The pixel values were measured on the lateral radiographs of the affected limb immediately after the reduction surgery, at the time of plate removal, and final follow-up. The measurement area was between the most distal screw of the proximal fracture fragment and the most proximal screw of the distal fracture fragment. As the pixel values differed depending on the radiographic conditions, they were calculated as the pixel value ratio (PVR) based on the humeral condyles on the same image and used as the bone mineral density value (►**Fig. 1**). The measurement methods were the same as those used in a previous study.[10]

In the mediolateral and craniocaudal views, the lines connecting the midpoints of the distal and proximal radial articular surfaces were used as the length of the radius. The fracture line location and the most distal and proximal screw positions were calculated as a percentage of the length from the distal end of the radius and the length of the radius (length from the distal end of the radius to the fracture line, most distal screw position, or most proximal position/radial length $\times$ 100 [%]; ►**Fig. 2**). The amount of relative change in position of the most distal and most proximal screws was calculated by subtracting the respective positions at the time of radial reduction from the respective positions at the time of final follow-up (most distal or most proximal screw positions at final follow-up [%] – most distal or most proximal screw positions at radial reduction [%]). Moreover, the radial thickness and width were calculated as ratios based on the radial length on the same radiograph (radial thickness/radial length or radial width/radial length; ►**Figs. 3** and **4**).

Statistical Analysis

Statistical analysis was performed on all affected limbs, with refracture as one of the variables. The with or without plate removal, sex, affected limb (right or left), fixation method (locking system or conventional system), plate application method (bridging or compression), and the presence or absence of ulnar union were tested with Fisher's exact test using IBM SPSS Statistics for Windows, version 28.0 (IBM Corp., Armonk, NY).

Logistic regression analysis was performed within the P and R groups using Stata, with the occurrence of refracture as the dependent variable and each variable under ination as the independent variable. After extracting independent variables with $p < 0.05$ in univariate analysis, the final model was created using the forward–backward stepwise selection method. Independent variables with strong correlations were excluded to avoid multicollinearity. Multivariate analysis was performed using the final model with a significance level of $p < 0.05$.

Normally and non-normally distributed data are shown as mean $\pm$ standard deviation and median (range, minimum to maximum), respectively.

Results

Cases

The study included 181 limbs. Dog breeds in all cases are shown in ►**Appendix Table 1** (available in the online version). There were 56 male, 27 castrated male, 62 female, and

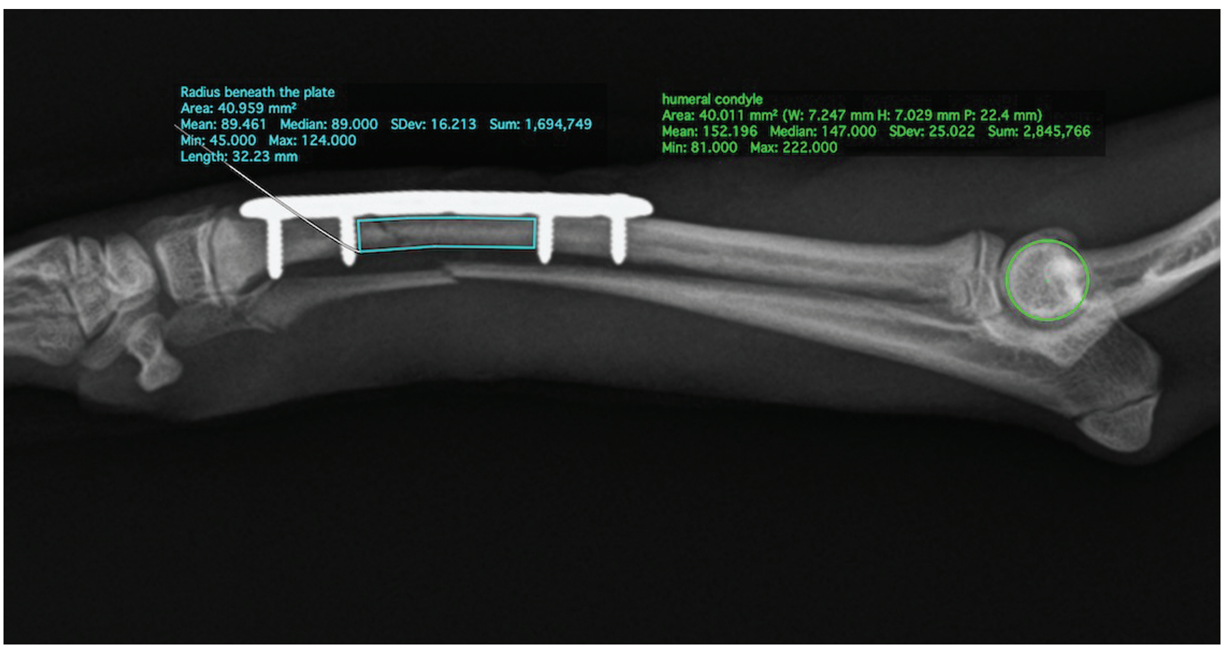

Fig. 1 Measurements of pixel value ratio on a radiograph of the radius beneath the plate. The area of measurement was the distance between the most distal and proximal screws of the proximal and distal fracture fragments (rectangle). The pixel value ratio was calculated based on the humeral condyle (circle) of the same radiograph.

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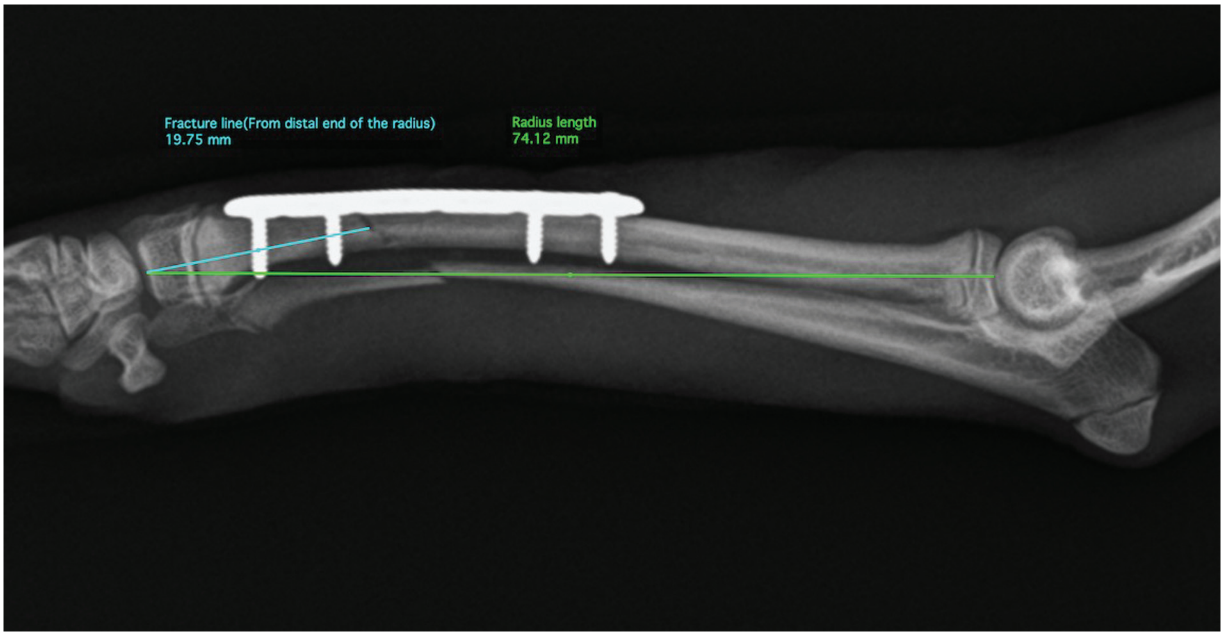

Fig. 2 Measurement of the location of the fracture line on the radiograph. The location of the fracture line was calculated as a percentage of the length from the distal end of the radius and the length of the radius (length from the distal end of the radius to the fracture line/radius length × 100 [%]). The method of measurement of the most distal and most proximal screw positions is the same.

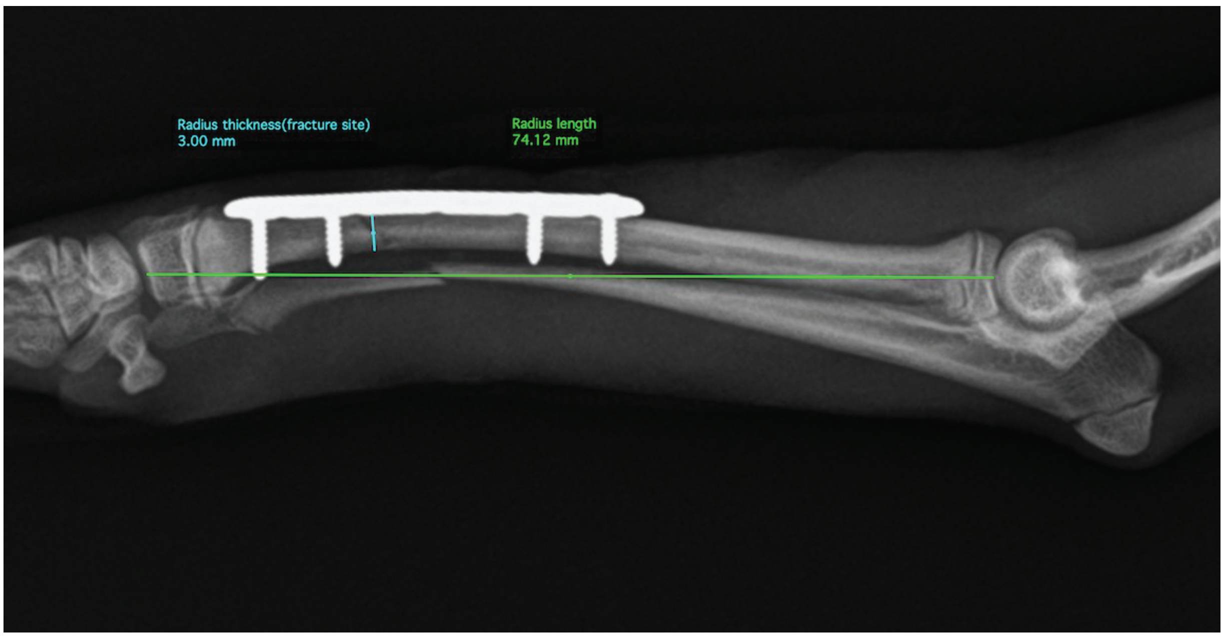

Fig. 3 Measurements of radial thickness on radiographs (mediolateral view). The radial thickness was measured at the initial fracture site and the most distal or proximal to the plate. In the mediolateral view, the line connecting the midpoints of the distal or proximal articular surfaces of the radius was used as the length of the radius. The radial thickness was calculated as ratios based on the radial length on the same radiograph (radial thickness/radial length).

31 spayed female dogs. The median age was 9 months (range, 1–107 months), and the median body weight was 2.4 kg (range, 0.9–5.0 kg).

Among the 181 limbs affected by the fracture, 77 and 104 were right and left forelimbs, respectively. Moreover, 116 and 65 plates were used in the locking and conventional systems, respectively. A list of plates used for fracture reduction is shown in the ►**Supplementary Table S1** (available in the online version). The techniques used for applying the plate for fracture reduction were the bridging and compression methods in 174 and 7 limbs, respectively. There were 161 and 20 affected limbs with and without ulnar union, respectively.

Refractures were observed in 10 of the 181 limbs (5.5%). Fisher's exact test revealed a significant association between the occurrence of refracture and plate removal ($p = 0.04$). The

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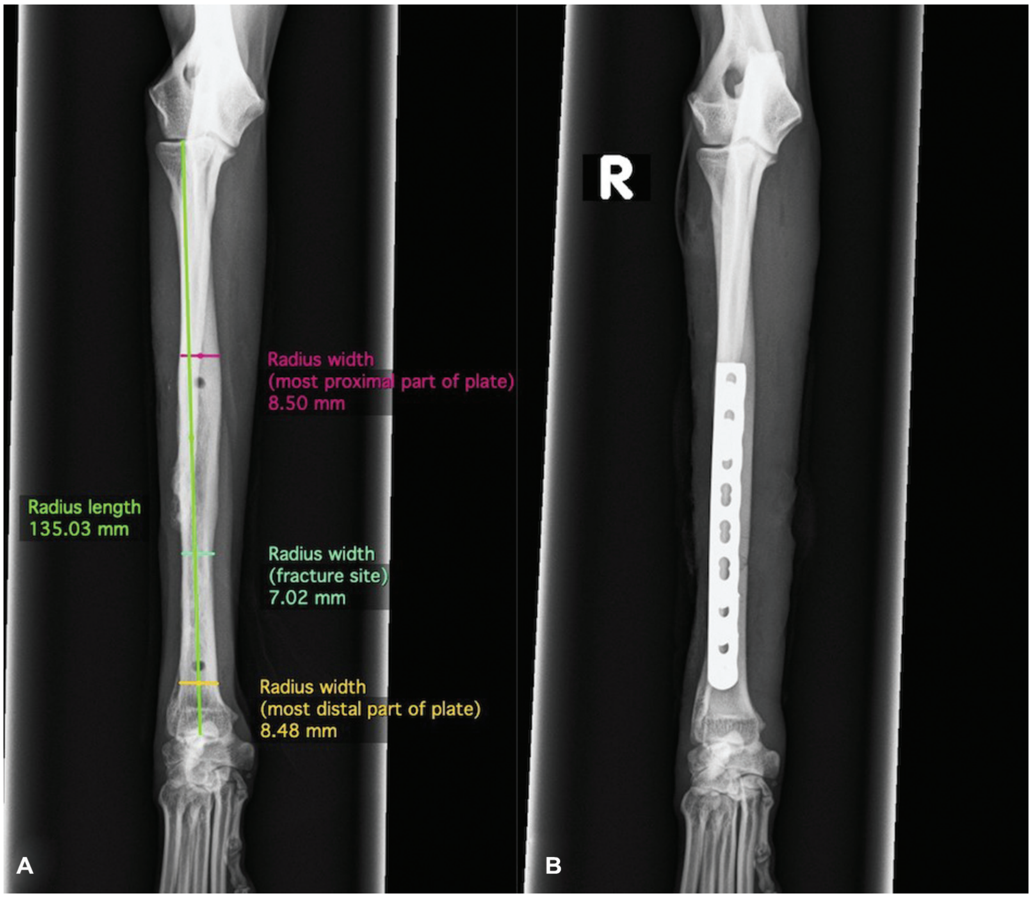

Fig. 4 Measurements of radial width on radiographs (craniocaudal view). (**A**) After plate removal. (**B**) After reduction. The radial width was measured at the initial fracture site and the most distal or proximal to the plate. In the craniocaudal view, the line connecting the midpoints of the distal or proximal articular surfaces of the radius was used as the length of the radius. The radial width was calculated as ratios based on the radial length on the same radiograph (radial width/radial length).

adjusted residuals indicated significantly more non-refractured limbs in the P group than in the R group. However, as the coefficient of association was $\phi = 0.16$, little association was found between the refracture and plate removal. Refracture occurrence was not associated with sex, affected limb (right or left), fixation method (locking system or conventional system), plate application method (bridge or compression), and the presence or absence of ulnar union.

Non-plate Removal Group

In the P group, 141 limbs were included. Refractures were observed after radial union in 5 of the 141 limbs (3.5%; ►**Appendix Table 2** [available in the online version]), and the remaining 136 (96.5%) were non-refracture limbs. All refractures in this group occurred through the most distal screw hole (18.7 ± 3.5% from the distal radius; ►**Fig. 5**). In some cases in the P group, only the screws were removed without plate removal to reduce the stiffness of the plate and screw construction. The screws were removed when the radial union was observed on the radiographs. Among the non-refractured limbs, 93 underwent screw removal, whereas 43 did not. Moreover, among the refractured limbs, two underwent screw removal, whereas three did not. In both cases, screw removal was performed approximately 2 months after fracture reduction. At this time, the screws were removed, leaving only the most distal and proximal screws. Refracture occurred approximately 40 days after screw removal in one case and approximately 110 days after screw removal in the other.

►**Appendix Table 3** (available in the online version) shows the P group's general information and univariate logistic regression analysis results. Univariate analysis revealed a significantly lower age in months at the initial fracture and the final follow-up in the refracture group than in the non-refracture group ($p = 0.02$ and $p = 0.04$, respectively). Moreover, days until confirmed radius fracture healing were significantly lower in the refracture group than in the non-refracture group in the univariate analysis ($p = 0.02$).

►**Appendix Table 4** (available in the online version) shows the P group's radiographic measurements and univariate logistic regression analysis results. In univariate analysis, there was a significantly greater amount of position change of the most distal screw in the refracture group than in the non-refracture group ($p < 0.01$). Moreover, the SBDR was significantly higher in the refracture group than in the non-refracture group ($p = 0.02$).

The amount of position change of the most distal position of the screw and age in months at the time of final follow-up were included in the final model and evaluated using

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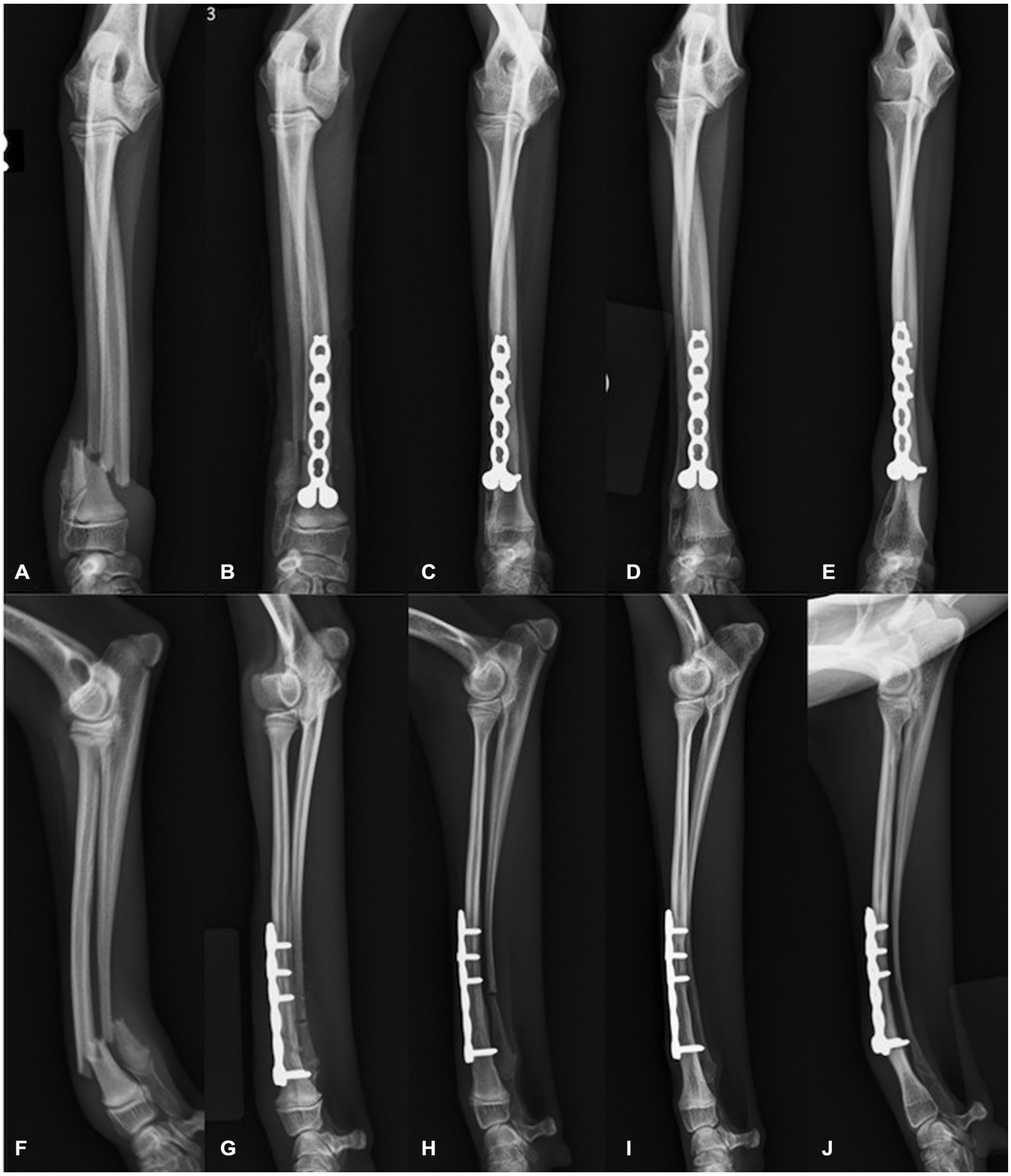

Fig. 5 Case of refracture in the P group: case number 4. (**A**) At initial fracture (craniocaudal view). (**B**) After reduction (craniocaudal view). (**C**) At radial union (55 days after surgery: craniocaudal view). (**D**) Before refracture (108 days after surgery: craniocaudal view). (**E**) After refracture (205 days after surgery: craniocaudal view). (**F**) At initial fracture (mediolateral view). (**G**) After reduction (mediolateral view). (**H**) At radial union (55 days after surgery: mediolateral view). (**I**) Before refracture (108 days after surgery: mediolateral view). (**J**) After refracture (205 days after surgery: mediolateral view). The patient fractured the radial–ulnar bone at 4 months and was treated with a plate and screws. Postoperative weight-bearing was well-improved, and the radius union was observed at 55 days postoperatively on radiographs. After 205 days postoperatively, however, the patient refractured at the most distal screw site of the plate.

multivariate analysis. Age in months at the time of initial fracture was excluded as it showed a strong correlation with age in months at the final follow-up. Multivariate analysis indicated $p < 0.05$ for the amount of position change at the most distal screw position (odds ratio [OR]: 1.79, $p = 0.04$, 95% confidence interval (CI): 1.01–3.14), which satisfied the significance level ($R^2 = 0.37$, Hosmer–Lemeshow test $p = 0.95$).

Plate Removal Group

The R group included 40 limbs. Non-refracture was observed after radial union in 35 of the 40 limbs (87.5%), whereas

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refractures were observed in the remaining 5 limbs (12.5%; ►**Appendix Table 5** [available in the online version]). All refractures in this group occurred at the same site as that of the initial fracture (29.7 ± 7.4% from the distal radius; ►**Fig. 6**). The refracture site was identical to the initial fracture site based on the length from the distal radius to the refracture site on the radiographs and subjective assessment.

Fig. 6 Case of refracture in the R group: case number 4. (**A**) At initial fracture (craniocaudal view). (**B**) After reduction (craniocaudal view). (**C**) At radial union (71 days after surgery: craniocaudal view). (**D**) After plate removal (76 days after surgery: craniocaudal view). (**E**) After refracture (78 days after surgery: craniocaudal view). (**F**) At initial fracture (mediolateral view). (**G**) After reduction (mediolateral view). (**H**) At radial union (71 days after surgery: mediolateral view). (**I**) After plate removal (76 days after surgery: mediolateral view). (**J**) After refracture (78 days after surgery: mediolateral view). The patient fractured the radial–ulnar bone at 10 months and was treated with a plate and screws. Postoperative weight-bearing was well improved, and the radius union was observed at 71 days postoperatively on radiographs. It was determined that radial union had been achieved, leading to the removal of the screws except for the most distal and proximal. After 78 days postoperatively, however, the patient refractured at the same site as the initial fracture site.

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No *p*-values satisfied the significance level in the univariate logistic regression analysis for each variable of the general information in the R group.

►**Appendix Table 6** (available in the online version) shows the measurement of radiographs and the results of the univariate logistic regression analysis in the R group. In the univariate analysis, a significantly lower PVR at the final follow-up was observed in the refracture group than in the non-refracture group ($p = 0.03$). Moreover, a significantly lower radial thickness ratio at the final follow-up was observed in the refracture group than in the non-refracture group ($p = 0.04$).

The PVR at the final follow-up and radial thickness ratio at the initial fracture site were included in the final model for multivariate analysis. Multivariate analysis indicated that PVR (OR: 0.67, $p = 0.04$, 95% CI 0.47–0.97) and radial thickness ratio (OR: 0.05, $p = 0.04$, 95% CI 0.01–0.81) had $p < 0.05$ and satisfied the significance level ($R^2 = 0.57$, Hosmer–Lemeshow test $p = 0.99$).

Discussion

This study aimed to identify the risk factors for refracture after radial union with and without plate removal in small-breed dogs. In the P group, only the amount of position change of the most distal screw demonstrated statistical significance in the final multivariate analysis model. Additionally, in univariate analysis, increased SBDR and younger age in months were observed in the refracture group than in the non-refracture group. These results indicate that the amount of position change of the most distal screw, SBDR, and age in months may be risk factors for refracture in this population. This suggests that the screw placed in the distal radius is relatively proximal as the distal radius grows, resulting in the screw diameter becoming relatively large compared with the bone width, thereby reducing bone strength and increasing the risk of refracture.

In the plate removal group, PVR and radial thickness ratio of the initial fracture site at the last follow-up demonstrated statistical significance in multivariate and univariate analyses. These results indicate that bone mineral density and radial thickness at the initial fracture site after plate removal may be risk factors for refracture. This suggests that the IIO occurring beneath the plate increases the risk of refracture.

Internal fixation using plates and screws is a reliable treatment method for radial–ulnar fractures in small dogs.[3,4,13] However, complications associated with this treatment, including dermatitis, cold sensitivity, osteopenia, plate failure, screw loosening, malunion, and nonunion, have also been reported.[14] It is considered that refractures after bone union are more likely to occur at the same site as the initial fracture or from the screw removal site if the plate and screws were all removed[15] or at the most distal and most proximal screw sites if the plate was not removed.[16] In the current cases where the plate was not removed, all refracture sites were at the most distal screw hole, and a significant increase was found in the amount of position change at the most distal position of the screw. Although no significant differences were observed in the final model in the multivariate analysis, dogs in the refracture group had younger age in months than those in the non-refracture group; thus, the elongation of the radius during the growing period may have caused screw position change. Generally, screws placed in the distal radial fragment are positioned proximal to the growth plate. Therefore, when the radius grows, the distance between the distal articular surface of the radius and the most distal screw increases, which results in the most distal screw being relatively proximal. Moreover, radial–ulnar fractures in small-breed dogs have been reported to occur more frequently (15–37%) in the distal radius.[17] The refracture location in the P group (mean $18.7 \pm 3.5\%$ from the distal end of the radius) is also consistent with the location where the highest frequency of radial–ulnar fractures in small-breed dogs occurs. In the univariate analysis, the refracture group in the P group had a significantly increased SBDR and younger age in months than the non-refracture group. This may have resulted in a narrower bone width and larger SBDR. As a large screw diameter relative to the bone width reduces bone strength, it is recommended that SBDR should not exceed 0.4.[18] Similarly, in the external fixation techniques, External Skeletal Fixation (ESF)-related fractures have been reported to occur when pins with diameters close to 30% of the bone diameter were used.[19] *In vivo* experiments on canine femurs showed that when 20% of the femoral bone diameter was defective, there was a 42% reduction in torsional failure strength.[20] These results suggest that in dogs with a radial–ulnar fracture at the age of 3 to 5 months, the screw placed at the distal radius is relatively proximal as the bone grows, and the screw diameter becomes relatively large compared with the bone width at the most frequent site of distal radius fracture, which may result in reduced bone strength and risk of refracture. When two screws are placed parallel to the radius (T-plate or condylar plate), the SBDR is larger than when screws are longitudinally placed (straight plate), which may contribute to the fracture through the screw holes. However, in this study, four of the five cases of refracture with the retaining plates were straight plates (screws could not be placed in parallel) and one was a condylar plate (screws could be placed in parallel). These findings in this study are more likely to occur in growing dogs, where there is some period of radial lengthening after plate fixation. Therefore, repairing fractures of the distal end of the radius in such dogs may require a smaller SBDR within which plate failure does not occur, postoperative motion restrictions, and external splint fixation. Moreover, a report has shown that longer WLs reduce the stiffness of the plate and screw constructions[21]; thus, the destabilization method may also be beneficial.

Refracture can occur as a complication after plate removal and is associated with IIO, characterized by cortical bone necrosis and thinning beneath the plate.[22] IIO occurs early (8–12 weeks) after plate placement due to inadequate blood supply[23] and later (24–36 weeks) due to reduced mechanical stress.[24] Moreover, bone mineral density decreases at 28 weeks after plate placement in the femur owing to changes in apatite orientation caused by reduced mechanical stress on the cortical bone.[25] The increased inflammatory

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cytokines are associated with decreased bone mineral density, resulting in cortical osteonecrosis at 36 weeks after plate placement in the radius[26]; thus, there are many undefined pathogenesis of IIO. These reports suggest that IIO is a risk factor for refracture after plate removal. However, risk factors for refracture after plate removal in clinical cases have not been reported in dogs. Risk factors for refracture after plate removal in clinical cases in animals have been reported in horses, while comminuted fractures, aging, and infection are reported risk factors for refracture, apart from IIO.[27] In this study, all refractures observed after plate removal occurred at the same site as the initial fracture site. Additionally, the PVR and radial thickness ratio of the initial fracture site at the final follow-up were significantly lower in cases with plate removal, suggesting that refracture after plate removal in dogs is associated with IIO. In the R group, PVR was significantly different only at the final follow-up; therefore, we considered that PVR did not increase over time in the refracture group, whereas it increased in the non-refractured group. It has been reported that the bone remodelling cycle in 1- to 2-year-old dogs is approximately 12 weeks.[28] As refracture in the R group was observed in four of the five cases within 90 days after plate removal, we considered that refracture may have occurred before bone mineral density developed. However, the accurate cause of the nondevelopment of bone mineral density remains unclear, and further case–control and long-term follow-up studies are needed.

A limitation of this study is that variations in radial morphology between breeds were not considered. As the length, thickness, width, and cortical and medullary bone area of the radius vary between breeds, variations in measurement results are expected. Another one is that the degree and duration of exercise limitation after plate removal were not considered. As the bone remodelling cycle is approximately 12 weeks in 1- to 2-year-old adult dogs,[28] it may be necessary to remove the exercise limits carefully and gradually after plate removal. However, the degree of exercise limitation was not clearly documented in the medical records. Not considering the size of the implants (plates and screws) in the plate removal group is also a limitation. In this study, since the plate removal group focused on the post-plate removal follow-up, the size of the implants was not measured. Because IIO is caused by reduced mechanical stress on the bone beneath the plate, the decreased radial thickness and reduced PVR may have been influenced by the implant sizes. However, since radial thickness and PVR were significantly different at the final follow-up (at the time of refracture) rather than immediately after plate removal, it remains unclear whether implant sizes affected the results of this study. Additionally, PVR was not measured in the P group. Although the coefficient of association was lower, the refracture rate was higher in the R group than in the P group (12.5 vs. 3.5%, $p = 0.04$, $\phi = 0.16$). All refracture cases in the P group were under 6 months of age at the time of radius fracture, and the refractures occurred after 2 months during the postoperative period. Our previous study reported that patients aged $<$6 months of age at the time of radius fracture recovered from IIO after 2 months postoperatively.[10] Although plate removal may be possible in theory, refracture rates have increased with plate removal. Deciding whether or not to remove the plate becomes challenging, especially when both causes of refracture in the P and R groups occur simultaneously. Additional study is needed on the long-term prognosis and management of IIOs that occur after plate fixation to bone.

This study indicated a significant association between the occurrence of refracture and plate removal (although the coefficient of association was $\phi = 0.16$). In cases where the radial fracture occurs at a young age, and the screw positioned at the most distal end of the radius is expected to be relatively proximal as the bone grows, it may require a smaller SBDR within which plate failure does not occur, postoperative motion restrictions, and external splint fixation. Moreover, in cases with decreased radial thickness and bone mineral density beneath the plate during plate removal, not removing the plate may be an option as the risk of refracture is higher.

Authors' Contribution

All authors contributed to the conception of the study, study design, and interpretation. All authors drafted, revised, and approved the submitted manuscript.

Conflict of Interest

None declared.

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