# Initial Clinical Application and Results of the Advanced Locking Plate System (ALPS) in Small Animal Orthopedics: Two Hundred Eighty Two Procedures

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**KEY WORDS:** Advanced Locking Plate System (ALPS); complication; fracture repair; internal fixator; locking bone plate

#### **ABSTRACT**

Dogs and cats with fractures, arthrodeses, or corrective osteotomies (282 fixations) stabilized using the ALPS bone plating system between May 2007 and April 2012 were evaluated retrospectively to describe the authors' experience with this system, assess rate of bone union, and evaluate post-operative complications. Cases with follow-up radiographs taken at least 8 weeks postoperatively or cases with bone healing confirmed prior to week 8 were included. Signalment, preoperative infection, fracture location, fracture type, surgical fixation method, implant size, additional fixation, intraoperative complications, and postopera-

tive complications were recorded for each patient.

Two hundred eighty-two fixations were performed on 266 patients, including 240 fractures, 26 corrective osteotomies, 14 arthrodesis, and 2 additional procedures. All 10 reported intraoperative complications occurred in the first year; each involved screw failure. Postoperative complications were reported in 9 of the 282 procedures (3.2%), of which 7 cases were major complications (2.5%) and 2 cases were minor complications (0.7%). With the exception of two amputations, all treated cases achieved bone union or progression towards bone union (99.3%). This study demonstrated a high rate of bone union (99.3%), accompanied by a low postoperative complication rate (3.2%), when using the ALPS system in

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small animal orthopedics.

#### INTRODUCTION

The principles of internal fracture fixation by plating are based on the conviction that precise reconstruction and absolute stability are essential for successful bone union (Mueller, et al, 1970; Schatzker, et al, 1987; and Perren, 2002). However, this fixation type typically requires an extensive surgical approach, often resulting in damage to local soft tissue and blood supply, which may lead to infection and possibly delayed healing or non-union, as opposed to an open but do not touch approach (Perren, 2002). Conventional bone plate fixation has also been associated with early temporary increased bone porosity under the bone plate, resulting from insult to the periosteal blood supply secondary to implant-bone contact (Perren, 2002). Biological internal fixation is a recently developed alternative providing optimal, rather than absolute, stability with minimal soft tissue disturbance and minimal underlying bone contact (Perren, 2002; Hernanz, et al, 2007).

A new generation of plates, called internal fixators, has been developed utilizing a locking mechanism between the plate hole and the screw head (Perren, 2002; Voss, et al., 2009). These devices are widely used in human surgery and have demonstrated advantages, including decreased risk of screw loosening, allowance for insertion of only monocortical screws, fewer screws needed for stability, and avoidance of bone necrosis under the plate (Perren, 2002; Perren, 2003; Miller, et al, 2007).

The Advanced Locking Plate System (ALPS) (Kyon, Zurich Switzerland), was conceptualized and designed to preserve the vascular supply, increase resistance to infection, and accelerate healing (Tepic, presented 2007). Titanium ALPS plates have holes designed for either non-locking or locking screws (titanium alloy). The ALPS system integrates the Point Contact Fixator (PC-Fix) development work from the AO Research Institute, Davos, Switzerland (Tepic, et al, 1997; Haas, et al, 2001; Perren, 2002).

Since 2007, ALPS has been used for fracture stabilization, arthrodeses, and osteotomies in small animals. To the authors' knowledge, there is only one published report on ALPS use, and experience with its application is limited (Inauen, et al, 2009).

This retrospective study describes our experience with ALPS, the rate of bone union, our postoperative complications, as well as the type and frequency of our associated complications. Fractures of the radius and ulna are particularly common in small dogs, and often result in higher complication rates. Therefore, our comparatively low small dog radioulnar fracture complication rate is particularly interesting.

#### **MATERIALS AND METHODS**

# **Inclusion Criteria**

Medical records from dogs and cats with fractures, arthrodeses, or corrective osteotomies stabilized using ALPS between May 2007 and April 2012 were included in this retrospective study. Patients with radiographically confirmed bone healing prior to 8 weeks, and those with radiographs out to at least 8 weeks postoperative, were included

#### Fracture Classification

Fractures were classified as diaphyseal, metaphyseal, or articular and fracture type was classified as simple:

- transverse or short oblique
- simple long oblique or spiral, comminuted-1 (maximum two large cortical fragments)
- comminuted-1' (segmental fracture), and
- comminuted-2 (more than two cortical fragments), or delayed union/non-union

Medical records for patients undergoing arthrodeses or corrective osteotomies were classified by location.

#### **Implants**

Type of procedure, plate size, and any additional fixation were retrieved from medical records. Four ALPS plate sizes, identified

by plate width, were used in this study (5, 6.5, 8, and 10 mm). Whenever indicated, locking screws were used (1.5 mm cortical/2.4 mm locking for 5mm and 6.5 mm plate; 2.4 mm cortical/3.2 mm locking for 8 mm plate; 2.7 mm cortical/4.0 mm locking for 10 mm plate). In some cases, the shortest locking screw was too long and the far cortex was engaged, or standard non-locking screws were used. Plate sizes were selected using the suggested implant reference chart (Figure 1). Double or triple plating (Table 1) was also implemented. In cases of insufficient bone support to provide additional support for total load across the fracture, or to increase strength when a distal fracture fragment would allow only one, or possibly two, screws in a single plate.

# **Surgical Technique**

Standard surgical approaches were made. Care was taken to not further disrupt periosteal or muscular attachments to bone or bone fragments, and to not disturb fracture hematomas. Axial and rotational alignments were re-established by manual traction and manipulation. The majority of fracture repairs used an "open but do not touch" technique, as described by Houlton, et al. (2005), a variation of open reduction permitting viewing of fracture fragments with minimal biological consequences.

# **Bacterial Culture**

Bacterial cultures with strain identification were performed on all dogs with open fractures and those that failed to heal following surgery in another hospital. Treatment was based on susceptibility results.

#### **Postoperative Care**

The postoperative care protocol included 2 to 3 days of antibiotic therapy and NSAID administration, the intermittent application of an icepack for swelling and cage rest pending radiographic confirmation of bone union. Dogs were allowed leash walking beginning 2 weeks postoperatively for 5 to 10 minutes, two or three times a day. This was increased to 10 to 15 minutes at 4 weeks postoperative.

#### **Evaluation of Outcome**

Clinical assessment for lameness, complication evaluation, and radiographs were generally performed every 3 weeks for all patients, whether at the referral facility or by the referring veterinarian. Records of included animals were followed to approximately 8 weeks or until bone healing was noted radiographically. The referral hospital confirmed fracture union with the presence of a bridging callus over three cortices on two orthogonal projections. Fracture union was determined in all cases by the radiographic appearance of a visible callus bridging at least one cortex on both orthogonal views (Hernanz, et al. (2007)). Cases with radiographic signs showing good healing progression, no signs of implant loosening, and no indication of other abnormalities at follow-up, were assumed to be free of complications. Postoperative complications were noted and classified as either major, requiring surgery or amputation, or minor, not requiring surgical intervention.

#### **RESULTS**

# **Patient and Fracture Description**

Two hundred eighty-two procedures were performed on 266 patients (Table 1, 2, and 3), including 240 fractures, 26 corrective osteotomies, 14 arthrodeses, 1 preventive fixation following a tibial turberosity advancement, and 1 triple pelvic osteotomy revision. Patients had a mean age and weight of 32 months and 4.6 kg respectively. Surgeries were performed by either a diplomate of the Japanese College of Veterinary Surgeons (JCVS) or a JCVS resident.

Of the 155 patients with radioulnar fractures, 140 patients (91%) were small breed dogs, including Toy poodles, Pomeranians, Chihuahuas, and Italian Greyhounds. There were 211 long-bone fractures. Prior to ALPS fixation, eight fractures were considered to have a delayed union, and 21 were non-union.

Bacterial cultures with strain identification, using specimens collected at surgery, were performed on 15 dogs and 3 cats with open fractures and 38 dogs and 5 cats that had prior surgery in other hospitals, but

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Table 1. Continued

216 Toy Poo 217 Chihush 218 Chihush 219 Papillon	shua	9	65	4.0	1	Radius/Ulna			Short oblique	MLS, MS	Double plating		
218 Oil-10	$\overline{}$	9	30	3.7									
_				-		Radius/Ulna			Simple transverse	15 x 2	Double plating		
219 Pauline	shua	12	36	3.0	c	Radius/Uha			Fracture union disorder	15×2	Double plating		
	in .		3	1.7		Radius/Ulna			Short oblique	45 x 2	Double plating		
220 Italian (	Grey Hound		36	4.9		Radius/Ulna			Short oblique	#6.5			
221 Pomera	$\overline{}$	4		2.0		Radius/ Ulna			Simple transverse	WS.			
222 Kebu		7	13	29.3	M	femur			Simple transverse	800	(MFIn		
223 (34)-44		8	27	1.0	M	Radius/Ulra				45 x 2			
_	$\overline{}$		9	_					Simple transverse		Double plating		
224 Shiba	$\overline{}$	-	- 4	4.3	М	femur			Simple transverse	86.5			
225 Toy Poo	$\overline{}$	-	9	2.7		Radius/Ulna			Simple transverse	15			
226 Noy Poo	-	-	7	2.0		Radius/Ulna			Simple transverse	ni.			
227 Missell	Breed	-	- 3	1.8	M	femur			Simple transverse	16	(MPI)		
228 Toy Poo	ode	11	34	3.1		femur			Simple transverse	86.5	(MPH		
229 Pomera	onian	- 3	5	1.0		Femur			Short oblique	NS.			
230 Toy Poo	ode		10	15	3	Radius/Ulna			Simple transverse	85 x 2	Double plating		
291 Noy Poo	ode	-	58	1.8	c	Radius/Ulna			Simple transverse	15 x 2	Double plating		
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232 Sorder	colle		26	36.0	М	Tibra				ma			
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295 Japanes	-		52	5.2	С	Tibla	Close		Comminuted-1	m 8			
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297 Somali		-	29	5.0	C	Radius/Ulna			Simple transverse	#5	UM Pin		
238 Mod 8	Breed	7	4	1.4	M	Titia/Flouia			Short oblique	#5			
239 Mixed B	Breed	17		3.0		Radius/Una			Practions union disorder	85	VM Pin		
240 Mixed I	Brood	10	190	4.6	5	Tibla			Short oblique	W 8			
341 ispanes	ne ot	6	49	3.3	5	Radius/Ulna			Montagia	#5	Suture anchor		
312 (apones	-		39	5.2	F	tium			Comminuted 1	#5			
243 America	$\overline{}$	-	69	4.8	c	Titra			Practure union disorder	7.0			
244 Japanes	-	-	2	2.4	- N	femur			Comminuted-2	78			
_	-	-	_		1								
245 Japanes	$\overline{}$	-	16	3.8		Metacarpai			Simple transverse	#5	Triple plating		
3% ispanes	$\overline{}$	-	4	2.3		Radius/Ulna			Short oblique	#5	Double plating		
347 Japanes	_	4	24	4.3	¢	Ottos celoli			Fracture union disorder	#5			
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249 Japanes	ne cat		36	4.0	5	Tenur	Open/Grade 1		Comminuted-1	#8			
250 Japanes	nse cat	6	10	3.7	М	Radius/Ulna			Simple transverse	15×2	Double plating		
251 Japanes	763-989	5	12	2.5	F	Radius/Ulna			Short oblique	15	(MPA		
252 Japanes	ese cart	8	3	2.0	M	femur			fracture union disorder	ma			
253 Abyrein	NGA .	6	12	2.5	s	Calcaneus			Simple transverse	15			
253 Abyroin	$\overline{}$	6	12	2.5	8	Radius/ Ulna	open		Simple transverse	15			
254 Scottish	$\overline{}$	34	10	2.3	- 1	Tible			Short oblique	112	Lag sovew		
255 Japanes	$\overline{}$		60	4.7	1	Mandible			Simple transverse	15			
256 Japanes	$\overline{}$	-	60	5.0	3	Titra			Comminuted 1	45 x 2	Double status		
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257 Japanes	$\overline{}$	-	36	6.6	6	Tibia			Comminuted-2				
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261 Japanes	ese cat	7	4	2.5	м	Téra			Simple transverse	M.S. AS	Double plating		
262 Japanes	mecat	41	84	4.0	5	Tible	Open/Grade3		Comminuted-1	#8	157	Antibiotic resistant infortion	Amputation
263 Japanes	roe cat	6	26	7.9	c	Radius/Ulna			Simple transverse	86.5	VM Pin		
264 Abyssin	$\overline{}$	7	12	3.2		Vicacavial			Comminuted 1	15	Cuire		
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265 Japanes													
265 Japanes 266 Japanes	$\overline{}$	10	180	2.6		Tible			Comminuted-1	45	VMPh		

failed to heal. Of the 61 preoperative culture cases, 11 were treated with antibiotics based on susceptibility results. Bone union was unsuccessful in two of the cases found with infection at the time of surgery. In both cases, MRSA was detected, and when infection control failed, amputations were performed. For the remaining 180 dogs and 25 cats in which infection was considered unlikely, bacterial culture was not performed. Only one of these cases resulted in a postoperative infection.

With the exception of the two amputations, all treated cases achieved bone union or, for those cases in which union was not complete at the end of this study, a progression towards bone union, as indicated by radiographic evidence of callus formation. Double (n=72) or triple (n=6) plating technique was used in 78 cases (Tables 1 and 3). Additional fixation, including cerclage, lag screw, IM pin, tension 8 band, and/or external skeletal fixation, was implemented in another 35 cases.

# **Complications**

Intraoperative complications were reported in 10 animals, including 1 stripped screw head and 9 screw fractures. Postoperative complications were reported in 9 of the 282 procedures (3.2%), including 7 (2.5%) major postoperative complications and 2 (0.7%) minor postoperative complications. Of the nine postoperative complications, four resulted from implant failure (plate breakage or loosening of a screw), and five were biological failure (infection or refracture).

Five patients with major postoperative complications, including two radioulnar fractures, one radioulnar corrective osteotomy, one humeral fracture and one comminuted tibial fracture, required a second surgery. Bone union was achieved in all five cases, and all patients made a full functional recovery. Two patients with antibiotic resistant infections resulted in amputation. The two postoperative cases with minor complications that received no additional surgical intervention were both radioulnar fractures. Postoperative complication details and reso-

lutions are summarized in Table 1.

Two cases required amputation; each presented with a local infection at the fracture site after a previous reduction attempt at a referring institution. In both cases, fracture reduction was attempted at the owners urging, despite advice that bone union was unlikely. In each case, methicillin-resistant Staphylococcus aureus (MRSA), and additionally in one case, pseudomonas aeruginosa, was detected by culture and amputation was indicated.

#### **DISCUSSION**

This retrospective study was initiated to evaluate the clinical application of the Advanced Locking Plate System (ALPS) as an alternative to the more conventional Dynamic Compression Plate (DCP) System in small animal orthopedics. Our results with ALPS demonstrated a high rate of bone union or progression toward bone union (99.3%), with low postoperative complications (3.2%).

Until the introduction of internal fixators, fracture stability relied on the friction provided by the screws between the bone plate and the bone, resulting in a compression of the plate to the bone (Perren, 2002; Voss, et al, 2009). Internal fixators, such as PC-Fix, rely on splinting the fragments of a fracture internally with locking bolts so that the blood supply is not compromised by compression of the periosteum (Eijer, et al, 2001). ALPS has not been tested experimentally in vivo, nor has it been tested in a clinical trial. However, the limited bone contact and fixation method are similar to PC-Fix, suggesting that observations from the PC-Fix project are relevant to ALPS. Separate in vitro testing of the ALPS 10 plate showed a 20% higher bending strength than stainless steel (DCP 3.5), validating the design process (Blake, et al, 2011). Following approximately 8 years of animal testing, advantages of PC-Fix over conventional plating include a significantly increased resistance to infection, reduced impact on bone remodeling, and faster, more consistent healing (Tepic, et al, 1997; Haas, et al., 2001; Hertel, et al,

Table 2. Procedure by Type of Fixation and Location

Location	Localization (% total of 240 fractures)	Dogs (Fractures/ Animals)	Cats (Fractures/ Animals)	Patient age range (months)	Patient mean age (months)	Patient body weight range (kg)	Patient mean body weight (kg)	Diaphyseal (N)	Metaphyseal (N)
Fractures									
Humerus	2.5%	4	2	5 – 96	81	2.0 – 34.0	9.0	4 (67%)	2 (33%)
Radius / Ulna	64.6%	147	8	4 – 117	4	1.0 – 43.0	2.7	123 (81%)	29 (19%)
Femur	11.3%	23	4	3 – 168	27	1.7 – 21.0	4.0	25 (92%)	2 (8%)
Tibia	9.6%	11	12	3 – 180	36	1.2 – 35.4	3.9	21 (91%)	2 (9%)
Acetabular	3.3%	7	1	5 – 89	25	2.8 – 7.5	4.0		
Illial	2.1%	3	2	4 – 39	14	2.3 – 10.2	5.2		
Mandibular	3.3%	7	1	6 – 192	60	3.3 – 34.0	4.7		
Maxilla	0.8%	2	-	6	6	34.0	34.0		
Metatarsal	0.8%	1	1	12 – 48	30	3.2 – 9.8	6.5		
Metacarpal	0.4%	-	1	18	18	3.8	3.8		
Phalanges	0.4%	1	-	24	24	26.0	26.0		
Calcaneus	0.4%	-	1	12	12	2.5	2.5		
Scapula	0.4%	1	-						
Total Fractures / Animals		207 / 194	33 / 32						
Corrective Oste	eotomies								
Femoral		15	-	5 – 88	11	1.0 – 21.5	6.0		
Radial		9	-	11 – 96	31	2.8 – 10.6	4.5		
Tibial		2		6 – 7	6.5	3.3 – 4.4	3.9		
Total Osteotomies / Animals		26 / 24	0						
Arthrodesis					•			•	
Tarsal		7	-	24 – 120	72	3.0 – 15.8	10.0		
Carpal		3	1	55 – 84	63.5	3.0 – 10.3	6.4		
Shoulder		2	-	10 – 72	41	3.4 – 3.5	3.5		
Elbow		1	-	97	97	5.0	5.0		
Total Arthrodesis / Animals		13 / 13	1/1						
Other									
Preventive (TTA)		1	-						
Triple Pelvic Osteotomy revision		1	-						
Total Fractures / Animals		248 / 233	34/33						
Total Fractures / Animals		282 / 266							

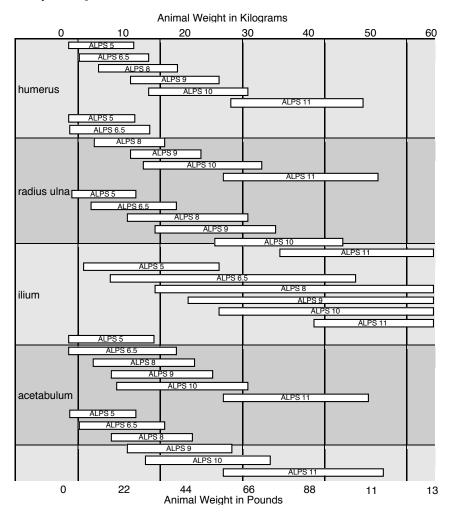
2001).

The intent of biological internal fixation, for which ALPS is particularly amenable, is to minimize damage to the surrounding soft tissue by using indirect reduction, thereby avoiding the increased bone exposure required by exact reduction (Perren, 2002). To maintain stability, an internal fixator relies on locking the screws in the plate rather than on compression and friction between

Table 3. Fracture Type and Additional Fixation

Location	Fracture Type	N (Fracture number)	Additional Fixation	N
Humerus	Short oblique	1	Lag screw	2
	Salter-Harris Type 4	2	I/M pin	1
	Comminuted -1	1		
	Fracture union disorder	2		
Total		6		3
Radius / Ulna	Simple transverse	106	Ulnar I/M pin	5
	Short oblique	24	Ulnar I/M pin + tension 8 band	1
	Comminuted-1	2	K-wire	2
	Comminuted-1'	1	External skeletal fixation	1
	Comminuted-2	1		
	Montegia	1		
	Fracture union disorder	20		
	Corrective osteotomy	9		
Total		164		9
Femur	Simple transverse	9	I/M pin	5
	Short oblique	2	I/M pin + cerclage wire	1
	Salter-Harris Type 4	1	K-wire	2
	Comminuted-1	5	Lag screw	2
	Comminuted-1'	2		
	Comminuted-2	1		
	Long oblique	1		
	Fracture union disorder	6		
	Corrective osteotomy	15		
Total		42		10
Tibia	Simple transverse	7	Lag screw	2
	Short oblique	4	I/M pin	6
	Comminuted-1	7	External skeletal fixation	1
	Comminuted-2	2		
	Spiral	1		
	Fracture union disorder	2		
	Corrective osteotomy	2		
Total		25		9
Other Fracture Location	Acetabular	8		
	Illial	5		
	Mandibular	8		
	Maxilla	2		
	Metatarsal	2	K-wire	1
	Metacarpal	1		
	Phalange	1	Lag screw	1
	Calcaneus	1		
	Scapula	1		
Total		29		2

Figure 1. Implant Reference Chart



the plate and the bone (Perren, 2002). In this study, none of the treated animals had a detectable radiographic decrease in bone density under the plate.

Implant material, implant design and/ or surgical technique may each play crucial roles in the prevention of infection (Schlegel, et al, 2006). It has been suggested that an implant material with increased biocompatibility, such as titanium, may reduce susceptibility to local infection (Matter, et al, 1990; Pascual, et al, 1992). One investigation concluded that stainless steel may play a role in the inhibition of polymorphonuclear leukocytes superoxide production, resulting in device-related infections (Pascual, et al, 1992). A local bacterial challenge study compared infection rates of stainless steel DCP with titanium DCP in rabbit tibiae; the stainless steel DCP rate (75%) was significantly higher than the titanium DCP rate (35%, p<0.05) (Arens, et al, 1996). In the current study, only 3 (1.1%) of 282 fixations resulted in postoperative infection complications, two of which presented with bacterial infection before surgery. The third postoperative infection was believed to be the result of poor plate size selection, resulting in skin necrosis over the plate.

Additionally, bacterial infection risk may be increased with periosteum compression when using DCP. Conversely, minimizing

damage to local blood supply, thereby preserving the vitality of the underlying bone, may reduce infection risk. Bone loss seen near conventional implants was originally attributed to unloading or stress shielding of the bone (Perren, 2002). Several papers have suggested that preservation of bone fragment viability and soft tissue immediately deep to the plate was key to unimpaired fracture healing using internal fixators (Rittmann, et al, 1974; Gautier, et al, 1992; Fernández Dell'Oca, et al, 2001). ALPS follows this principle by combining two unique features. First, the underside of the ALPS plate allows only very small contact areas with the bone, thereby reducing periosteal blood supply occlusion. Second, the use of locking screws minimizes required drilling depth, thereby limiting vascular damage within the medullary canal.

A local bacterial challenge study plated 38 intact rabbit tibiae using either titanium DCP or PC-Fix; infection occurred in 12 of the DCP and 5 of the PC-Fix tibiae (p=0.022) (Eijer, et al, 2001). The periosteum saving geometry of ALPS plates makes them especially suitable for double plating when extra strength is required, as bone under the plate is not compromised by occluded perfusion. Double or triple plating is an acceptable alternative to using lag screws. In the authors' opinion, this can increase the strength because the plates support each other in the direction where their respective bending is weaker, as well as allowing for additional screws, rendering the device usable in distal fractures. In this retrospective study, of the initial 282 surgeries 78 (27.7%) were treated using a double or triple plating technique. Of those, only one (Case 29) was reported to have postoperative complications.

All 10 intraoperative complications, each involving a 1.5 mm conventional screw failure, occurred within the first year of ALPS use and no such incidents have occurred since. Each of these 10 cases was left untreated, and the screw shaft remained in the bone without incident. Although

intended for self tapping, the original ALPS conventional 1.5 mm screws lacked cutting flutes and required high insertion torque in cortical bone. Subsequently, cutting flutes were added and all locking screws were redesigned to reduce the insertion torque by about factor two (presented by Tepic 2010). Currently all ALPS screws, both locking and non-locking, are manufactured from a titanium alloy (TiAI6V4) that is about 50% stronger than c.p. titanium Grade 4 used for plates and, originally, for conventional non-locking screws.

In this study, postoperative complications occurred in 9 of 282 procedures (3.2%), of which 4 (1.4%) were due to implant failure. This complication rate is relatively low when compared to several published studies using both conventional repair and internal fixators (Hunt, et al, 1980; Duhautois, et al, 2003; Reems, et al, 2003; Haaland, et al, 2009). A study using a plate-rod construct for diaphyseal fracture repair in 47 dogs and cats reported a complication rate of 31.9% (15/47 cases) (Reems, et al, 2003). A separate study of 121 dogs and cats with diaphyseal fractures repaired using interlocking nails reported 26 complications (21.5%) (Duhautois, et al, 2003). A clinical experience study reported a complication rate of approximately 11% repairing 47 small animal fractures using a locking compression plate system (Haaland, et al, 2009).

Study investigators believe intraoperative and postoperative complications generally coincide with the necessary adjustment period in learning proper handling techniques required by a new material, in this case, titanium. In particular, titanium is weakened by excessive contouring, especially with reversals of direction. Stainless steel is more tolerant in that respect. Proper plate sizing and double plating options also differ from conventional systems. Two postoperative complications were believed to be related to handling errors. In the first case, poor plate selection resulted in an undersized plate, resulting in a plate failure

that may have been avoided using a doubleplating technique. In the second case, skin irritation developed over the plate. It is believed that a successful outcome would have been more likely if a smaller plate had been selected. However, the smaller plate size was not available at the time.

Radius and ulna fractures are particularly common in small animals and often result in high complication rates, especially in small breed dogs. Complications can include delayed union, nonunion, malunion, and growth deformities (Rudd, et al, 1992; Voss, et al., 2009). One report on bone plate fixation of 22 distal radius and ulna fractures in 18 small- and miniature-breed dogs reported a 54% complication rate, including 18% catastrophic complications (Larsen, et al, 1999). A separate internal fixation system study on the repair of long-bone fractures in cats and small dogs, reported an overall complication rate of 19.7% (Voss, et al, 2009). In the current study, 92% (140) of the radioulnar fractures occurred in small breed dogs, and of those, only five (3.6%) had reported postoperative complications, a low rate compared to previous studies. Of the reported five postoperative complications in small breed dogs, three (2.1%) were major complications and 2 (1.4%) were minor complications.

A study that may help explain this decreased complication rate in small-breed dogs using ALPS suggested that these dogs have decreased vascular density at the distal diaphyseal-metaphyseal junction compared with large breed dogs. This reduced vascularity was shown to correspond to the region associated with a poor prognosis for fracture healing in small breed dogs (Welch, et al, 1997). The authors suggest that these observations, combined with the previously discussed observation that the key to unimpaired fracture healing is preservation of the periosteal blood supply through minimal contact between the underlying bone and the ALPS plate resulted in the decreased complication rate, particularly in small breed dogs (Rittmann, et al, 1974; Gautier, et al,

1992; Fernández Dell'Oca, et al, 2001).

Although only 13 cases involved arthrodesis. The authors found the ALPS system particularly effective, warranting future investigation. The ALPS system did not result in bone density loss under the plate and rarely induced skin irritation, thereby negating the need for plate removal. In this study, only the first case had a plate removed following bone healing. The authors found ALPS of particular value treating fractures of the distal humerus, femur, tibia, bridging of comminuted fractures and, in particular, acetabular fractures. Because plate bending is easy to achieve and does not require precision, it can be readily applied to the acetabulum's unusual anatomical features. Of course, as stated previously, repeated contouring may weaken the plate.

# **CONCLUSIONS**

This retrospective study successfully establishes the usefulness of the ALPS plating system for the stabilization of a variety of fracture types, arthrodeses, and corrective osteotomies in small animal orthopedics, while simultaneously demonstrating a low postoperative complication rate.

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