Synthesis Pengo System plates for the treatment of long-bone diaphyseal fractures in dogs

C. Rahal¹, C. C. Otoni¹, O. C. M. Pereira-Júnior¹, A. L. L. Blum², L. C. Vulcano¹
¹School of Veterinary Medicine and Animal Science — São Paulo State University (UNESP), Botucatu, São Paulo, Brazil
²Faculty of Biologic Science and Health, Iguacu University, Rio de Janeiro, Brazil

Summary
A Brazilian orthopaedic company designed a stainless steel plate called Synthesis Pengo System (S.P.S.), which has one fixed and one changeable extremity. According to the assembly of the changeable extremity, it is possible to obtain dynamization or neutralization of the fracture site. Since the S.P.S. plate was developed for use in human patients, the aim of this study was to evaluate this system in long-bone diaphyseal fractures in dogs. Eight dogs with closed diaphyseal fractures of the femur (n = 1), radius and ulna (n = 5), and tibia (n = 2) were used. Patients were aged seven months to three years and weighed 18 to 31.2 kg. The S.P.S. plate was assembled with one fixed extremity and one changeable extremity in dynamization mode. The trail bar was positioned for synthesis modules with holes for cortical screws. The modules were positioned close to one another in two fractures and far away from the fracture site in the others. The bone healing occurred by external callus. Since motion at the fracture site determines the amount of callus required, the secondary bone healing that was observed in all of the cases indicated less rigid fixation of this system. A potential benefit of this system was a lesser interface contact with the bone since it was only done by trial bar. The major disadvantage was the prominence of the implant. It was possible to conclude that the S.P.S. plate appears to be a suitable method for the treatment of diaphyseal fractures in dogs.

Keywords
Fracture, treatment, plate, dogs, S.P.S.

Introduction
The treatment of long-bone diaphyseal fractures by internal fixation method most frequently utilizes intramedullary pins, interlocking nails, bone plates, or plate-rods (1, 2). Bone plates are considered to be one of the best implants as they have the potential to restore the stability of the fractured bone and allow early return of the limb function (1, 3, 4). In addition, they resist the axial loading, torsional, bending forces that act on fractured bone (4).

A large variety of bone plates are useful in small animal orthopaedics. Some plates were designed for human surgery and other ones especially for veterinary use, such as triple pelvic osteotomy plate, acetabular plate, veterinary T plate, cuttable plate, carpal arthrodesis plate (5-9). Age, body weight and behaviour of the patient, type and location of the fracture, size of bone and soft tissue condition are factors that must be considered in selecting a bone plate (1, 3).

Biomechanical and biological studies of the bone led to the concept of biological plating (10). The limited contact dynamic compression plate (LC-DCP), for example, was designed with grooves on the undersurface (2, 10, 11). These grooves minimize the interruption of the blood flow because the limited contact between the plate and bone allows a small bone bridge beneath the plate, and the stress is evenly distributed on the plate (1, 4, 10, 11).

Based on these concepts a Brazilian orthopaedic company designed a stainless steel plate called S.P.S. (12) for providing fracture alignment and stabilization with concomitant reduction of vascular impairment, and bone healing stimulation by axial motion across the fracture site. This device consists of a modular system that is composed of a trail bar and synthesis modules with lodging for the trail bar, and holes for cortical screws, blockade cortical screw, and dynamic screw. The S.P.S. plate has one fixed and one changeable extremity. According to the assembly of the changeable extremity, it is possible to obtain dynamization or neutralization of the fracture site. Also, the system may be used in neutralization mode and, at an opportune time during the treatment, the blockade screw may be removed. Since the S.P.S. plate was developed for use in human patients, the aim of this study was to evaluate this system in long-bone diaphyseal fractures in dogs.

Materials and methods
Animal population and surgical procedure

Eight dogs that had been admitted to the Unesp - Botucatu veterinary hospital with closed diaphyseal fractures of femur (n=1), radius and ulna (n=5), and tibia (n=2) were enrolled in a prospective study. The fractures were due to motor vehicle accidents (n=4), fall (n=1), horse kick (n=1) and unknown (n=2). Patients were aged seven months to three years and weighed 18 to 31.2 kg. All of the dogs were admitted with unilateral fractures apart from one dog (case #2) that had fractures in both forelimbs. Besides a femur fracture, case #6 had contralateral craniodorsal coxofemoral luxation. Two dogs (cases #4 and #8) had displacement of radius and ulna fractures previously plated.
After premedication with acepromazine\textsuperscript{a} (0.05 mg/kg IM) and morphine\textsuperscript{b} (0.5 mg/kg IM), general anaesthesia was induced with ketamine chlorhydrate\textsuperscript{c} (3 mg/kg IV), and diazepam\textsuperscript{d} (0.3 mg/kg IV), and maintained with isoflurane\textsuperscript{e}. In addition, epidural anaesthesia was performed with 2% lidocaine\textsuperscript{f} (1 ml per 4.5 kg), and morphine (0.1 mg/kg) in cases of femur or tibia fractures. All of the patients were prepared for aseptic surgery. Following the traditional approach to the bones (13), the S.P.S. plate was assembled with one fixed extremity and the changeable extremity in dynamization mode (Fig. 1). The trail bar was positioned for synthesis modules with holes for cortical screws. The modules were positioned close to each other (less than 2 mm) in two fractures and far away from the fracture site in the others. Coxaferoral luxation was treated by transarticular pinning maintained for 21 days. Only one forelimb in case #2 was treated with the S.P.S. system.

\textbf{Post-operative care}

Cephalexin\textsuperscript{g} (30 mg/kg, PO, q8h), was administered on the day of the surgery and for two to five days postoperatively. Carprofen\textsuperscript{h} (2.2 mg/kg, SC/PO, q12h), or meloxicam\textsuperscript{i} (0.2 mg/kg, SC/PO, q24h), were administered for five days postoperatively. Tramadol\textsuperscript{j} (2 mg/kg, PO, q8h) was administered for five days postoperatively and when required.

\textbf{Post-operative evaluations}

Postoperative evaluation included aspect of surgical wound, swelling of operated limb, and visual gait examination. Weight bearing after surgery was allowed as tolerated, but the owners were instructed to limit exercise. No external coaptation was used. Radiographic examinations were taken immediately after the surgical procedure and every month or every two weeks when close to bone healing. The S.P.S. system was removed once the bone had healed. Callus formation in the fractures was radiographically classified as: ‘none’, ‘minimal’, ‘moderate’ or ‘abundant’.

The limb functional results were classified as follows (14): ‘excellent’, normal function of the limb; ‘good’, functional use of the limb but partial weight-bearing after exercise; ‘fair’, full weight-bearing when standing, light to moderate lameness when walking slowly, but no weight-bearing running; ‘poor’, non-use.

\textbf{Results}

The prominence of the implant was the most common problem that was observed during the application of the system due to the difficulty of closing the skin incision over the implant. The surgical wounds healed without any complications. A mild swelling of the operated limb was observed for a few days. Case #6 showed ‘fair’ use of the operated limb for two months postoperatively. The other dogs showed ‘good’ (Cases #4, #8) to ‘excellent’ (Cases #1-3, #5, #7) use until plate removal.

Radiographic evaluation showed that bone healing occurred in most of the cases by moderate (n=3) or abundant external callus (n=3) (Figs. 2 and 3). Minimal callus (Fig. 4) was observed when modules were positioned close to one another (Table 1). Radius and ulna synostosis were detected in all of the cases at the fracture site. In addition, synostoses were observed in case no. 2 at the places where the screws engaged the ulna. Tibio-fibular synostosis at the fracture site occurred in case #8. Cases #5 and #7 had nonunion of the ulnar and fibular fractures, respectively. Plate loosening or breakage was not observed in any other cases except for loosening of three screws which was observed in case #4.

The bone layer development around the trail bar, especially when the modules were positioned far away from the fracture site, hinders the system removal. Case #6 developed a seroma after S.P.S. removal, but it was quickly resolved. No significant angular or rotational deviation.
S.P.S. plates for diaphyseal fractures

was seen. In all cases the bone could support loads without refracturing after S.P.S. plate removal and the dogs had normal limb function. Follow-up ranged from one to four months after S.P.S. plate removal.

Discussion and conclusion

The type of fracture healing is influenced by the amount of interfragmentary movement at the fracture site and the stability of the fixation method (2, 11, 15). Secondary bone healing observed in all cases in the present study indicated less rigid fixation of this system when it was used in dynamization mode. The dynamization of the S.P.S. occurs passively during weight-bearing due to

![Fig. 2 Craniocaudal radiographs of the fracture in case #6 treated with the S.P.S. plate with the modules positioned far away from the fracture site: a) before surgery, b) immediately after surgery, c) three and d) five months after surgery, and e) immediately after plate removal. Note the bone healing by abundant external callus.](image1)

![Fig. 3 Mediolateral radiographs of the radius and ulna fracture in the case #1 treated with S.P.S. plate with the modules positioned far away from the fracture site: a) before surgery, b) immediately after surgery, c) 2.5 months after surgery, and d) immediately after plate removal. Note the bone healing by moderate external callus.](image2)
As tibial osteotomy induced in dogs showed that early axial dynamization appeared to accelerate callus formation and remodeling (16). In addition, faster callus maturation was observed when a sliding plate, that was composed of two halves connected together to permit sliding of the one within the other, was compared to dynamic compression plate in the fixation of radius osteotomy in sheep. (17)

Although the S.P.S. plate had been assembled in dynamization mode in order to obtain a faster maturation of the callus, this was not true, especially in cases #5 and #8. The distance between the modules may have influenced the dynamization of the system in case #5, since the modules were assembled too close to one another. On the other hand, case #8 had been previously plated.

The external callus formation size in the present cases may be associated with fracture type, number of screws, and especially the sliding of the module (12). A study of tibial osteotomy induced in dogs showed that early axial dynamization appeared to accelerate callus formation and remodeling (16). In addition, faster callus maturation was observed when a sliding plate, that was composed of two halves connected together to permit sliding of the one within the other,

![Fig. 4 Mediolateral radiographs of the radius and ulna fracture in case #5 treated with the S.P.S. plate with the modules positioned close to each other: a) before surgery, b) immediately after surgery, c) eight months after surgery, and d) immediately after plate removal. Note the bone healing by minimal external callus.](image-url)

### Table 1 Clinical and radiographic data of eight dogs with diaphyseal fracture treated with the S.P.S. plate.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Dog signalment</th>
<th>Fracture description</th>
<th>Time between trauma and surgical procedure</th>
<th>Number of holes for cortical screws in proximal (P) and distal (D) modules</th>
<th>Callus formation classification</th>
<th>Time of bone healing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.4 kg 10-mo-old male Shar-Pei</td>
<td>distal third of the diaphysis; transverse of left radius and short oblique of left ulna</td>
<td>26 d</td>
<td>3P/2D</td>
<td>moderate</td>
<td>2.5 mo</td>
</tr>
<tr>
<td>2</td>
<td>26 kg 3-y-old female Boxer</td>
<td>middle third of the diaphysis; transverse of left radius and short oblique of left ulna, presence of one small bone fragment</td>
<td>2 d</td>
<td>4P/3D (modules close to each other)</td>
<td>minimal</td>
<td>4.5 mo</td>
</tr>
<tr>
<td>3</td>
<td>23.3 kg 7-mo-old male crossbred</td>
<td>distal third of the diaphysis; multifragmental of right radius and transverse of right ulna</td>
<td>9 d</td>
<td>4P/3D</td>
<td>abundant</td>
<td>1 mo</td>
</tr>
<tr>
<td>4</td>
<td>24.1 kg 2.8-y-old male crossbred</td>
<td>distal third of the diaphysis; transverse of left radius and ulna</td>
<td>1 mo (plated)</td>
<td>4P/2D</td>
<td>moderate</td>
<td>5 mo</td>
</tr>
<tr>
<td>5</td>
<td>31.2 kg 3-y-old male crossbred</td>
<td>middle third of the diaphysis; transverse of left radius and long oblique of left ulna</td>
<td>16 d</td>
<td>4P/4D (modules close to each other)</td>
<td>minimal</td>
<td>8 mo</td>
</tr>
<tr>
<td>6</td>
<td>18 kg 3-y-old female crossbred</td>
<td>distal third of the diaphysis; multifragmental of right femur</td>
<td>8 d</td>
<td>4P/3D</td>
<td>abundant</td>
<td>5 mo</td>
</tr>
<tr>
<td>7</td>
<td>27.8 kg 2-y-old male German Shepherd</td>
<td>middle third of the diaphysis; short oblique of right tibia and fibula</td>
<td>7 d</td>
<td>3P/3D</td>
<td>abundant</td>
<td>4 mo</td>
</tr>
<tr>
<td>8</td>
<td>26.6 kg 10-mo-old male crossbred</td>
<td>distal third of the diaphysis; transverse of left tibia and fibula</td>
<td>16 d (plated)</td>
<td>7P/4D</td>
<td>moderate</td>
<td>9.5 mo</td>
</tr>
</tbody>
</table>

*ddays, *mm*onths, *yy*ears.
the distance between the modules. The flexion and torsion tests that were carried out on the S.P.S. plate showed that the greater the number of module screws and the shorter the distance between the modules, the greater the stiffness and the lesser the deflection (18). Abundant or moderate callus was observed when the modules were positioned far away from the fracture site, which suggests more flexible fracture fixation.

A potential benefit of this system was a lesser interface contact with the bone since it was done by trail bar. Biological fracture treatment using limited contact plate has shown good clinical results without any significant complications in human patients (19, 20). In addition, the trail bar may be used for reconstruction and stabilization in multifragmental fractures (12) as used in cases #3 and #6.

The major disadvantage of the S.P.S. system was implant prominence. Since the device was developed for humans, only middle breed dogs were used and fractures were located at the diaphyses of long bones due to the difficulty of obtaining soft tissue coverage. Although soft tissue tension over the plate can lead to wound breakdown or soft tissue irritation, this was not observed in the present case series. In addition, the synthesis modules should not be contoured because the lodging in the trail bar can be lost. For this, special contoured plates were designed for the bone extremities (12). However, in the present study only the straight plate system was used.

In a study including 255 dogs and cats, the most common reason that was observed for plate removal was construct instability, followed by infection, soft tissue irritation, and chronic lameness (21). Except for the bone screw loosening in case #4, the other dogs only had plate removal due to the implant size. The bone screw loosening in case no. #4 was probably associated with poor bone quality due to the previous surgery. The design of both extremities of the trail bar hindered S.P.S. removal especially in fractures with abundant external callus due to bone layer around the trail. New instruments need to be developed in order to solve this problem.

It was possible to conclude that the S.P.S. system appears to be a suitable method for the treatment of diaphyseal fractures in dogs.

Acknowledgement
The authors would like to thank CNPq.

References
18. Yoneda A. Mechanical properties of an osteosynthesis system with relative stability. [Dissertation. Ribeirão Preto (SP): School of Medicine, University of São Paulo, Brazil; 2006.

Correspondence to:
Shiholo Canevese Rohal DV, MS, PhD
School of Veterinary Medicine and Animal Science
UNESP, Botucatu, Ribeirão Preto, São Paulo, Brazil
Phone: +55 14 381 16252, Fax: +55 14 381 54398
E-mail: shiholo@fmvz.unesp.br