Thesis for the Degree of Master of Veterinary Medicine

Evaluation of Growth Deformities after Ulnar Ostectomy in Surgical Repair of Radioulnar Diaphyseal Fracture in Immature Dogs : A Retrospective Study

GRADUATE SCHOOL

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Abstract

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Growth deformities induced by damage to the growth plate cause many problems, including osteoarthritis, pain and lameness. This study aimed to investigate the effects of ulnar ostectomy on the development of growth deformities after radioulnar diaphyseal fracture repair in immature dogs. Small-breed dogs under 12 months of age with repaired radioulnar diaphyseal fractures were classified into groups with and without ulnar ostectomy. Changes in joint orientation angles involving the medial proximal radial angle, lateral distal radial angle, valgus angle, sagittal plane angle, and development of elbow incongruity between the day of the operation and follow-up of the bone union were investigated in both groups. In the group with ulnar ostectomy, there were no changes in the joint orientation angles. In the group without ulnar ostectomy, changes in the lateral distal radial angle, valgus angle, and sagittal plane angle were observed as the valgus and procurvatum progressed. There was no statistically significant difference in the prevalence of elbow incongruity between the groups. Based on the results, ulnar ostectomy is useful for preventing angular limb deformities. Considering the clinical and financial problems associated with angular limb deformities, concurrent ulnar ostectomy should be considered in immature dogs with radioulnar fractures.

Keywords: immature dog, radioulnar fracture, ulnar ostectomy, angular limb deformity, elbow incongruity

초록

미성숙 개에서 요척골간골절 교정 시 척골절골술 병행에 따른 성장 기형 평가

(지도교수: 정종태)

김현우

제주대학교 대학원 수의학과

성장판 손상에 의해 유발된 성장기형은 골관절염, 통증, 파행과 같은 많은 문제를 일으킨다. 이 논문에서는 미성숙한 개에서 요척골간골절 교정 수술 시 척골절골술의 병행 여부가 성장기형의 발생에 미치는 영향을 조사하였다. 12개월령 이하의 요척골간골절 교정수술을 받은 환자들을 척골절골술을 병행한 군과 척골절골술을 병행하지 않은 군으로 분류하고, 수술 당일과 골유합시점의 내측근위요골각도, 외측원위요골각도, 외반각도, 시상면각도의 변화와 주관절 부조화 발생여부를 조사하였다. 척골절골술을 병행한 군에서는 관절방향각의 변화가 없었으나,

척골절골술을 병행하지 않은 군에서는 외반과 전방만곡이 진행되는 양상으로 외측원위요골각도, 외반각도, 시상면각도의 변화가 나타났다. 두 군에서 주관절 부조화 발병 여부의 통계적 차이는 없었다. 결과적으로, 척골절골술은 각기형을 예방하는데 유용하였다. 각기형의 발생시 임상적, 경제적 문제점을 고려하였을 때, 성장기 요척골절 환자에서 골절 수술을 행할 때 척골절골술을 병행하는 것이 고려되어야 할 것이다.

Keywords: immature dog, radioulnar fracture, ulnar ostectomy, angular limb deformity, elbow incongruity

Contents

I. Introduction

The radius and ulna are paired bones that comprise the antebrachia in dogs. The radius is important for weight-bearing, but the ulna is relatively unimportant. The radius and ulna articulate proximally with the humerus at the elbow joint, and distally with the carpal bones at the carpal joint. The medial collateral ligament attaches to the styloid process of the radius and provides medial carpal stability. The lateral collateral and palmar ulnocarpal ligaments attach to the styloid process of the ulna and provide lateral and partial carpal stability, respectively.[1,2]

Radioulnar fractures are common in small animals. Approximately 18% of fractures in dogs and cats involve the radius and the ulna.[2,3] If only one of the radius or ulna is fractured, the other bone acts as an internal splint and can avoid surgical repair; however, in most cases, both bones are fractured and require surgical repair.[4] Applicable surgical repair methods include the use of IM pins, external fixation, bone plate and screw fixation, and K-wire fixation.[3] Especially in the case of small dogs, fractures of the radius and ulna occur easily even with minimal trauma, and the complication rate is higher in dogs weighing < 5 kg than in larger dogs.[4-7] These complications include growth deformities, delayed union, nonunion, malunion, and joint stiffness.[8] Owing to the nature of the paired bones, radial and ulnar fractures in immature animals can cause severe growth deformities.[3,4] Most ulnar growth in immature dogs occurs on the distal ulnar growth plate. The distal ulna of the other animals was flat and prone to shear fractures. However, the distal ulna of dogs is not sheared because of its conical configuration, and the shear force is converted into a compressive force that damages the germinal cartilage. As a result, the longitudinal growth of the radius is restricted by a shortened ulna, and asynchronous growth occurs.[9] Radiographic abnormalities of the growth plate are not always visible immediately after injury.[8] Even after successful fracture repair surgery, there is a possibility of growth deformity due to preceding ulnar growth plate injury.[4,10] In a previous study that examined eight immature dogs and cats with radioulnar fractures fixed with plates and screws, four had length asymmetry between the fracture and normal bone, and one had a valgus deformity.[11] Owners of skeletally immature animals should be aware of this, periodically monitor gradual changes in angulation or length, and immediately intervene if growth abnormalities are identified.[4]

Treatment options for growth deformities of the radius involve stapling of the radius and proximal or distal ulnar ostectomy in immature dogs and corrective osteotomy in mature dogs.[12,13] Some practitioners have introduced a method of ulnar ostectomy during radioulnar fracture surgery in immature dogs to avoid additional damage or when preceding growth plate damage is suspected.[4,8,13,14] To date, no studies have compared the development of growth deformity according to concurrent ulnar ostectomy with radioulnar diaphyseal fracture repair in immature dogs.

This study aimed to compare the development of a growth deformity involving angular deformities and incongruity of the elbow in the surgical repair of radioulnar fractures in skeletally immature dogs with and without ulnar ostectomy.

Ⅱ. Materials and Methods

Animals

This study included small-breed dogs younger than 12 months of age with radioulnar diaphyseal fractures corrected using a plate and screws at Samsung Animal Hospital, Kwon and Jung Animal Hospital, Thenaun Animal Hospital, and Time Animal Hospital from January 2020 to December 2022 . Chondrodystrophic breeds were excluded. Medical records collected included breed, sex, age, and body weight. All signalments were recorded on the day of the surgery.

The dogs were divided into groups with ulnar ostectomy (UO group) and without ulnar ostectomy (non-UO group). Ulnar ostectomy was performed as a resection of the partial ulna 6-12 mm from the fracture line.

Measurements

In both groups, radiographs taken on the day of the operation (DO) immediately postoperatively and on the day of bone union (BU) were compared. Frontal and sagittal plane radiographs were obtained. The follow-up day when the fracture line disappeared in the cortical bone in the frontal and sagittal planes on radiographs was judged as BU. Radiographs were evaluated using a PACS DICOM viewer (Radiant™; Medixant, Poznan, Poland).

First, the joint orientation angles were evaluated using the center of rotation of the angulation method.[15] Examples of the images depicting the image evaluation criteria are shown in Figures 1 and 2.

Joint orientation lines were drawn on the frontal and sagittal planes. At the elbow level of the frontal plane, a joint orientation line was drawn from the proximal aspect of the radial head to the medial coronoid process, or from the most distal aspect of the humeral condylar capitulum to the trochlea. At the carpus level in the frontal plane, a joint orientation line was drawn from the most lateral aspect of the articular surface of the distal radius to the lateral aspect of the radial styloid (Figure 1). Because the canine radius has one anatomical axis in the frontal plane, the radial axis in the frontal plane was determined by drawing a straight line crossing the center of 25%, 50%, and 75% of the entire length of the radius. If the straight line did not pass through the three central points, it passed through the centers of the 25% and 75% points. Joint orientation angles were determined by measuring the angles between the anatomic axis and joint orientation lines in the elbow and carpus and were referred to as the medial proximal radial angle (MPRA) and lateral distal radial angle (LDRA), respectively. The valgus angle (VA) was obtained by subtracting LDRA from MPRA.

Since the canine radius has a natural procurvatum, the axes of the proximal and distal radial diaphyses were drawn in the sagittal plane. These axes were drawn by connecting the centers of the 1/3 and 2/3 points of the length of each proximal and distal diaphysis, respectively (Figure 2). The angle between the proximal and distal radial axes is referred to as the sagittal plane angle (SPA).

Second, elbow incongruity was examined at the BU. Elbow incongruity was determined by step positioning between the lateral coronoid process and radial head, altered humeroulnar articular space, the elliptical appearance of the trochlear notch, and altered humeroradial articular space in the sagittal plane of the radiograph.[16] Example images depicting the evaluation criteria are shown in Figure 3.

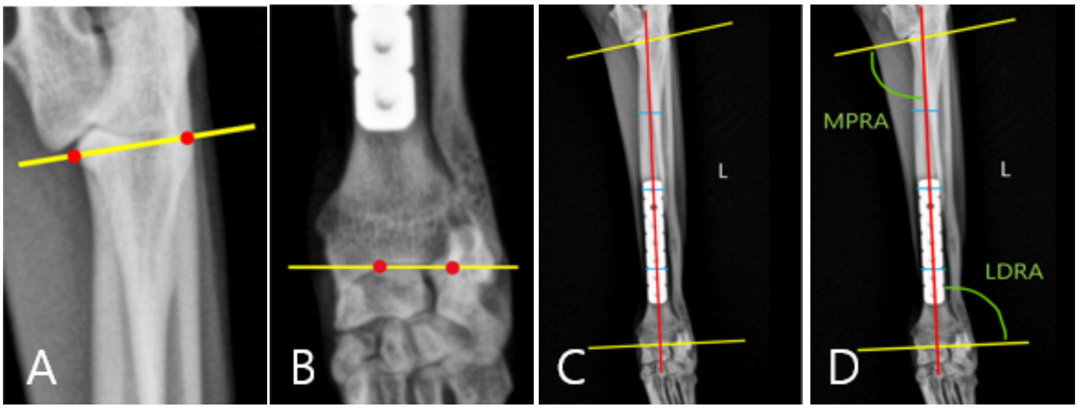

Figure 1. Joint orientation angle, frontal plane

(A) Elbow joint orientation line was drawn from the proximolateral aspect of the radial head to the medial coronoid process or from the distal-most aspect of the humeral condylar capitulum to the trochlea **(B)** Carpal joint orientation line was drawn from the most lateral aspect of the articular surface of the distal radius to the lateral aspect of the radial styloid **(C)** The radial axis was determined by drawing a straight line crossing the center of the 25, 50, and 75% of the entire length of the radius **(D)** Medial proximal radial angle (MPRA) was measured between the anatomic axis and joint orientation line at elbow joint level. Lateral distal radial angle (LDRA) was measured between the anatomic axis and joint orientation line at the carpal joint level.

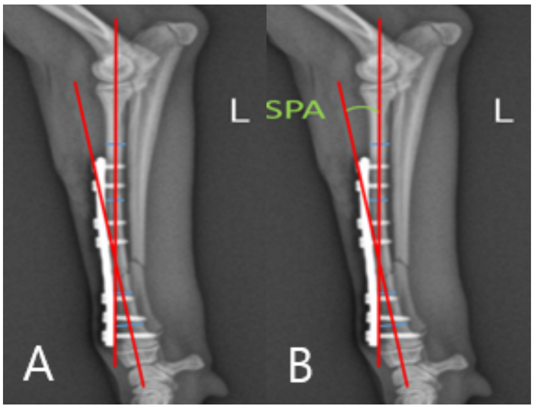

Figure 2. Joint orientation angle, sagittal plane

(A) The axes of the proximal and distal radial diaphysis were drawn by connecting the centers of the 1/3 and 2/3 points of the length of each proximal and distal diaphysis **(B)** Sagittal plane angle (SPA) was measured between the axes of the proximal and the distal radial diaphysis.

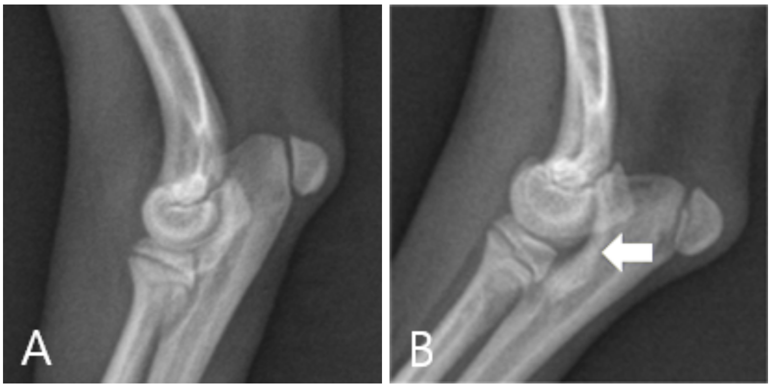

Figure 3. Comparison of elbow joint congruence

(A) Congruent elbow joint **(B)** Incongruent joint with step (white arrow) between lateral coronoid process and the radial articular surface

Statistical analysis

All statistical analyses were performed using a commercial statistical software package (SPSS® Statistics, version 24.0; IBM Corp., Armonk, NY, USA). The breeds and sexes of both groups were evaluated using Pearson's Chi-squared and Fisher's exact tests. The body weight and age of both groups were evaluated using the Mann-Whitney U test. The change in joint orientation angle in both groups was evaluated using the nonparametric Wilcoxon signed-rank test. The development of elbow incongruity in both groups was evaluated using Pearson's Chi-squared and Fisher's exact tests. Statistical significance was set at $p < 0.05$.

III. Results

Animals

The medical records of 28 dogs were searched and used for this study. Thirteen and 15 dogs were in the UO and non-UO groups, respectively.

The breeds in the UO group consisted of three Italian greyhounds, six Pomeranians, three poodles, and one Chihuahua. The breeds of the non-UO group consisted of one Italian greyhound, five Pomeranians, five Poodles, one Shiba Inu, one Maltipoo, one Spitz, and one Chihuahua. The breeds of the two groups were not statistically different.

The UO Group consisted of seven males, five females, and one intact male. The non-UO group consisted of eight males, four females, two intact males, and one spayed female. The sexes of the two groups were not statistically different.

The body weights of the UO and non-UO groups were 2.4 ± 1.43 and 3.0 ± 2.18 kg, respectively. The body weights of the two groups were not statistically different.

The age of the UO and non-UO groups was 4.9 ± 2.75 and 6.0 ± 3.12 years, respectively. The age of the two groups was not significantly different.

The breeds, sexes, body weights, and ages of both groups are summarized in Table 1.

Table 1. Breed, sex, bodyweight and age of dogs which conducted for this study

		UO group	Non-UO group	*p*-value
Breed	Italian greyhound	3	1	> 0.05
	Pomeranian	6	5	
	Poodle	3	5	
	Shiba inu	0	1	
	Spitz	0	1	
	Maltipoo	0	1	
	Chihuahua	1	1	
Sex	Male	7	8	> 0.05
	Female	5	4	
	Castrated male	1	2	
	Spayed female	0	1	
Bodyweight(kg)		2.4±1.43	3.0±2.18	> 0.05
Age(months)		4.9±2.75	6.0±3.12	> 0.05

$*p < 0.05$ is considered significant

Data are presented as the mean ± standard deviation

UO, the group with ulnar osteotomy. Non-UO group, the group without ulnar osteotomy

Joint Orientation Angle

The MPRA did not change significantly from DO to BU in the UO and non-UO groups. LDRA did not change significantly from DO to BU in the UO group but decreased in the non-UO group. VA did not change significantly from DO to BU in the UO group but increased in the non-UO group.

SPA did not change significantly from DO to BU in the UO group but increased in the non-UO group.

The joint orientation angles of both groups are summarized in Tables 2 and 3.

Table 2. Joint orientation angles of the UO and non-UO groups in the frontal plane

	Group	Time		*p*-value
		DO	BU	
MPRA	UO	78.7±2.52	78.1±2.74	> 0.05
	Non-UO	79.4±2.71	79.6±2.90	> 0.05
LDRA	UO	84.3±2.37	84.3±2.72	> 0.05
	Non-UO	84.7±2.48	80.9±4.92	*< 0.05
VA	UO	-5.6±3.74	-6.6±3.25	> 0.05
	Non-UO	-6.5±3.71	-0.9±5.12	*< 0.05

*$p < 0.05$ is considered significant

Data are presented as the mean ± standard deviation

MPRA, medial proximal radial angle, LDRA, lateral distal radial angle, VA, valgus angle

Table 3. Joint orientation angles of UO and non-UO groups in the sagittal plane

	Group	Time		*p*-value
		DO	BU	
SPA	UO	8.9±1.67	9.0±1.83	>0.05
	Non-UO	8.4±2.44	12.9±3.53	*<0.05

*p < 0.05 is considered significant

Data are presented as the mean ± standard deviation

SPA, sagittal plane angle

Incongruity

Incongruity occurred in 0 and 3 patients in the UO and non-UO groups, respectively. Three of the incongruities in the non-UO group had step formation between the radial head and the lateral coronoid process, and one had a widened humeroulnar space. No statistically significant differences were found between the two groups.

The elbow incongruity of both groups is summarized in Table 4.

Table 4. Elbow incongruity development of UO and non-UO group

		Group		Total	p-value
		UO	Non-UO		
Incongruity	No	13	12	25	> 0.05
	Yes	0	3	3	

*p < 0.05 is considered significant

Ⅳ. Discussion

Breeds of the UO and non-UO groups were limited to small breeds because larger breeds have different growth patterns, which can cause confusion in the interpretation of the results.[17] Chondrodystrophic breeds were excluded because they have a high incidence of angular deformities, which could cause confusion in the interpretation of results.[12] The age of the groups was under 12 months because small-breed dogs can grow skeletally up to 12 months.[17] Body weight and sex were compared between the two groups as factors affecting growth.[17,19,20] The two groups did not have statistically significant difference in all signalments.

The MPRA did not change significantly in either group. It is presumed that the synchronous growth of the radius and ulna occurred at the elbow level in both groups. LDRA levels did not change in the UO group but decreased in the non-UO group. It is presumed that valgus deformity occurred at the carpal level due to preceding damage to the distal ulnar growth plate in the non-UO group.[16] VA did not change in the UO group but increased in the non-UO group because it was obtained by subtracting LDRA from MPRA. Changes in the LDRA and VA in the non-UO group represent the progression of carpal valgus.

SPA did not change in the UO group but increased in the non-UO group. It was presumed that growth of the radius was restricted to the carpal level because of preceding damage to the distal ulnar growth plate.[16] Changes in the SPA in the non-UO group represent the progression of the procurvatum of radius.

In many studies, valgus and procurvatum have caused osteoarthritis, pain, lameness, and obvious cosmetic disfiguration of the limb owing to irregular load distribution across the elbow and carpus.[18,21] Early intervention is less invasive and economical than late intervention when malformations occur. In addition, in a recent study on the short-term outcomes after performing ulnar ostectomy on radioulnar asynchronous growth in juvenile dogs, lameness symptoms and elbow incongruity improved, but the angular deformity that had already occurred did not improve.[22] In addition, anesthesia and surgery have disadvantages, such as clinical complications and economic distress for the owner.[23,24] In this study, the UO group had less angular deformation than the non-UO group. Therefore, performing ulnar ostectomy during corrective surgery for radioulnar fractures is expected to reduce the risk of angular deformity and the need for additional surgery.

Radioulnar incongruity is an inaccurate matching joint caused by growth plate damage or unbalanced growth of the radius and ulnar.[25] In the hypothesis stage of this study, it was expected that the prevalence of incongruity would increase due to the induction of asynchronous growth of the radius and ulna in the non-UO group; however, no significant difference was found. The relatively short ulna, compared to the radius, induced by distal ulnar growth plate injury is a major factor in elbow incongruity. In both groups, it is estimated that there was no significant difference in growth of longitudinal axes of the radius and ulna. In this study, owing to the limitations of retrospective studies, a comparison of the length growth of fractured and normal legs was not made. However, in a previous study comparing growth after distal femoral physeal fractures in dogs under 10 months of age, the younger the age of the injury, the more severe the femoral shortening.[26] This is because rapid growth occurs at less than 6 months of age. Therefore, further studies targeting dogs aged < 6 months are required.

This study has several limitations. First, the number of dogs was small, and there were few variations in body condition scores and nutrition. Obesity and nutrition are important factors in bone growth in humans and animals.[27,28] Therefore, obesity and nutritional status are likely to affect the growth patterns of immature dogs. Second, radius and ulnar lengths were not evaluated. As this was a retrospective study, radiographs of the unfractured contralateral forearm were not always obtained. The length of paired bones is an important factor in growth deformities. Further studies that include data on length growth are needed.[4,9] Finally, no evaluations were performed after the day of bone union. As bone growth continues after healing, additional studies on bone union are needed.

V. Conclusion

Joint orientation angles were compared between DO and BU in the UO and non-UO groups. The development of elbow incongruity at the BU was compared between the two groups.

In the UO group, no significant changes in the joint orientation angles were observed. However, in the non-UO group, changes in the joint orientation angles, including the LDRA, VA, and SPA, which represent the progression of valgus and procurvatum, were observed. The development of elbow incongruity did not differ significantly between the two groups. Considering the complications and need for additional surgery when angular deformities occur, ulnar ostectomy during fracture repair may be suitable for preventing angular deformities.

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