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Advanced Locking Plate System (ALPS): rationale, biomechanics and early clinical use

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There has been a change of emphasis over the last few years with regard to the fixation of fractures, from a mechanical to a more biologic emphasis. The phrase often used has been “biological fracture fixation". The philosophic change also has been towards a more “flexible" fixation with less precise, indirect methods of fracture reduction. The importance of the blood supply to the fracture – and the preservation of the vasculature under the plate – is emphasized.

Porosity of bone under a plate was originally thought to be as a result of stress protection; however, the shape of the area of the porosity did not correlate with the pattern of unloading provided by the plate, and the transient nature of this phenomena did not equate with the continued “protection" (stress protection) assumed to be provided by the plate. Plates with reduced contact had less porosity, and plates with more flexibility (and thus greater bone contact) had greater temporary porosity. These findings were re-assessed to be the result of bone remodeling secondary to bone necrosis – as a result of the loss of the vascular supply, and not remodeling changes consistent with Wolff’s law. As a result, the emphasis turned to minimal plate contact with the bone so as to preserve the vascular supply under the plate. In addition, the more flexible fixation applied through indirect reduction was consistent with the strain theory (described by Perren) whereby small unstable gaps were avoided. Similarly, the indirect reduction methods provided a minimum of biologic interference at the time of implant application. This flexibility of fixation was attained by bridging the fracture gap at greater distances and decreasing the size and material properties of the implant [e.g., Dynamic Compression Plate (DCP®) to Low-Contact DCP (LC-DCP®) designs, and commercially pure Titanium (cpTi) implants; Synthes®; Davos SW].

To preserve the stability at the bone-implant interface the locked construct was developed [Point Contact Fixator (PC-Fix®; Synthes®; Davos SW)], which also minimized the risk of loosening and fretting abrasion possible at the screw-plate interface; the latter also was minimized by using more corrosive-resistant materials such as Ti. The issues of premature push-out of the screw in the plate, or alternatively jamming of the locked screws (“cold-welding") were addressed by changing from a Morse taper (PC-Fix®) to a conical thread screw connection [e.g., Less Invasive Stabilization System (LISS®), Locking Compression Plate (LCP®); Synthes®; Davos SW]. Finally, the local resistance to infection has been shown to be affected by the preservation of the vascularity under the plate (DCP® vs. PC-Fix® in a rabbit model was shown to be 1:750).

The biomechanical properties of these locking implants were first described using the PC-Fix®. At this time, the biomechanics of conventional plating was described as a mixed mode transfer between the bone segments and implants, whereby the bending moments and transverse forces are balanced by the reactive forces created by compression in areas of contact, and the torsional and axial forces transferred by the screws directly or by screw-dependant friction between the implant and bone. In this usage, contact between the implant and bone is required. In contrast, with the PC-Fix® the biomechanics was described as a screw-only transfer as a result of locking the head of the screw into the plate (an “internal fixator”), whereby there is a transfer of all moments between the screw and the implant. In addition to the decreased trauma to the bone (vascular supply under the plate due to the minimal, or point contact) as a result of the plate application, there also was a reduction of the trauma to the endosteal vascularity as a result of placing monocortical screws. The latter could be applied as a result of fixed angle construct at this junction – provided that the bone could with-
stand implant yielding loads (re: adequate
cortical purchase), which limits their ap-
plication to the diaphysis.
The object of this preliminary device was to be able to contour the implant and then apply monocortical screw fixation such that the PC-Fix® retained the versatility of the conventional plating systems, while eliminating their major drawback of direct bone contact.
In vivo experimental data showed improved bone healing thought to be as a result of the reduction of implant related damage to the bone. Although the majority of the articles published since this time have emphasized the mechanical properties of these implants as compared to the more conventional systems, it was the preservation of the blood supply that was the initiating factor in their development. Development of these ideas over time (Synthes) moved away from the strict idea of a point fixator, due to the assumption that the technological changes (compression plating to point-contact internal fixation) might be too large a change for the average surgeon, to a combination of the two ideas. In the latter, the ideas behind limited contact plate application (LC-DCP®), which was a compromise of the area of bone surface subjected to the pressures (2000-3000 N) that result from screws that compress the plate to the bone with the addition of fixed angle locking constructs the spherical gliding principle (DCU® of the plate hole) was abandoned (LISS® plates). Later the “combi-hole” was introduced (LC P®) that allowed both applications in a single implant. This combination, however, has diametrically opposed functions: compression vs. pure splinting: the conventional plate screw closes the gap between the plate and bone while locking screws keep the plate away from the bone surface. This combined approach does not take full advantage of either technique, which led to general recommendations to avoid using the two techniques within the same bone fragment (i.e., the combination of the two techniques within the same bone fragment should be the exception rather than the rule). A number of plate/screw designs have been produced that have attempted to include all of the above parameters.
The original design, and proof of concept of the PC-Fix®, both experimentally and clinically, was developed at the AO Research Institute by Slobodan Tepic in the 1990s. The design concept returns to the philosophy of point contact as opposed to minimal contact, thus not being totally dependent on the splinting principle of the internal fixator while retaining the ability to use compression (interfragmentary compression when deemed appropriate), and returning to a Ti implant, both of which were believed to enhance the biological properties to the fixation. The biologic benefits proposed were: reduced damage to the blood supply, and thus increased resistance to infection and improved bone healing. Because the ALPS plates minimize contact with the periosteum, the surgical insult (iatrogenic trauma) to the periosteum is reduced preserving bone perfusion. Endosteal vascularity also is protected by use of monocortical screw fixation. This preservation of the vascularity has been proposed to reduce the potential for infection and accelerate healing as compared to conventional bone plates. In addition, since the plates are manufactured from titanium, there is improved biocompatibility with the tissues and a further absence of fretting corrosion.
The technical features of the ALPS system include: biocompatibility due to the materials used (cpTi and Ti alloy), the ability to use both standard and locking screws in all plate holes, an optimal plate geometry for increased strength, improved plate contouring in 3-dimensions due to the ability to perform both in-plane and out-of-plane bending, and thus greater ability to utilize the plates in varying locations, and finally, specially designed instrumentation that allows bending (in either plane) while preserving the screw-holes such that the locking mechanism is not adversely impacted. A variety of sizing is available to enable their use in all sizes of dogs and cats.
The principle of application remains accurate contouring to the bone surface and compression of the plate to bone; however, due to the geometry of the plate, the contact area between the plate and bone is minimized. The advantage of this approach is greater construct strength in that plate contact with bone minimizes the shear loads to the screws and improves the torsional resistance to failure.

The mechanical strength of these plates was designed to be comparable to similar standard plates used for fracture fixation. The manufactured construct similarities are between the 3.5-mm Ti LC-DCP and the ALPS 10. Relative sizing was adjusted from this point of reference. Original plate availability was the ALPS 5, 8 and 10. The numerical designation refers to the width (in mm) of the plate. The ALPS plates use 1.5-mm, 2.4-mm and 2.7-mm standard cortical screws, and 2.4-mm, 3.2-mm and 4.0-mm locking screws, respectively, in the ALPS 5, 8 and 10. The screw sizing is designed such that the standard cortical screw may be removed and replaced in the same hole with the larger locking screw. It also should be noted that insertion of a locking screw also compresses the plate to the bone within the final seating of the screw into the locking taper of the plate. An ALPS 11 also is available (2009) that uses the same screws as the ALPS 10; more recently an ALPS 6.5 has been introduced (2010) that uses the same screws as the ALPS 5.

Plate application is performed after reduction is obtained (either anatomic or non-anatomic, re: direct or indirect techniques). The plate is contoured to match the bone surface and secured in the main proximal and distal bone fragments with a single standard screw (thus pressing the plate to the bone surface). The remaining screws placed are locking screws. These screws are placed using a drill guide that ensures their placement perpendicular to the plate (fixed angle construct). These screws also have the option of being placed either mono- or bi-cortically in areas where bone yield loads are lower, e.g., metaphysis or epiphysis. The preference is to place them mono-cortically, minimizing drilling into the endosteal cavity (preserving the endosteal blood supply); thus, less trauma is encountered with bilateral or orthogonal plate fixation when compared to any of the limited contact plates that utilize bicortical screw fixation. Generally, only 3-4 screws are placed into each major bone fragment. The original standard screws can be left in situ or replaced with locking screws (outside diameter of the standard screws = core diameter of the locking screws).
As noted, additional construct strength may be obtained by placing a second opposite or orthogonal plate. This concept is most useful in periarticular fractures where minimal screw purchase is obtained due to the limited bone volume of the metaphyseal/epiphyseal bone fragment(s) - and without expense to the biology. Although locking plates have been used in numerous locales since their introduction, their definitive recommended use in humans remains periarticular fractures, periprosthetic fractures and osteoporotic bone. The indications in veterinary surgery currently are evolving, but it appears that these recommendations are being borne out.

REFERENCES