

Innovations 2019





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- Benedikt Braun

Editorial

Dear reader,

Welcome to the 2019 edition of the Innovations magazine of the AO Technical Commission (AO TC) delivered to you with a new look incorporating the novel AO Foundation brand. In addition to providing the Innovations magazine as hardcopy and in electronic format, we offer you for the first time the opportunity of accessing a fully digital version via your preferred mobile electronic device.

As usual, the aim of the Innovations magazine is to inform its readers of the newest medical devices and techniques in trauma, spine, craniomaxillofacial (CMF), and veterinary surgery that have been developed by our AO TC surgeons in collaboration with our main industrial partner, DePuy Synthes (DPS). Also included are selected articles from the AO Research Institute Davos, AO Clinical Investigation and Documentation, and the AO Education Institute.

In our lead article we are honored to introduce the newly released Reamer Irrigator Aspirator System (RIA 2). This completely redesigned and improved system offers either an efficient method for clearing the intramedullary cavity of debris or to obtain large volumes of autogenous bone graft. It reduces complication rates compared with iliac crest bone graft harvesting, decreases pulmonary insult and thermal necrosis in comparison to standard reaming. The RIA Task Force guided product improvement: RIA 2 offers various improvements and opens new applications. The inclusion of smaller reamer head sizes in the RIA 2 system allows access to previously limited anatomies. Apart from applications in trauma procedures, bone graft harvested with RIA 2 could be used in spinal fusion surgery. Sterile packed procedure kits improve efficiency by decreasing hospital inventory and preoperative complexity.

The trauma-related part of this magazine comprises the new Universal Small Fragment System. It was designed by a dedicated Task Force (formed by selected members of the following Expert Groups: Hand, Foot and Ankle, Upper Extremity, Lower Extremity) to simplify small fragment procedures. The innovative concept allows existing and future 2.7 mm/3.5 mm implants to be supported with only one basic set of instruments. This distinctly reduces operating room complexity and speeds up the operation workflow. The new set composition was used to optimize several instruments which are highlighted in the article.

Additionally, the Foot and Ankle Expert Group was involved in the development of three new products to improve foot surgery: Partially Threaded Cannulated Compression Headless Screws, Quick Insertion Screws, and Y-shaped Nitinol staples as continuous compression implants for hammer toe treatment. Finally, the AO Technical Commission Trauma approved new MatrixRIB self-drilling screws and screw guides developed by the Thorax Surgery Expert Group for improved OR efficiency, more reliable screw insertion, and consistent screw locking in thorax surgery.

In the spine section an overview is given of PROTI 360°, a family of integrated titanium-coated PEEK cages that promote spinal fusion in patients with degenerative disc disease. These implants have design features that provide primary mechanical stability to the spine and promote faster and long-lasting biological fixation with the vertebral end plates. The major spine innovation is the Symphony Occipito-Cervico-Thoracic System which has been developed as an enhanced set of instruments and implants for posterior fixation of the upper (occipito-thoracic) spine.

The AO Technical Commission CMF is pleased that the new CMF distractor has been approved and launched. The device is used for lengthening or bone transport to correct congenital deficiencies or posttraumatic defects in the mandible, the midface, or the cranium in pediatric and adult patients.

The showcase of AO TC Innovations concludes with a report from the Veterinary Expert Group on the use of the Human LCP Distal Femoral Plate for veterinary applications.

During the annual Davos courses, the AO Technical Commission organizes Meet the Experts Sessions to update course participants on recent innovations, new products, and new surgical techniques which have been approved by the AO TC. Some of the presentations address medical devices which have not yet been introduced into the AO Foundation course programs due to their novelty. Therefore, the Meet the Experts events are the ideal forum for course attendees to acquaint themselves on the forefront of innovation. To reach a broad audience all sessions are recorded and available for later online viewing via the AO Video hub. Furthermore, most presentations are streamed via the Internet so that surgeons worldwide can join. This magazine offers a summary of all Meet the Experts Sessions held in 2018. Do check out the Meet the Experts Session topics for the 2019 Davos courses on the back cover of this magazine.

An essential part of the AO TC work is dedicated to analyzing and documenting the performance of implants, instruments, and surgical techniques which have been approved by the AO Technical Commission. Long-term efficacy and safety have always been the main the AO TC objectives in product development. In 2020 interesting times are ahead of us in the medical device field. By May 26, 2020, all medical device companies must demonstrate and maintain compliance in accordance with the EU Medical Device Regulations (MDR). These regulations require that companies must provide more evidence of safety and performance of their products. In this regard the AO Technical Commission is well prepared to support our development partners. We will continue our strategy of fostering evidence generation for products which are developed in the AO TC. The AO Technical Commission will carefully monitor the MDR effects in order to adapt and to react as needed.

In addition to running pre-clinical and clinical studies, the AO TC organizes Experts Symposia with the purpose of exploring potential disadvantages or shortcomings of current clinical solutions. These findings are used to improve existing devices and treatment applications as well as to kick off new development projects within the AO Technical Commission in closed collaboration with the industrial partner(s). The symposia are held in the US, Latin America, Europe, and Asia-Pacific and intend to collect feedback from various regions by considering their different economic situations and healthcare demands. The AO TC Experts Symposia article explains how these events are run and what were the outcomes of the most recently held events.

We want to highlight one of the clinical problems that our AO TC surgeons are working on with the goal of improving patient care: A main topic in the Lower Extremity Expert Group is treatment of complex distal femoral fractures in osteoporotic bone. These are challenging fractures where currently available implants and surgical techniques are not enough, as expressed by considerably high complication rates. Discussions at our AO TC Experts Symposia have confirmed the need for better solutions in this area. In the article on distal femoral fracture fixation, an overview is provided on the complexity of the clinical problem and how it might be addressed with innovative double fixation constructs.

The main industrial partner for the AO Technical Commission is DPS. The collaboration between AO TC and DPS has been very successful and productive to date, with more than 450

new products launched and approved by the AO Technical Commission between 1995 and 2019 alone. This also underlines the creativity of our AO TC surgeons and their innovative power to guide development projects from the scratch until introduction into clinical practice. However, there are more ideas for improving patient treatment than can be realized in our collaboration with our industrial partner. If the industrial partner is not interested in developing certain new products, AO TC has the possibility to collaborate with third parties on development projects. It is therefore our responsibility to use this option by accurately defining development projects and by screening potential industry partners for later realization. The article on new partnerships for the AO Technical Commission in this magazine explains how the processes for third party collaborations are defined, and where we currently stand.

This year, 2019, was a thorough introspective review of the AO TC organizational structure with the goal to optimize it in terms of innovation mining, collaboration with industry partners, and development activities given the expectation of our surgeon network. The primary goal of the AO TC is to offer surgeons—the motor of innovation and permanent improvement—a platform to work effectively to fulfill the AO Foundation's mission. After several strategic meetings with all our stakeholders, the AO TC decided to implement a new group structure for our AO TC surgeons in 2020. The main change is how the groups of the AO Technical Commission Trauma are organized. Refer to the article on the new AO TC group structure to familiarize yourself with the changes and the expected improvements. The AO Technical Commission is confident that the new structure means a benefit for all stakeholders to foster innovation.

We are glad to inform you that two new Task Forces have already started their work under the umbrella of the AO Technical Commission in 2019: The Internal Distraction Task Force and the Smart Digital Solutions Task Force. Both Task Forces rely on the strengths of interdisciplinary knowledge exchange. In this Innovations magazine we describe why these Task Forces were formed and what their goals are. The AO TC perceives a high potential in the creation of flexible and agile Task Forces to address specific clinical problems and push innovation forward.

We hope you enjoy reading the 2019 edition of the Innovations magazine. Do not hesitate to contact the AO Technical Commission at any time, for we welcome your feedback and involvement.

Yours sincerely,



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RIA 2 System: new generation reamer-irrigator-aspirator

The RIA 2 (Fig 1) is the next generation reamer-irrigator-aspirator device. Intended for use in adults and adolescents, its indications are to clear the medullary canal of bone marrow and debris, enlarge the medullary canal for the insertion of an intramedullary implant or prosthesis, to harvest morselized autogenous bone and bone marrow for bone grafting purposes, and to remove infected and necrotic bone and tissue from the medullary canal in the treatment of osteomyelitis.

The RIA 2 system consists of a powered reamer with exchangeable cutter heads ranging from 10 mm to 18 mm in 0.5 mm increments (Fig 2). The reamer has integrated tubes for delivery of irrigation saline, and aspiration of tissue from the intramedullary cavity. The aspiration tube can be connected to a closed bottom filter, allowing the collection of bone graft material (Fig 2). The reamer heads, tube assemblies, drive shaft seals, and graft filters are designed for single-patient use only.

Improved features of RIA 2 compared to RIA 1

- Exchangeable reamer heads allow for intraoperative flexibility
- Smaller reamer head sizes allow improved access to previously limited anatomies, such as the tibia
- Sterile packed procedure kits improve efficiency by decreasing hospital inventory and preoperative complexity
- Designed for simplified assembly and handling

Advantages of RIA 2

RIA 2 offers many advantages over conventional reaming and addresses several unmet clinical needs, as outlined below.

Efficient harvest of autograft

Bone grafting is a common adjunct in the management of many traumatic and reconstructive orthopedic procedures [1]. Approximately 500,000 bone graft harvesting procedures are undertaken every year in the United States [1].

Autogenous bone is considered to be the “gold standard” bone grafting material [2]. It is osteoinductive (containing bone morphogenetic proteins [BMPs] and other growth factors), osteogenic (due to the presence of osteoprogenitor cells) and osteoconductive (providing a scaffold) [3]. Autogenous bone is widely used for augmentation and acceleration of bone regeneration, and for the restoration of bony defects [2].

To date, the most common harvest site for autogenous bone graft is the iliac crest [2], but this necessitates an additional surgical procedure with well-documented complications and discomfort for the patient. Complication rates of up to 30% have been reported from iliac crest bone grafts [4]. Potential complications include infection, hematoma/seroma, fracture, nerve and vascular injuries, chronic donor site pain, hernias, unsightly scars, and poor cosmetic outcome [2]. These complications are associated with substantial costs, including prolonged hospitalization.

The RIA system provides an efficient method for obtaining large volumes of autogenous bone graft. Reaming a medullary canal using the RIA device is clinically proven to have lower complication rates and reduced donor site pain compared to iliac crest bone graft (ICBG).

The RIA system harvests 38–48 cc mean volume of graft per procedure [4–6]. In a comparative study conducted by Dawson et al, the RIA system produced 17 cc more graft on average than anterior ICBG [5]. Harvesting bone graft with RIA reduces the rate of complications from 19.4% to 6.0% [2] and significantly reduces donor site pain ($P < .004$) compared to ICBG [5]. Union rates and time to union are better [7, 8] or comparable [5] comparing the RIA system to ICBG. The RIA system produces bone graft with concentrations of viable cells and growth factors better or consistent with ICBG [9]. The use of RIA autograft allows hospitals to realize cost savings, as it is less expensive than both demineralized bone matrix (DBM) allograft and bone morphogenetic protein (per/10 cc) [5]. Furthermore, studies comparing bone healing in patients treated with autograft or allograft have shown a comparable or better time to union and union rates with autograft [10].

Fewer complications during reaming

Despite the widespread acceptance of standard reaming, there are well-documented complications and adverse events associated with its clinical use. The incidence of heterotopic ossification with the use of standard reaming has been reported to be as high as 35.7% [11]. Further complications include fat embolism syndrome, adult respiratory distress syndrome, sudden intraoperative deaths and aseptic cortical thermal necrosis [12]. Additionally, the use of standard reaming for the insertions of nails for impending and pathological fractures secondary to metastatic cancer may additionally cause systemic embolization of malignant cells, potentially increasing the rate of distant metastasis [13].

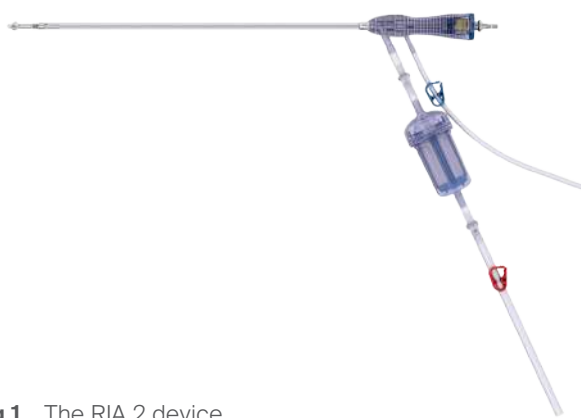


Fig 1 The RIA 2 device.

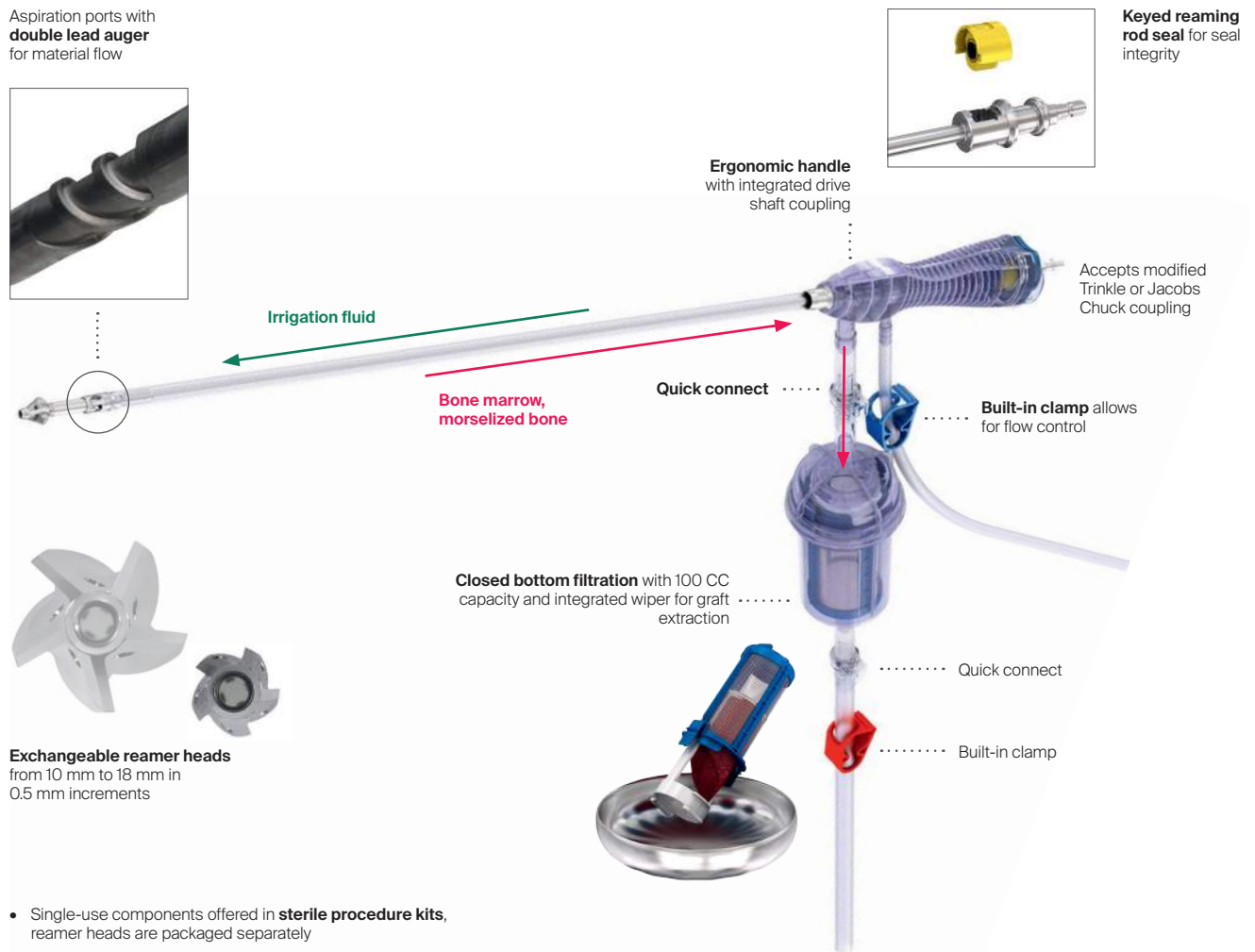


Fig 2 Components of the RIA 2 system.

RIA offers a solution to many of the complications associated with standard reaming. Reaming with RIA has been reported to reduce the risk of heterotopic ossification: incidences of heterotopic ossification for the RIA system have been reported to be between 0 and 0.86% [2, 14]. The RIA system significantly reduces the total emboli score during reaming ($P < .05$) and nail insertion ($P < .05$) compared to standard reaming [15], thereby decreasing pulmonary insult. Furthermore, RIA has been demonstrated to reduce heat generation compared to standard reaming and may therefore reduce the risk of thermal necrosis [16]. By reducing such complications, RIA offers cost savings for hospitals and better patient outcomes.

Management of infection

Medullary cavity infection can delay healing of long bones and often requires surgery and prolonged medical treatment, resulting in increased morbidity for the patient, and often a poor functional result. While standard reaming of the medullary canal for the debridement of the infected cavity has been shown to be a beneficial method of infection control [17], it can be associated with an increased risk of thermal necrosis, a lack of control of infected bone particles, and the risk of infected material propagation [18]. The RIA system is an effective adjunct in the treatment of long-bone osteomyelitis [17]. A study conducted by Zalavras et al [19] demonstrated no recurrence of osteomyelitis of the tibia and femur when the RIA system was used for intramedullary canal debridement.

Reduced procedure time

Use of RIA may provide economic benefits to hospitals by way of reduced length of hospital stay and operating time. Patients with bone graft harvested via the RIA system have a shorter duration of operation ($P < .0001$) and length of stay ($P < .0001$) compared to patients who had autogenous anterior ICBG [7]. Additionally, the RIA system significantly increases the chances that patients leave on the day of surgery versus patients treated with ICBG [20].

Improved patient outcomes

Although most fractures heal uneventfully, nonunions remain a relatively common problem [5]. Although ICBG has long been the gold standard source of autograft used in the treatment of nonunions, several studies have reported better or comparable union rates and time to union with the RIA system vs ICBG [5–8].

Bone graft harvesting can result in complications, such as residual pain and nerve injury. Chronic pain is the most common complication with ICBG [2]. Studies comparing pain after bone graft harvesting have shown that patients treated with RIA had significantly lower pain scores than those patients treated with ICBG [5, 21], and a lower incidence of chronic pain at follow-up [8].

Summary

RIA 2 provides an efficient method for clearing the intramedullary cavity of debris and obtaining large volumes of autogenous bone graft. It reduces complication rates compared to ICBG harvesting, decreases pulmonary insult and thermal necrosis in comparison to standard reaming, and offers cost-saving opportunities for hospitals.

The development process for RIA 2

Convened in 2013, the RIA Task Force (RIATF) is a dynamic group of nine internationally renowned trauma and orthopedic surgeons, tasked with providing expert clinical guidance throughout the development of RIA 2.

The Task Force has been active in testing the next generation RIA prototypes and guiding technical improvements from a global clinical standpoint. Medical members of the RIATF have undertaken testing of the device in anatomy laboratories (Fig 3) in Davos

(December 2015) and Solothurn (May 2016), Switzerland; West Chester, Pennsylvania (October 2016, April 2017, and April 2018), and in Orlando, Florida (October 2018), USA. These usability laboratories are a critical part of the development process.

The RIATF is at the forefront of evidence creation relating to indications for RIA usage, complications associated with RIA usage, and biomechanical considerations during reaming. Past and present medical members of the RIATF are heading up several research studies focusing on the RIA system:

- Retrospective clinical study regarding RIA indications and complications (Christoph Müller)
- Biomechanical investigation of the influence of the reaming diameter (RIA) on failure loads of human femora [22] (Michael Raschke)
- Biological properties of harvest material [9] (Ingo Marzi)
- Animal polytrauma study to establish local and systemic safety of RIA 2 (Hans-Christoph Pape).



Fig 3a–d Prototype testing of RIA 2.

Additionally, the RIA Task Force seeks to educate orthopedic surgeons throughout the world in conjunction with AO Trauma, to facilitate successful use of the new device. The RIATF members have produced educational material (Frequently Asked Questions about the Reamer Irrigator Aspirator system and Annotated Reamer Irrigator Aspirator Abstracts, Fig 4), which will feature in the curricula of AO Courses on IM nailing, infection, and orthogeriatrics.

A webinar entitled “Using the RIA without complications” was presented by Prof Peter Giannoudis in Switzerland in September 2016. A webcast highlighting the new features of RIA 2 will be offered in 2020. A video demonstrating complication-free use of the RIA device both in bone models and in the operating room will be available later in 2019.

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RIA-FAQ

Frequently Asked Questions about the Reamer Irrigator Aspirator system

What are the approved indications for the use of the Reamer Irrigator Aspirator system (RIA)?
Indications for the use of RIA (Fig 1) are:

- To clear the medullary canal of bone marrow and reaming debris
- To effectively size the medullary canal for the acceptance of an intramedullary implant or prosthesis
- To harvest freely microvial autogenous bone and bone marrow for any surgical procedures requiring bone grafts to facilitate fusion and/or fill bone defects
- To remove infected and necrotic bone and tissue from the intramedullary canal in the treatment of osteomyelitis.

What other uses of RIA are described in the literature?
The use of RIA has also been reported in the management of impending pathologic fractures [1]. When reaming an intact femur, many surgeons have recommended venting the bone distally in order to minimize the intramedullary pressure production during reaming. With the use of RIA, distal venting may not be necessary since the device is designed to minimize the build-up of pressure during reaming.

Can I use the RIA in patients with osteomyelitis?
Yes, the RIA system can be used and may provide some advantage in the debulking of intramedullary infection due to the irrigation and aspiration of the intramedullary cavity [2–4].

Can I use the RIA in oncology patients?
Yes, RIA can be used in oncology patients. The use of RIA may provide some advantage in depressing embolization of intramedullary contents [1].

What materials, in addition to the RIA assembly, are required for the use of RIA?
Additionally required materials include:

- 1–2 liter container of irrigation fluid (eg, isotonic 0.9% NaCl)
- Irrigation tubing set (“T”-type, crotch bladder, crotchless)
- 2–5 liter suction container. Because the system will not work properly if the suction container becomes completely filled, it is therefore helpful to use a large suction canister. It is also important to have an adequate level of suction. Ideally, the RIA suction tubing should be connected to its own dedicated suction device. If other items are attached to the suction source, these should be closed off during the use of RIA to achieve optimal suction
- Aspiration/suction tubing (minimum 6 mm or 1/2 inch diameter)
- If you wish to harvest intramedullary material for bone graft, the graft filter for RIA (Item 352.2295) is also required.

What type of power is required for the RIA?
A power drill that provides 3.5–4.5 Nm of torque and 700–800 RPM is recommended.



Fig 1a–b The Reamer Irrigator Aspirator system (a) with attached power tool (b)

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RIA

Annotated Reamer Irrigator Aspirator Abstracts

The following selection of research papers can be found in this edition of *Injury*:

Giannoudis PV, Suk M, Page HC (editors):
The Reamer Irrigator Aspirator (RIA) System: Applications and results of treatment.
Injury. 2010 Nov; 41 Supp 2:S1–S98.

Giannoudis PV, Suk M, Page HC: The journey just started but what's the future hold? *Injury*. 2010; 41 Supp 2:S1–S5.

Introduction to supplement
In the introduction to the supplement on RIA, the editors note that the use of RIA has just started in the scientific community and they pose the question, “what does the future hold?”

Pfeifer R, Sellert R, Page HC: The biology of intramedullary reaming. *Injury*. 2010; 41 Supp 2:S4–S8.

Annotated abstract
This paper reviews the local biologic and physiologic effects of intramedullary reaming of long bones. The consequences for vascularity, pathophysiology of intramedullary pressure generation, and temperature increase are reviewed. Techniques for avoiding local and systemic complications are summarized.

Husselby EE, Lyberg T, Opdahl H, et al: Intravasation of bone marrow content. Can its magnitude and effects be modulated by low pressure reaming in a porcine model? *Injury*. 2010; 41 Supp 2:S9–S15.

Annotated abstract
Investigators examined the impact of RIA with a traditional reaming system on the intramedullary pressure (IMP) and the intravasation of bone marrow contents in 20 young Norwegian landrace pigs that were exposed to femoral intramedullary reaming.

The investigators found a strong correlation between increased IMP and increased coagulation and cytokine responses. The number of emboli was not significantly correlated to IMP, but was strongly correlated to changes in the coagulation and cytokine responses. The investigators indicated that this study confirms the connection between increased IMP, increased coagulation activation, and the magnitude of pulmonary emboli in a model evaluating the effects of intramedullary reaming of intact pig femora. Lowering of IMP during reaming, as obtained with RIA, reduced the magnitude of and the effects of bone marrow extravasation.

Lowering AT, Elliott JE, Beasley KM, et al: Pulmonary pathways and mechanisms regulating transpulmonary shunting into the general circulation: An update. *Injury*. 2010; 41 Supp 2:S16–S23.

Annotated abstract
This paper reviews the pathology of embolic insult following routine surgical procedures. One pathway for emboli to bypass the pulmonary microcirculatory sieve is through an intracardiac shunt such as an atrial septal defect or patent foramen ovale. In the absence of intracardiac shunts, another pathway is an indetectable large diameter intrapulmonary arteriovenous anastomoses. These anastomoses are closed at rest but can open during hyperdynamic conditions such as exercise in more than 90% of healthy humans. The present evidence demonstrates the existence of indetectable intrapulmonary arteriovenous anastomoses in healthy humans that are modulated by exercise, oxygen tension, and body positioning. The authors identify several clinical conditions associated with both arterial hypoxemia and an increased risk for embolic events. They also suggest precautionary measures that should be taken during interventions to keep intrapulmonary arteriovenous anastomoses closed in order to prevent or reduce the incidence of prebascular embolism.

Green J: History and development of suction-irrigation reaming. *Injury*. 2010; 41 Supp 2:S24–S31.

Annotated abstract
This paper reviews the development of a reamer system that integrates suction and irrigation into its design. In addition, reaming the intramedullary canal using this negative pressure system provides a unique source of biological material that is being increasingly investigated. The author indicates that the cells and tissue harvested with this device have tremendous therapeutic promise.

Fig 4a–b Educational material developed by medical members of the RIA Task Force.

The RIA Task Force Chair, Hans-Christoph Pape, says: “Advances in the surgical treatment of trauma have generated the need for more sophisticated RIA instrumentation. The new generation RIA device will allow surgeons to continue to improve outcomes in complex cases where patients require reaming and bone grafting”.

What next for the RIATF?

Medical members of the RIATF recently received funding approval for a new international, multicenter, prospective registry to investigate treatment options and their outcomes on long-bone defects. The study aims to recruit 600 cases during a 3-year enrollment period starting in the fourth quarter of 2019.

Exploratory analyses will be conducted to investigate relationships between the different types (categories) of bone defects, treatment methods, complications, and outcomes.

While the RIA Task Force (Fig 5) will be disbanded at the end of 2019 once RIA 2 is launched, selected members will offer expert clinical guidance for a new project to develop and to validate a long-bone graft cage. The graft cage is a biodegradable device to hold bone graft tissue in situ for the duration of healing of long-bone defects. Animal studies show better healing in long-bone defects treated with graft cage versus existing methods, and the aim is to extend this benefit to the clinical setting.



Fig 5a-b

- a** Members of the RIA Task Force following a RIA 2 usability laboratory in Orlando, Florida, 2018.
- b** Members of the RIA Task Force in Davos, Switzerland, 2018.

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Universal Small Fragment System

Clinical problems and challenges

Over time, the collaboration of the AO Technical Commission (AO TC) and DePuy Synthes has resulted in the development of numerous implants and instruments to address specific clinical problems. Surgeons can choose from a large variety of standard and anatomically precontoured plates with instruments for application of conventional screws, locking screws, and variable angle locking screws. The sequential introduction of plating and screw technologies has led to a total number of more than 20 DePuy Synthes sets to support small fragment procedures involving shoulder, clavicle, elbow, tibia, and fibula anatomies. Surgical treatment of small bone trauma occurs worldwide about every 18 seconds and represents about 25% of all bone trauma cases. The number of sets and the material volume for these frequently performed procedures place a significant burden on hospital resources in terms of reprocessing, storing, and transporting the equipment. It is also difficult for surgical teams to remain proficient in using so many different systems. Training staff to use such a large portfolio of osteosynthesis material is also a considerable cost factor for the healthcare provider. In addition to this, the large number of parts in the sets entails an increased risk for missing and/or broken instruments. Realizing this burden on all involved stakeholders resulted in the clear need to provide a simplified solution for small bone procedures which improves ease of use and hospital efficiency.

Approach to define a solution

Since one of the goals of this improvement initiative was to ensure universal instrument use across small bone anatomy, the AO Technical Commission formed a dedicated Task Force by involving medical members of several different AO TC Expert Groups: Upper Extremity, Lower Extremity, Hand and Foot. The Task Force members were from different continents, which facilitated potential regional aspects and demands. Coming

up with a new set configuration for small bone procedures was an ideal opportunity to review and to optimize individual instruments in terms of surgical steps required and streamlined workflow. Efforts were made to improve instrument ergonomics as well as cleaning and sterilization processes.

New solution

From a conceptional viewpoint, the new Universal Small Fragment (USF) System was designed to perform more procedures with less equipment. This is markedly influenced by how the system is provided to the surgeon depending on the intended procedure. The USF System consists of two components: (1) Core Set and (2) Modular Anatomic Implant Trays. The Core Set (Fig 1) is composed of a USF Insertion Tray, a USF Standard Plate Tray (Stainless Steel and Titanium options), an Auxiliary Tray, a USF Reduction Tray and a USF Screw Rack (Stainless Steel and Titanium options) which can be customized.

Eight streamlined anatomical implant trays (Elbow Implant Set, Shoulder/Clavicle Implant Set, VA LCP® Proximal Tibia Implant Set, LCP® Proximal Tibia Implant Set, VA LCP® Distal Tibia Implant Set, LCP® Distal Tibia Implant Set, VA LCP® Distal Fibula Implant Set, LCP® Distal Fibula Implant Set) which include most implants (to cover about 80% of the procedures; remaining implant portfolio is provided sterile packed) can be coupled with the core set to support specific small bone procedures (Fig 2).

All upper extremity trays as well as the LCP® lower extremity trays are available in stainless steel and titanium options. The VA LCP® lower extremity trays are only provided in stainless steel. The modular concept of the USF System offers the flexibility to build different system configurations to meet the surgeon's needs. This approach also helps to reduce the weight of the required sets to be transferred to the operating room.

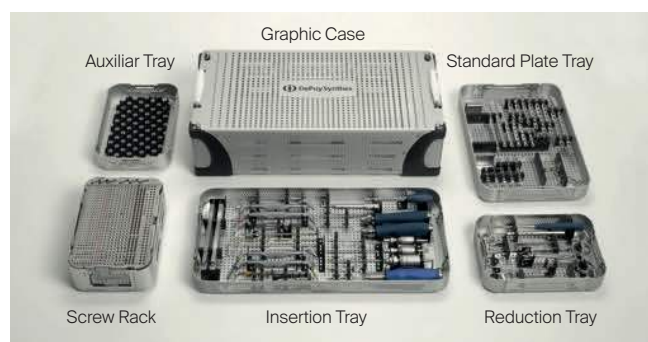


Fig 1 USF System Core Set: Insertion Tray (instruments for 2.7 mm and 3.5 mm nonlocking, locking and variable angle locking implants), Standard Plate Tray (2.7 mm and 3.5 mm locking implants for multi-anatomy use), Reduction Tray (features common reduction instruments), Auxiliary Tray (for customization) and Screw Rack (allows customization by screw type). There is also a reduced Core Set option which comprises an Insertion Tray without drill bits, an Auxiliary Tray, and a Reduction Tray.



Fig 2 USF System Core Set and eight streamlined anatomical implant trays.

The USF System Core Set can support all 2.7 mm/3.5 mm non-locking, locking, and variable angle locking plate technologies. It comprises, in addition to existing and well-established instruments, several new and optimized instruments for intuitive use as described in the following.

Guides for drilling

All instruments for preparing screw holes have a color-coded labeling to indicate their proper use depending on the screw size:

- Orange: for 2.7 mm screws
- Black: for 3.5 mm screws

The new 2.7 mm and 3.5 mm Non-Locking Drill Guides (Fig 3) have a single-banded mark on the instrument side for drilling

a lag screw hole, and a double-banded mark on the instrument side for preparing a gliding hole. There are threaded 2.7 mm and 3.5 mm Neutral Sleeve Adapters which can be mounted to the lag screw side (single-banded side) of the Non-Locking Drill Guides to neutralize cortex screws. The lag screw side of the 3.5 mm Non-Locking Drill Guide and the 3.5 mm Neutral Sleeve Adapter are coated in gold color to indicate that they are used together and in combination with the 2.5 mm drill bit which is also coated in this color.

The new 2.7 mm and 3.5 mm Variable Angle Drill Guides (Fig 4) have on one instrument side a tubular, freehand guide with a variable angle spherical tip which is marked by a single band and on the other side a 30-degree cone to drill within the appropriate range of applying variable angle locking screws.



Fig 3 The 2.7 mm and 3.5 mm Non-Locking Drill Guides (left) and their design features as exemplified on the 3.5 mm instrument (right). Instead of using the spring-loaded feature of the former drill guide to drill a hole for a neutralized cortex screw, a Neutral Sleeve Adapter can be mounted to the lag screw side of the instrument to achieve the neutral position.

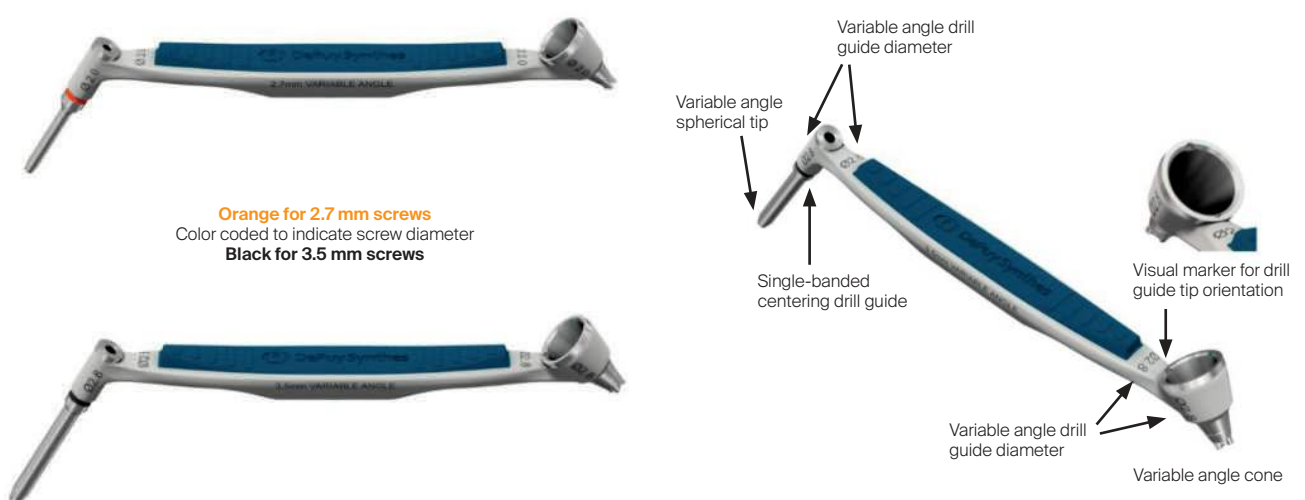


Fig 4 The 2.7 mm and 3.5 mm Variable Angle Drill Guides (left) and their design features, as exemplified on the 3.5 mm instrument (right).

The 2.0 mm and 2.8 mm Threaded Guides (Fig 5) with single-banded marks are provided for drilling of 2.7 mm and 3.5 mm locking screw holes and variable angle locking screw holes at a nominal angle. These guides have an internal recess to allow their application to the plate with a Star Drive screwdriver.

All guides for drilling have engraved figures that are clearly visible to indicate the drill bit diameters which are supposed to be used.

Drill bits

All quick coupling drill bits have color-coded labeling and coating for easy identification and coordinated use with the drill guides:

Drill bits with orange marks for drilling of 2.7 mm screw holes:

- 2.0 mm drill bits with 30 mm and 60 mm calibration: single-banded orange mark (for use with corresponding Non-Locking Drill Guide, Threaded Guide and Variable Angle Drill Guide)
- 2.7 mm drill bit with 125 mm length: double-banded orange mark (for use with corresponding Non-Locking Drill Guide)



Orange for 2.7 mm screws
Color coded to indicate screw diameter
Black for 3.5 mm screws



Used in either a locking or a variable angle locking screw hole at a nominal angle



(Internal) Recess to allow StarDrive screwdriver insertion

Fig 5 Threaded Guides for drilling holes for 2.7 mm and 3.5 mm locking screws and variable angle locking screws at a nominal angle. Design features are described and exemplified for the 2.8 mm Threaded Guide. The Insertion Tray contains four 2.8 mm Threaded Guides and two 2.0 mm Threaded Guides.

Drill bits with black marks for drilling of 3.5 mm screw holes (Fig 6):

- 2.5 mm drill bits with 45 mm, 80 mm, and 150 mm calibration: coated in gold color with single-banded black mark (for use with corresponding Non-Locking Drill Guide)
- 2.8 mm drill bits with 45 mm, 80 mm, and 110 mm calibration: single-banded black marking (for use with corresponding Threaded Guide and Variable Angle Drill Guide)
- 3.5 mm drill bit with 150 mm and 195 mm length: double-banded black mark (for use with corresponding Non-Locking Drill Guide)

Depth gauge

The new depth gauge consists of two parts: a depth gauge sleeve and a depth gauge measuring insert (of polymer material) with hook tip (Fig 7). The depth gauge is provided disassembled in the USF Insertion Tray. A depth gauge key feature is used for secure assembly and to ensure that the metal sleeve stays on the depth gauge during clinical use and is not accidentally unlocked. There are two depth gauges to cover two length ranges: 0 mm to 60 mm and 40 mm to 100 mm. When using the depth gauge for determining the length of 2.7 mm locking and variable angle locking screws, 2 mm must be subtracted from the measurement provided by the instrument. This is not required for 3.5 mm screws or 2.7 mm cortex screws.

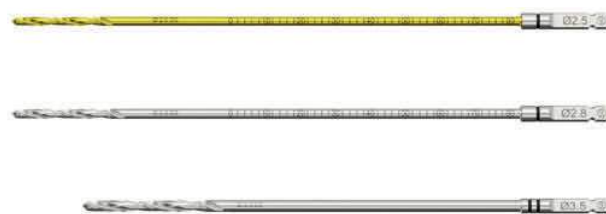


Fig 6 From top to bottom: 2.5 mm drill bit with 80 mm calibration, 2.8 mm drill bit with 80 mm calibration, and 3.5 mm drill bit with 150 mm length. All drill bits with black marks indicating their use with the corresponding drill guides.

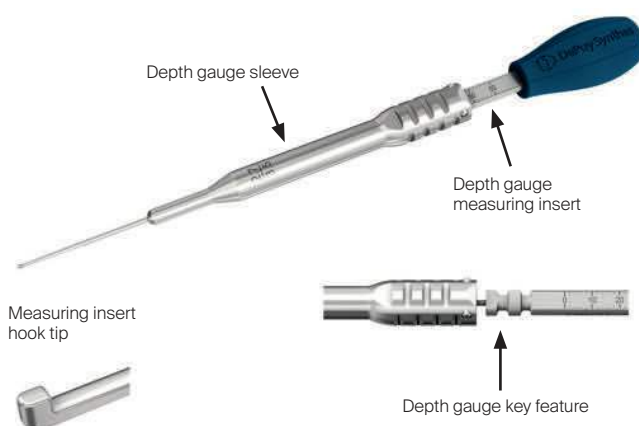


Fig 7 Depth gauge features. This instrument allows two-sided measurement and is designed for one- or two-handed use.

Plate bending irons

There are two new Plate Bending Irons: one with open and one with closed retention slots (**Fig 8**). Both include Recon plate bending pins for 3.5 mm and 2.7 mm holes. The instruments are ergonomically shaped to allow the use of the entire instrument length as a lever to apply force on the plates.

Further instruments of the USF Core Set are a new Periosteal Elevator and a new Universal Handle with soft-touch grip (**Fig 9**). Self-retaining drivers are provided for the Universal Handle to facilitate screw transfer intraoperatively.

In numerous handling tests, surgeons confirmed that the new instruments improve legibility under operating room lights, will facilitate easier identification and coordination by labeling as well as have improved ergonomics.

Benefits of the new USF System

The innovative concept of the USF System allows existing and future 2.7 mm/3.5 mm implants to be supported with only one core set of instruments, which markedly reduces operating room complexity and improves workflow efficiency. Compared with the existing system with more than 20 sets, the USF

System with eight modular anatomical implant trays has the following three signature benefits:

- Improved instrument and system ease of use by operating room teams and hospital staff
- Improved efficiency through reduction in instruments and trays needed for small fragment procedures
- Reduction in hospital costs associated with maintaining equipment.

The USF System is the first trauma platform to receive an Earthwards recognition for providing a more environmentally sustainable solution. The streamlined design, in-tray washing and eliminating the need to use additional sets per procedure are features which help to markedly reduce water and energy consumption (estimated reduction of up to 56%).

Introduction into AO teaching

It is intended that the USF System for small bone procedures gradually replaces the more than 20 existing implant and instrument sets. This entails that all teaching materials must be updated, which is coordinated with AO Trauma Education. The USF System is scheduled for introduction to AO courses by the end of 2020 after receiving AO TC 'Standard' approval (current AO TC approval category is 'Recommended').

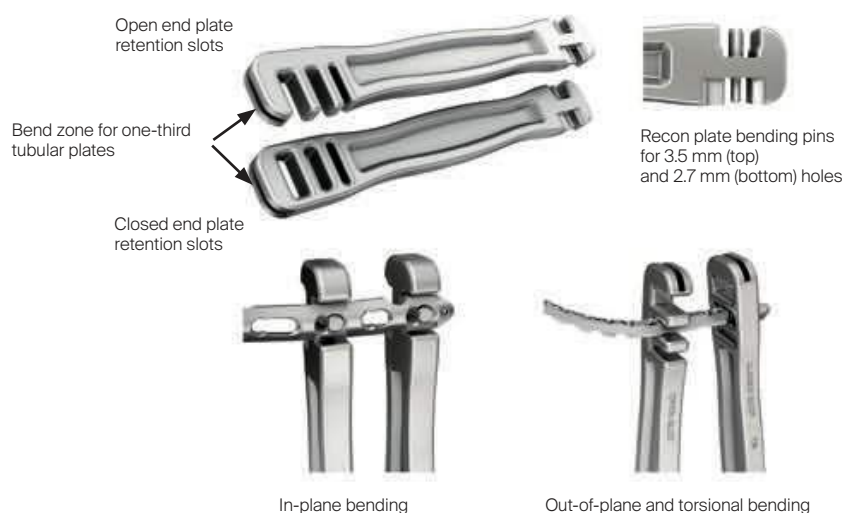


Fig 8 Features of the Plate Bending Irons. Use of two plate bending irons for in-plane plate bending and out-of-plane as well as torsional bending.



Fig 9 Periosteal Elevator with 6 mm Curved Blade (top). The Universal Screwdriver Handle (bottom) which is fully cannulated has an AO Quick Connect coupling. The drivers snap into the coupling without the need for pulling the collar back. An orientation notch indicates the flat location of the AO coupling.

Quick Insertion Screws

Background

In elective forefoot procedures the duration of the operation has a high impact on the overall costs for the case. Quick Insertion Screws are well accepted in elective forefoot procedures because they save time if correctly applied. The 2.0 mm Quick Insertion Screws are self-drilling and self-tapping, 11 mm to 18 mm in lengths and have a unique self-retaining driver shaft (Easy Loader) designed to reduce the risk of premature post breakages and allow insertion directly with the inserter flush to the bone surface. If the post breaks too early, the screw head allows further insertion with a manual driver shaft which can be used for removal as well. The Quick Insertion Screw can also be inserted by connecting directly to a wire drive under power.

Innovative design features

The new Easy Loader Screwdriver provided with the new Quick Insertion Screws has a special mechanism inside to protect the post of the screw from early breakage. This mechanism allows full insertion with countersink of the Quick Insertion Screws flush to the bone surface designed to prevent early breakage, which is intended to ensure that the duration for the screw insertion is reliably low.



Fig 1 Quick Insertion Screw in Easy Loader.

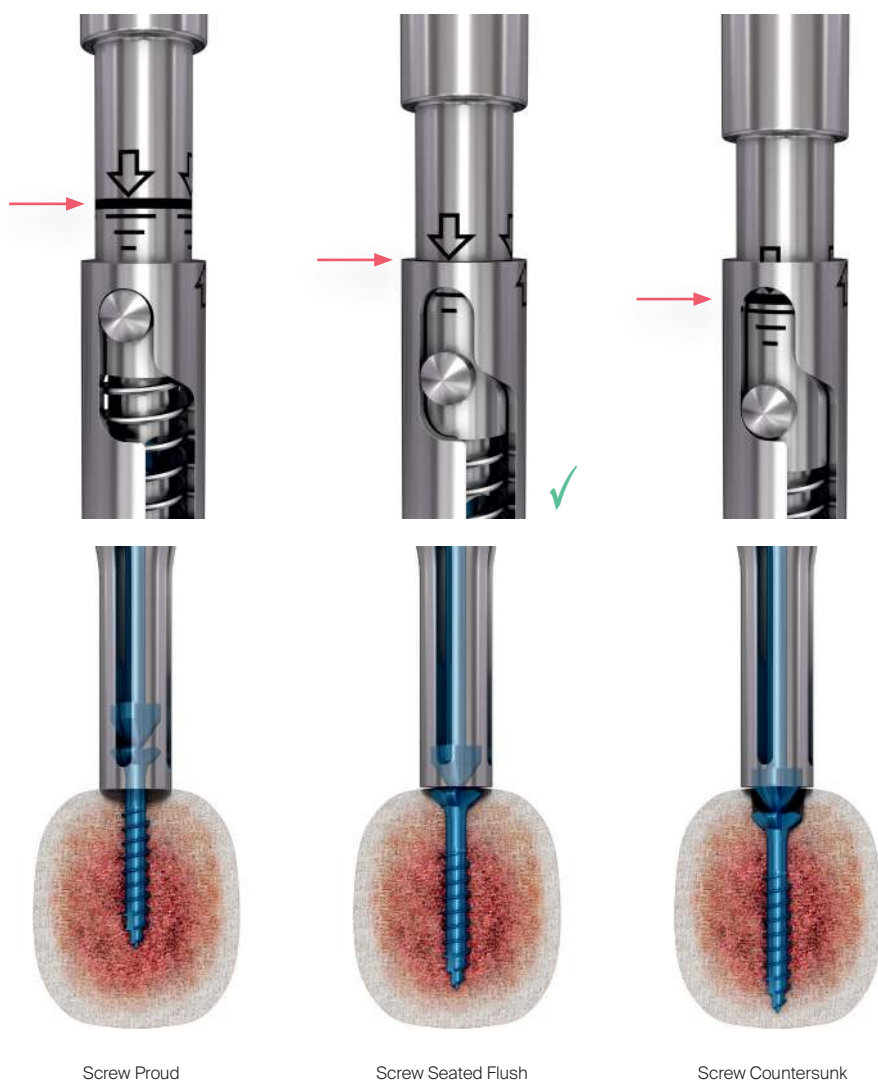


Fig 2 Positions of the Quick Insertion Screw during insertion in the Easy Loader Screwdriver. The Easy Loader is designed to protect the post from premature breakage.

Partially Threaded Cannulated Compression Headless Screws

Background

Cannulated Compression Headless Screws are available on the market with a variety of designs and in a wide range of diameters from 2.0 mm to 7.5 mm for numerous indications. Depending on the concept how compression between two fragments is achieved and how well the insertion of the screw can be performed depending on the individual situation, the screws provide a certain amount of compression between those two fragments. Even though the screw insertion seems to be relatively easy, it is challenging to reliably provide the intended compression between the two fragments when the K-wire guiding the screw insertion is the only element keeping the reduction during insertion.

Innovative design features

The new Partially Threaded Cannulated Compression Headless Screws have a compound cutting edge on the tip for easier insertion designed to reduce insertion force for cutting the thread into the bone. The thread on the shaft of the screw

comes in two different lengths. A differential thread pitch between the tip and head of the screw generates compression. The wider distal threads advance into the far fragment faster while the proximal threads gradually enable the two fragments to compress. The optimal compression is provided when the screw is fully seated at or below the bone surface.

Cutting efficiency testing

The cutting efficiency of the new screws was tested to measure the axial load needed for the screw to cut and to tap into simulated bone. The tests have shown that the axial load needed to insert the new Partially Threaded Cannulated Compression Headless Screws into a foam block simulant is lower than that of other similar devices. This is an important advantage regarding the insertion of the screw in two ways. In the cortex of the first fragment the improved cutting efficiency allows easier insertion and advancement of the screw. When the screw reaches the second fragment the improved cutting efficiency reduces the distraction of the far fragment, retaining initial reduction.

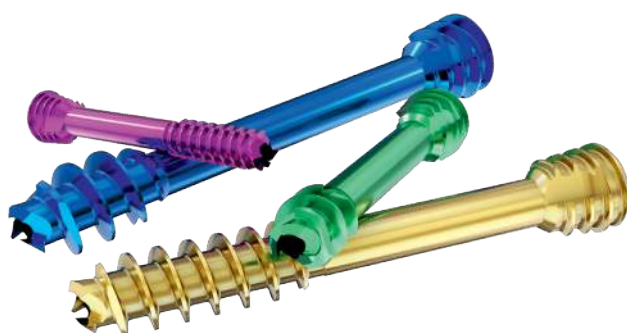


Fig 1 Cannulated Compression Headless Screws come in different sizes from 2.0 mm to 7.5 mm.



Fig 2 Compound Cutting Tip designed to enhance cutting efficiency.

Elite Y Compression Staples

Nitinol Compression Staples are used for several indications in the forefoot and midfoot. As in some cases limited space is available for positioning two legs of a straight staple in a short bone or bone fragment, the new Y staples offer an option to position two legs perpendicular to the bone axis ([Fig 1](#)).

The Elite Y Compression Staples are provided with three or four legs ([Fig 2](#)) and in different sizes and enhance options in tarsometatarsal, naviculocuneiform, talonavicular and calcaneocuboid fusions as well as in lapidus procedures.



Fig 1 Elite Y in Combination with Elite S.



Fig 2 Elite Y with 3 legs and 4 legs.

Improving the treatment of complex distal femoral fractures

Depending on the degree of comminution, patient factors, revisional history, and the possible involvement of prostheses, distal femoral fractures (AO/OTA classification type 33) can be challenging injuries with a relatively high mortality rate that approaches the mortality rate after hip fractures [1]. Both intramedullary nailing and lateral locked plating are commonly used surgical treatment methods with supposedly similar nonunion rates [2]. From a biomechanical perspective, intramedullary nailing offers a higher load bearing capacity compared to lateral plating because the fixation device is closer to the weight bearing axis of the femur. Lateral plating offers advantages over intramedullary nailing in far distal fractures and in complex articular fractures by allowing high screw density to capture bone fragments. Presumably, a prospective randomized trial is underway that might provide better understanding comparing the two methods [2].

There are clinical situations where single fixation devices (nail or plate) are not enough and additional fixation is required. Fracture type, comminution, bone loss, and bone quality influence fixation construct choice. Furthermore, limited patient compliance and inability of postoperative partial weight bearing are factors of growing importance for appropriate fracture treatment because of the increasing number of distal femoral fractures in elderly patients. In case of limiting weight bearing of the affected limb, outcome is associated with a prolonged recovery period and an increased risk of possible postoperative complications [3]. On the other hand, early mobilization without restrictions and full weight bearing improves the

postoperative outcome and decreases mortality [4]. The increasing number of recently published articles about double fixation constructs underlines the importance of considering all these aspects [5–10].

Being aware of the clinical challenges of distal femoral fracture fixation, the Intramedullary Nailing Expert Group (INEG) and Lower Extremity Expert Group (LEEG) of the AO Technical Commission focus on better distal femoral treatment solutions which comprise the combination of a plate and a nail as well as double plating.

1. Single lateral plating using the 4.5 mm VA-LCP Condylar Plate

1.1. Implant features

The most recent lateral plate which was developed by the LEEG together with DePuy Synthes (DPS) is the 4.5 mm VA-LCP Condylar Plate (Fig 1), which is part of the VA-LCP Periarticular Plating system. It features a screw hole technology which allows surgeons to direct variable angle (VA) locking screws at angles up to 15° in every direction and to lock them in the plate. The VA locking technology was introduced to offer several important surgical advantages: capture specific fracture fragments, target fragments with high-quality bone, avoid joint penetration, and bypass previously placed implants. The stainless steel version of the 4.5 mm VA-LCP Condylar Plate was launched in 2011 (see Innovations magazine 2/2011) and the titanium plate version together with dedicated screws (OPTILINK screw technology) in 2016 (see Innovations magazine 2016).



Fig 1a–d A 4.5 mm VA-LCP Condylar Plate in stainless steel with VA combi-holes in the plate shaft (a). Four columns of threads in the VA locking hole (b) provide four points of threaded locking between the VA-LCP plate and the VA locking screw (c). Screws can be angled within a 30° cone around the central axis of the plate hole (d).

In static and dynamic construct tests, the 4.5 mm VA-LCP Condylar Plate performed better than the 4.5 mm Broad LCP and the 4.5 mm LCP Condylar Plate which served as predicate devices.

1.2. Clinical case review

After release of the stainless steel plate the fixation system was mainly used in the US. In an article published in 2016, Tank et al [11] cautioned practicing surgeons against the use of the 4.5 mm VA-LCP Condylar Plate for metaphyseal fragmented distal femoral fractures due to the presumed higher rate of earlier mechanical failure. The authors reported eight construct failures when using the 4.5 mm VA-LCP Condylar Plate for fixation of 36 fractures (22% failure rate). The failures comprised three plate constructs that bent or broke at the level of the fracture site and five distal screw disengagements in the plate head with subsequent loss of fixation. All failures were observed in type 33-C fractures. The LEEG carefully reviewed this article

and raised concerns with the study data and the conclusion that were published as letter to the editor [12].

The LEEG members, together with one of the coauthors of the article, reviewed all clinical cases of the study based on a comprehensive list of factors (screw number, length of screws, bridging length, plate position, quality of reduction, bone quality, etc) which could have influenced construct strength (Fig 2). A detailed report about this case review is included in the 2018 edition of the Innovations magazine.

The most important finding was that malpositioning of the plate in the sagittal plane, insufficient screw placement in the distal fragment, and very long bridging distances in comminuted fractures were significantly associated with a higher mechanical failure rate. When these factors were considered, the failure rates of the 4.5 mm VA-LCP Condylar Plate and the LISS plate were no longer significantly different in the statistical evaluation.



Fig 2a-c Example of malpositioning of a 4.5 mm VA-LCP Condylar Plate. (a) An 81-year-old man with a high-energy, closed C3 fracture. (b) Postoperative situation using the VA-LCP Condylar Plate with a long bridging length. There is severe comminution and no medial contact of the main fragments. The variable angle locking screws in the distal fragment are too short and do not really capture the medial femoral condyle. The plate is positioned too anteriorly and distally. (c) After 2 weeks there was failure by screw cut out into the joint with a possible slight bending of the plate.

1.3. Revised surgical technique guide of the 4.5 mm VA-LCP Condylar Plate

Based on the case review findings, the LEEG revised the surgical technique guide of the 4.5 mm VA-LCP Condylar Plate to emphasize the importance of adequate plate placement (Fig 3), the angulation of VA screws, the number of screws in the distal fragment and the postoperative care management in case of long comminuted fractures.

The updated surgical technique guide comprises a note which points out that placing VA locking screws at a nominal angle provides maximum locking strength of the connection of the screw and the plate. It further states that off-axis angles should only be chosen when clinically indicated. A note was added to recommend filling all six screw holes in the plate head, if possible. An additional paragraph about the postoperative care was included. It explains that multifragmentary fractures with bridge plate constructs generally require more protection and patients should carefully be mobilized with partial weight bearing (and maybe an additional external splint). Progressive weight bearing is allowed after callus formation is seen during follow-up at 6 to 12 weeks.

1.4. Latest findings about 4.5 mm VA-LCP Condylar Plate performance

It must be emphasized that the most recent clinical study about the performance of the 4.5 mm VA-LCP Condylar Plate reported a failure rate of 9.3% [13]. This is less than half of the failure rate published by Tank et al [11]. The authors concluded that the use of the 4.5 mm VA-LCP Condylar Plate is a viable option in distal femoral fractures and has an acceptable failure and reoperation rate [13]. This is in line with the results of the previously mentioned case review performed by the LEEG.

Surgeons must be aware that every plate fixation construct, regardless of which plate is used, will fail sooner or later if the fracture does not heal. There is always a race between bone healing and plate fixation failure. The 4.5 mm VA-LCP Condylar Plate, when used as a single fixation device, also has its limitations in challenging fracture situations for which additional fixation must be considered.

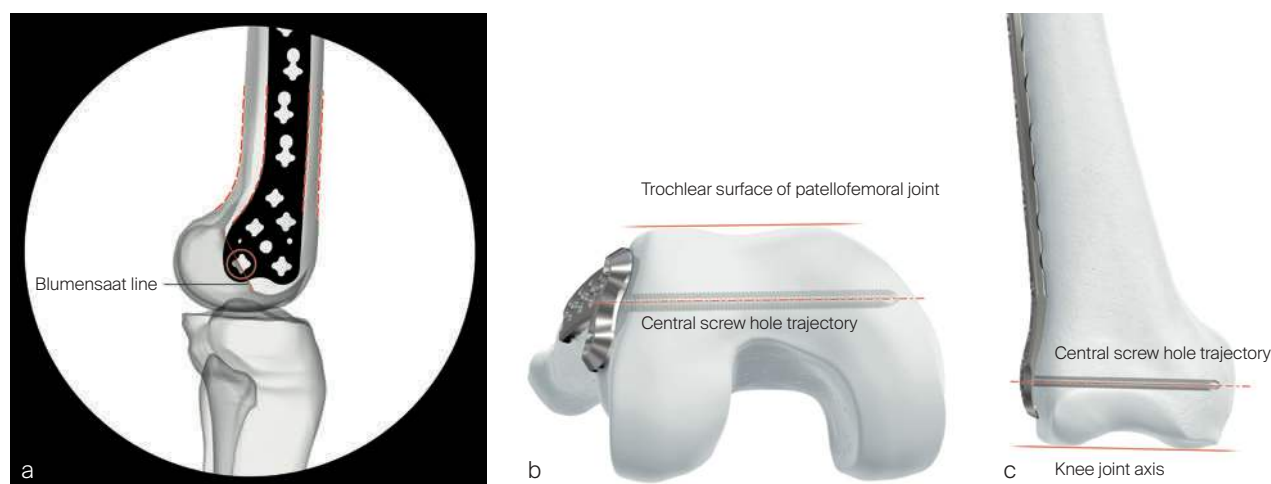


Fig 3a-c Correct positioning of the plate: in the lateral radiographic view, the distal shaft of the plate should be in line with the femoral shaft. The posterior edge of the plate is curved to mimic the posterior anatomical curvature of the condyle (a). In the inferior line view, the central screw axis should be parallel to the patellofemoral joint and this is usually anterior 1/3 from the joint (b). In the AP view, the central screw axis should be parallel to the knee joint axis (c).

2. Double fixation constructs of complex distal femoral fractures

2.1. Double plating

There is only a limited number of publications about why and how surgeons opt for double plating of fractures at the distal femur [5–8, 14]. Sanders et al [14] listed medial cortical comminution, a short distal condylar fragment, and loss of metaphyseal bone as indications for double plating. Treatment of nonunion is also named as an indication for double plating [6]. Bai et al [5] stated that after lateral plating a positive varus stress test during the operation can be an indication for lateral and medial double-plating fixation of distal femoral fractures.

To obtain a better understanding around double plating, the LEEG conducted, together with DPS, a web-based survey in 2018. The survey was sent to surgeons participating at AO TC Experts Symposia in Asia, Europe, and the United States. Seventy-three of the surgeons completed the questionnaire. For most of the surgeons the main reason for choosing double plating was based on a combination of factors as patient age, osteoporosis, and fracture type. About 75% indicated that they would use a medial plate in addition to a lateral plate in case of missing medial cortical bone (Fig 4). Most surgeons use double plating for multifragmentary metaphyseal fractures with or without articular involvement (Fig 5).

Using a medial plate in addition to a lateral plate in comminuted metaphyseal fractures with lack of medial cortical support reduces the risk of varus collapse. Since there is no dedicated anatomically shaped distal medial femoral plate for this purpose, surgeons frequently use various anatomical plates in an off-label manner (PHILOS – Proximal Humeral Plate 3.5, LCP

Proximal Tibial Plate 3.5, VA-LCP Proximal Tibial Plate 3.5, LCP Medial Proximal Tibial Plate 3.5, LCP Posterior Medial Proximal Tibial Plate 3.5, LCP Proximal Tibia Plate 4.5/5.0), which is not a satisfying situation from an AO TC perspective.

Surgeons who used double plating instead of a single lateral plate for the same indication claimed to have better clinical results (84%), decreased implant-related failures (73%), higher union rate (75%), lower revision rate (69%), as well as less time to full weight bearing (69%) (Fig 6).

Double plating also has disadvantages—in particular, the surgery time is longer. Further soft-tissue stripping and compromising the periosteal blood supply by double plating may induce a higher infection risk. Based on the survey, only a few surgeons raised concerns regarding a higher risk for neurovascular injuries.

One major concern of double plating is that too much construct stiffness could result in delayed healing or nonunion. Construct stiffness can be influenced by selecting the appropriate plate size to balance the fixation. According to our survey, 60% of the respondents indicated that they use small fragment plates as a medial plate. At the proximal tibia it is common practice to use double plating with small fragment plates. Considering the load transfer in the knee joint between proximal tibia and distal femur suggests that such a plating technique could be enough at the distal femur. However, this is pure speculation and requires further thorough analyses.

On a general note, the validity of the survey results reported in this article is limited by the response number. Clinical studies are required to verify the reported findings.

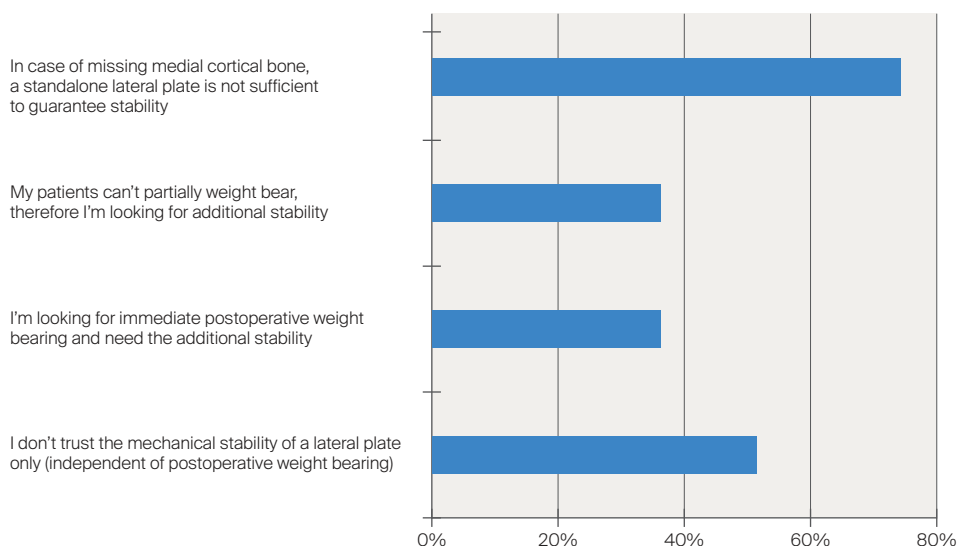


Fig 4 Main reasons for surgeons to use an additional medial plate.

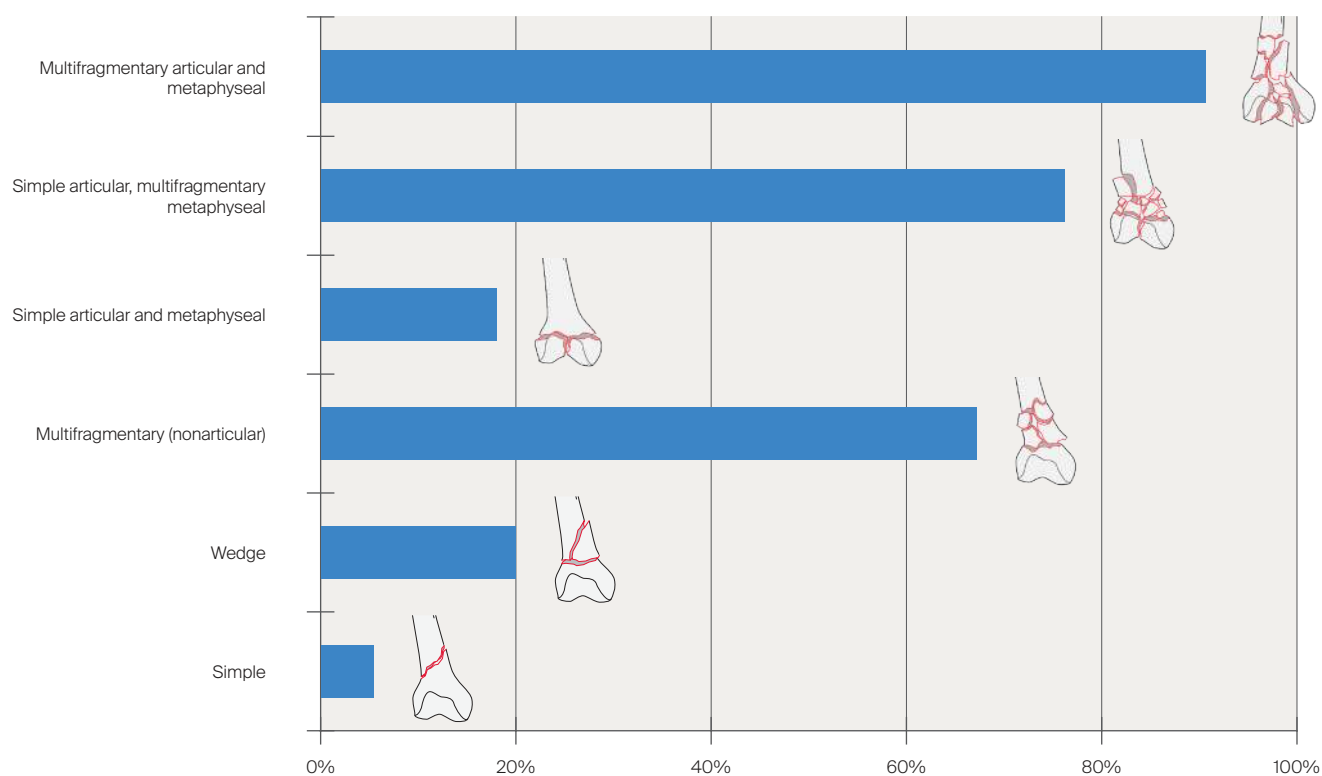


Fig 5 Percentage of surgeons who consider double plating depending on fracture type.

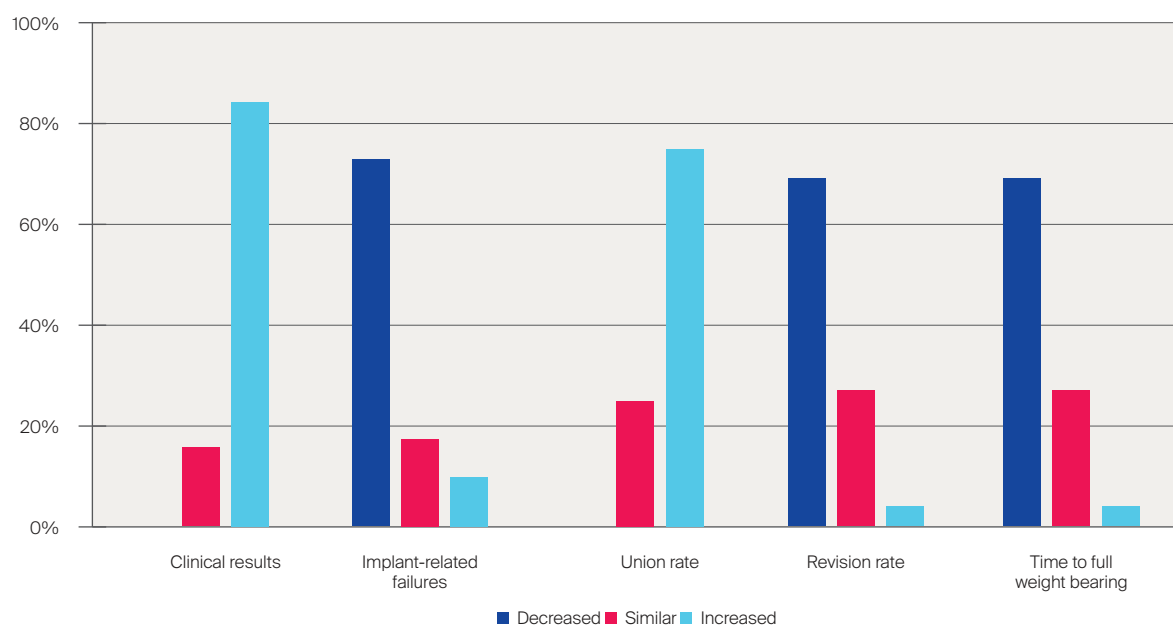


Fig 6 Clinical experience with double plating compared to lateral plating only.

Case 1: Periprosthetic fracture UCS IV.3.C (provided by Karl Stoffel, Basel, Switzerland)

An 87-year-old woman living in a nursing home with mild dementia and morbid obesity, but still able to mobilize herself independently with a walker. She had a simple fall (low-energy trauma) sustaining a left-sided distal femoral periprosthetic fracture UCS IV.3 C with medial comminution (Fig 7).

Fig 7a-b

- a** Conventional x-ray of an 87-year-old patient (only in one plane due to technical difficulties).
- b** The CT scans show a distal multifragmentary periprosthetic extraarticular femoral fracture with medial comminution in the presence of severe osteoporosis with thin cortical bone and rarefied trabeculae. Due to the fracture pattern, poor bone quality, obesity, and impaired compliance of the patient, it was decided to use a double plating technique with a lateral 4.5 mm VA-LCP Condylar Plate and a medial small fragment plate, allowing to insert many screws in the distal articular part from both sides.

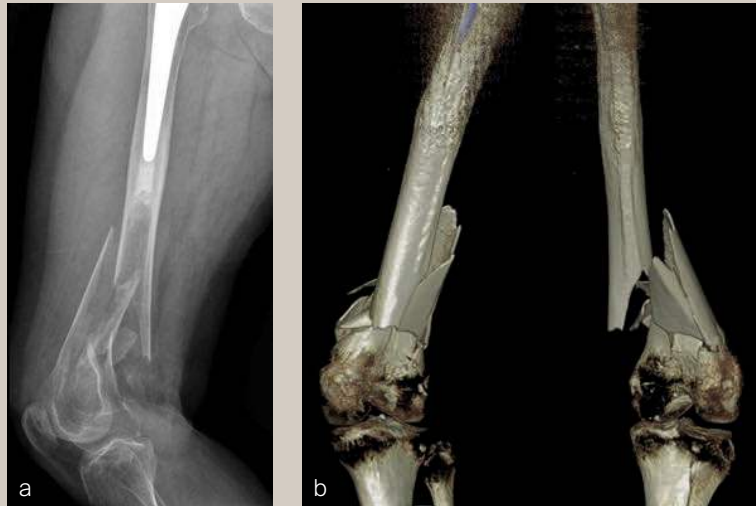


Fig 8a-b

- a** After application of an external fixator anteriorly, a 4.5 mm VA-LCP Condylar Plate was percutaneously applied and preliminary fixed with the nominal screw parallel to the joint. Proximal the plate was compressed to the bone using the Whirly Bird device.
- b** The long plate was proximally fixed to the shaft with a Locking Attachment Plate. Then, a second straight 3.5 LCP was precontoured (bending, twisting) and applied medially through a minimal invasive approach distally. The two screws proximally were inserted percutaneously.

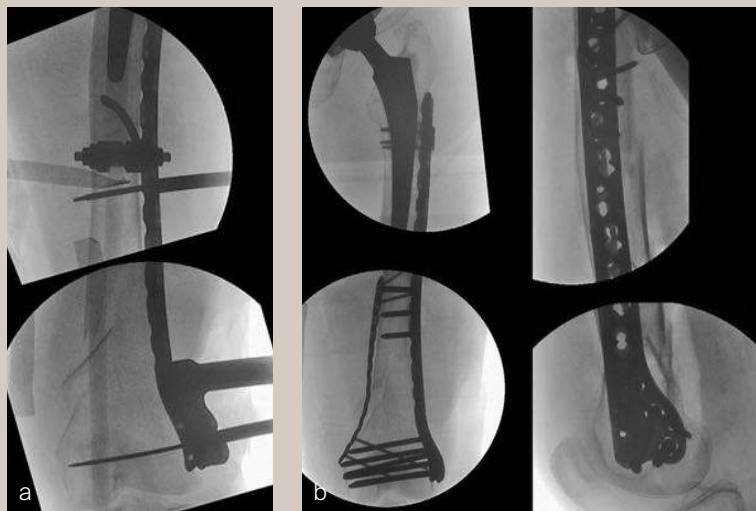
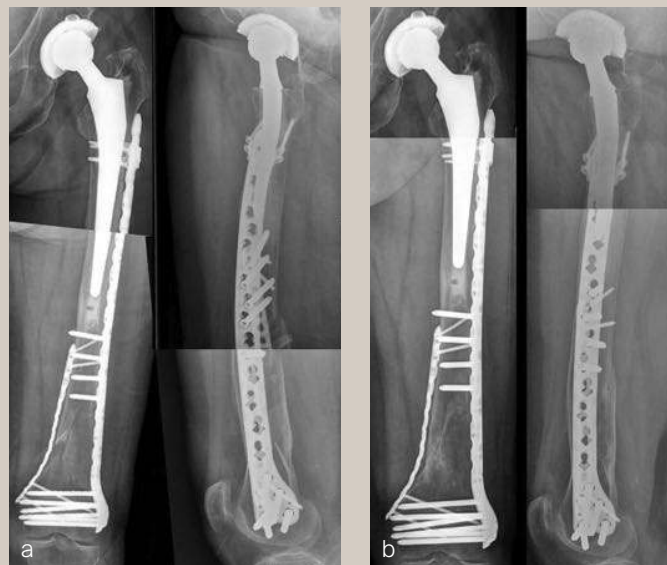


Fig 9a-b

- a** Postoperative x-rays demonstrate a well-reduced and aligned fracture, stabilized with two plates bridging the metaphyseal comminution. The lateral curved plate is in the anteroposterior and lateral views well centered and all screws in the distal plate are oriented at or close to nominal angle. Given the patient's age and comorbidities (eg, dementia) she was allowed to full weight bear using a walker.
- b** After 1 year the fracture is healed with the implants stable in situ. She is back to walking as before the injury.



Case 2: Periprosthetic fracture type UCS V.3.B1 (provided by Mark Lee, Sacramento, US)

An 82-year-old woman with no major medical problems was injured in a motor vehicle collision (Fig 10). She had a well-functioning total knee arthroplasty in place with no functional limitations.



Fig 10a-c Injury x-rays.

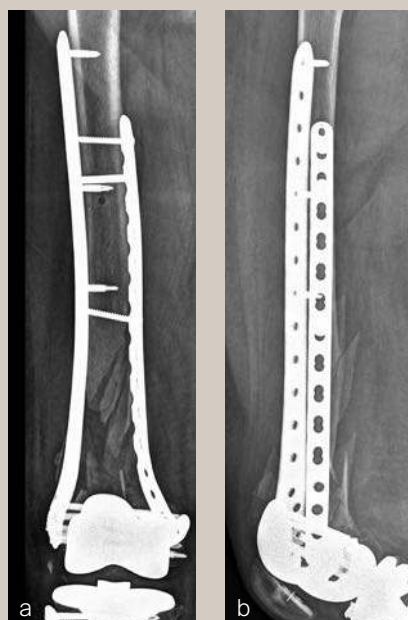


Fig 11a-b Postoperative x-rays. Dual plating (large fragment LISS plate lateral, small fragment proximal lateral tibia plate) was selected in this situation because of a small distal fragment size and the desire to allow for immediate unrestricted weight bearing.

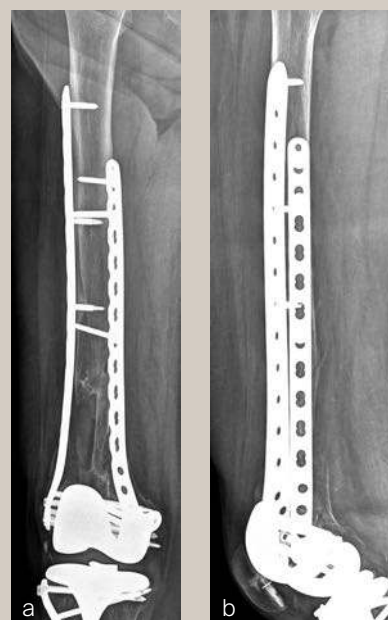


Fig 12a-b Follow-up x-rays at 1 year. The patient reached her premorbid functional status with no pain from her distal femur.

In this case there was only limited callus formation which is frequently observed for double plating. Hence, fracture healing progress might not be so obvious on conventional x-rays.

2.2 Plate and nail combination

An alternative to double plating is the combination of a retrograde intramedullary nail with a (lateral or medial) plate. Such a fixation construct relies mainly on a strong central load carrier and, together with the plate, resists displacements in all planes. Liporace and Yoon [10] hypothesize about the function of such a construct that placing a retrograde intramedullary nail first moves the weight-bearing axis of the femur more medial and closer to the anatomical axis of the femur. The laterally based locked plate provides added stability.

As with double plating, one of the main benefits of nail and plate combinations is the increased load-bearing capacity which is required for immediate weight bearing and early mobilization of the patient. Fontenot et al [15] recently reported on the biomechanical properties of a lateral locked plate alone or in combination with a supplemental medial plate or an intramedullary nail. The nail-plate group had the highest number of cycles until failure.

Combining a nail with a plate causes less soft-tissue insult than double plating. However, in cases of articular comminution double plating offers advantages over nail-plate constructs. Since the bone quality is diminished due to the presence of a

total knee arthroplasty component it could be advantageous to use nail-plate fixation constructs for periprosthetic distal femoral fractures [2, 10]. However, it is not always possible to insert a nail in presence of a knee prosthesis.

The potential benefit of linking the nail to the plate via interlocking screws is being debated and requires further investigations. The hypothesis is that there is more equal load distribution between the nail and the plate if there is linkage between them, which could be beneficial for fracture healing and avoid premature construct failure of one of the devices.

Case 3: Periprosthetic fracture type UCS V.3.B1 (provided by Christopher Finkemeier, Sacramento, US)

An 84-year-old woman sustained a left periprosthetic fracture (Fig 13). This fracture pattern is challenging for any singular implant to maintain fixation and alignment with immediate weight bearing. Therefore, a two-column fixation was chosen with a lateral locking plate (lateral column) and an intramedullary nail (middle column).

In addition to the benefit of a high fixation strength, the nail-plate construct offers the potential advantage over double plating that because of the presence of the nail, the lateral plate could be removed before complete healing should this be necessary due to pain or iliotibial band irritation.



Fig 13a–b Injury x-rays. The medial column is deficient because of a butterfly bone fragment. There is a low lateral column “escape” fracture line that is challenging for fixation with a lateral plate.

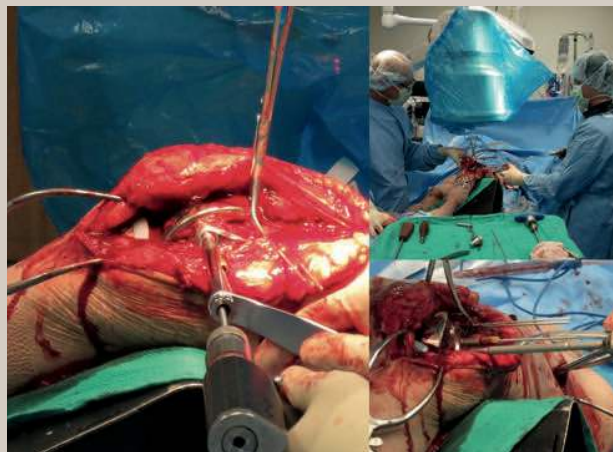


Fig 14 After restoration of coronal and sagittal plane alignment, a VA-LCP Condylar Plate was applied to hold the alignment and axis. Screws were placed out of the path of the nail. Unicortical screws were placed in the diaphysis.

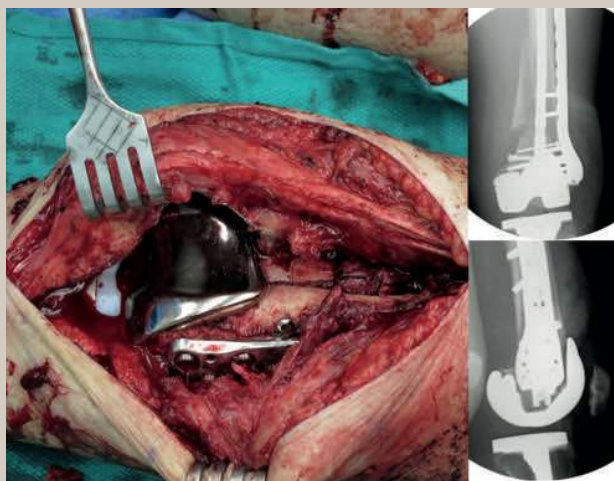


Fig 15 Placement of a retrograde femoral nail. Medial cortical substitution is covered by the nail.



Fig 16 Postoperative imaging. Immediately after surgery the patient could apply weight bearing as tolerated.



Fig 17 Follow-up x-rays at 4 months after surgery.

3 Outlook

The limited number of studies on double fixation which have been published so far have mostly reported good clinical results [2, 5–10, 14]. The potential of double fixation concepts is promising but there is a need for further investigations.

A factor which must be considered when selecting a double fixation method and device dimensions is the risk of peri-implant fractures due to potential stress risers adjacent to the fixation construct.

Every double fixation construct needs to be "adequately" balanced to induce bone healing. What "adequately" means in this context requires further clarifications. Since the load is transferred via two devices the dimensions of these devices (and the presence of a linkage between them in case of nail-plate constructs) determine how much load is transferred by which device and what the failure modes are.

There is alignment among surgeons that there is a growing need for composite fixation constructs for complex distal femoral fractures which allow immediate and full weight

bearing. This trend is driven by the increasingly aging population and high activity demands. High load bearing capacity of the fixation is eminent for mobilizing patients who cannot follow partial weight bearing protocols.

The AO Technical Commission continues to work on comprehensive solutions for complex distal femoral fractures. While the LEEG is considering the development of a dedicated distal medial femoral plate for double plating (and possibly a distal medial plate as a single plate, eg, for fixation of an oblique distal femoral fracture running from proximal medial to distal lateral), the INEG is focusing on the potential of plate and nail combinations. The AO Research Institute Davos (ARI) is supporting this work with their biomechanical testing possibilities, finite element (FE) expertise (do refer to the FE article of the ARI in this Innovations magazine) and morphological shape analyzes to come up with appropriate anatomically shaped implants.

The task of the AO TC Expert Groups is not only the development of new implant solutions but also to provide surgeons with recommendations and clinical guidelines when to use which fixation method under what conditions.

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MatrixRIB Self-Drilling Screws

Improvement of the MatrixRIB Fixation System—addressing the clinical need

The MatrixRIB Fixation System, approved by the AO Technical Commission Trauma in 2009, entered the market with the clear goal to improve outcomes for patients with rib fractures by providing a surgical alternative to traditional conservative approaches. The AO Technical Commission Thorax Surgery Expert Group later identified the need to increase efficiency in the operating room (OR), and in 2019 the AO Technical Commission Trauma approved the addition of self-drilling screws to the MatrixRIB Fixation System. Considering that 25–30 screws are typically inserted during a procedure, the self-drilling screws will reduce the duration and complexity of the procedure (through removal of drill bits and associated steps) and the amount of capital equipment needed in the OR (power tools not included in the MatrixRIB Fixation System).

New components added to the MatrixRIB Fixation System

The new self-drilling locking screws are 2.7 mm in diameter and available in 1 mm length increments from 8 mm to 20 mm. Self-drilling nonlocking screws are 2.7 mm in diameter and available in 10 mm and 12 mm lengths (Fig 1). These are provided as alternatives to the existing MatrixRIB Self-Tapping locking and nonlocking screws. The pointed, cutting tip of the MatrixRIB Self-Drilling Screws enables surgeons to insert the screws without drilling a pilot hole. The new MatrixRIB Self-Drilling Screws are designed to lock the MatrixRIB plates 1.5 to create the same secure construct as the MatrixRIB Self-Tapping Screws.



Fig 1a–b Self-drilling locking (a) and nonlocking (b) screws for the MatrixRIB System.

New screw guides are provided to ensure coaxial alignment of the self-drilling screws to the MatrixRIB plates 1.5 and MatrixRIB Splints, reducing the variability in screw alignment and orientation during insertion and ensuring construct locking strength (Fig 2 and Fig 3). The Plate Screw Guide engages with the contours of the existing plate profile (Fig 4). This Plate Screw Guide has also cut-outs on both ends that enable the surgeon to visually align to the adjacent screw holes.

The MatrixRIB Self-Drilling Screws can be used in both the open and Minimally Invasive Plate Osteosynthesis (MIPO) approaches. If a suture is needed during the MIPO procedure, the guide has a through hole where a suture could be used as a tether (Fig 5). The MatrixRIB Self-Drilling Screws are not meant to be used with the thick MatrixRIB plates 2.8 or in the 90° approach.

What are the advantages of the new self-drilling screws?

Three aspects of the new components are worth highlighting:

- Improved OR efficiency: The MatrixRIB Self-Drilling Screws improve procedure efficiency by reducing the number of steps required to insert screws.
- Simplified and reliable screw insertion: The MatrixRIB Self-Drilling Screws with Screw Guides reduce the variability in screw alignment during insertion to ensure locking strength.

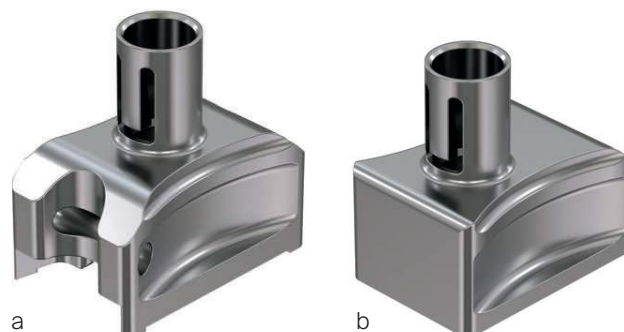


Fig 2a–b Self-drilling screw guide for MatrixRIB plates 1.5 (a) and Intramedullary Splints (b).

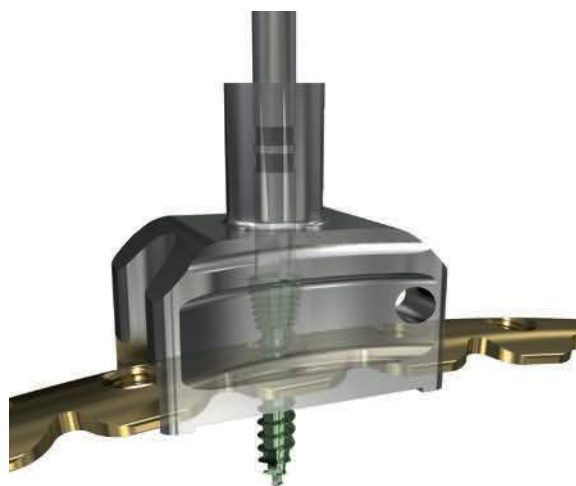


Fig 3 Self-drilling screw insertion with the guide for MatrixRIB plates 1.5.

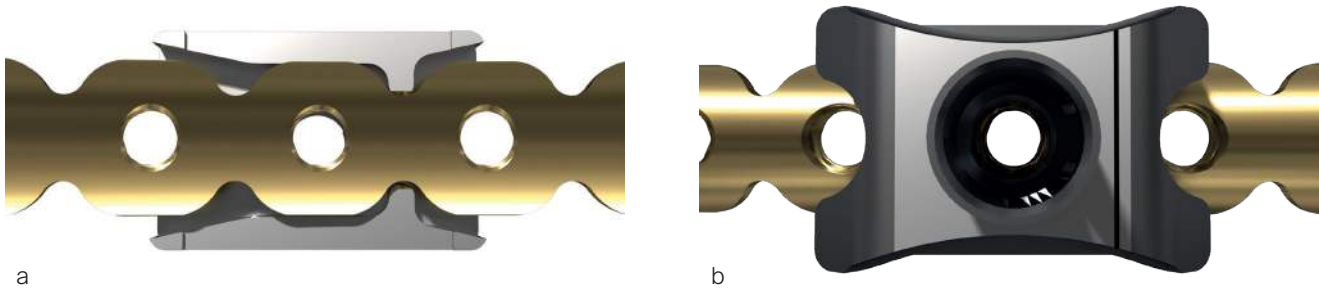


Fig 4a-b Self-drilling screw guide engaged on a MatrixRIB plate 1.5 with a pair of opposing side cuts (a). The guide has an etched line indicating location of the side cut interface (b).

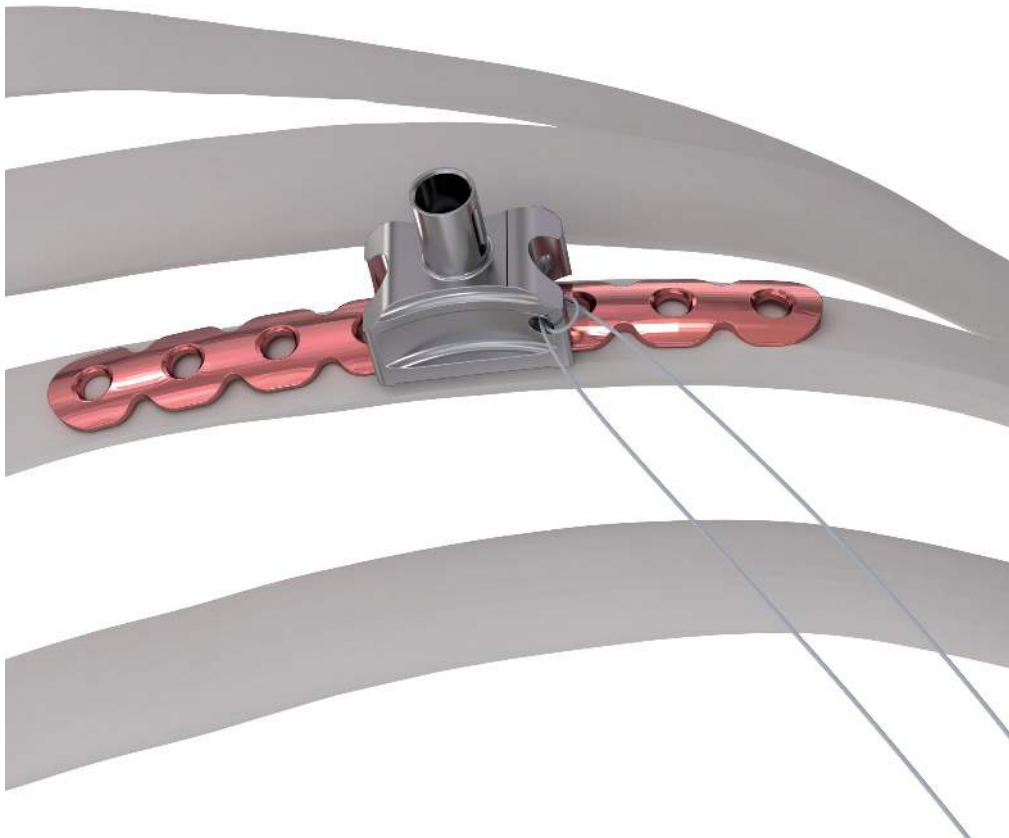


Fig 5 Self-drilling screw guide engaged on a MatrixRIB plates 1.5 with a suture placed as a tether.

PROTI 360°™

PROTI 360°™ is a family of integrated titanium interbody cages that promote spinal fusion, intended for use in patients with degenerative disc disease (DDD). The cage family includes the ACIS PROTI 360°™ System for cervical fusion, and the T-PAL PROTI 360°™ System and CONCORDE PROTI 360°™ Systems for lumbar interbody fusion.

Every year in the US, approximately 400,000 patients with DDD undergo spinal fusion surgery to help reduce pain and nerve root inflammation [1]. During this procedure, the intervertebral disc is removed, and an interbody spacer is implanted to potentially restore natural height and lordosis between two vertebrae.

Advantages of PROTI 360°™ integrated titanium implants

The PROTI 360°™ interbody device has unique design features that provide immediate mechanical stability to the spine and promote rapid and long-lasting biological fixation. The titanium-integrated polyetheretherketone (PEEK) implants combine the benefits of the constituent materials, PEEK and titanium. The integrated titanium on all external surfaces creates a wear-resistant, bioactive surface that promotes the attachment and growth of osteoblasts [2, 3], thereby maximizing the potential for bone growth in the intradiscal space. PEEK is a biocompatible material with mechanical properties that resemble human bone. The implants are radiolucent, meaning that surgeons can easily undertake imaging to assess the bone-healing process and fusion rate postoperatively [4].

Mechanical stability

The PEEK core of the interbody device has an anatomically relevant Module of Elasticity, providing mechanical stability and effectively dispersing dynamic loading in the spine to minimize stress-shielding effects (Fig 2).

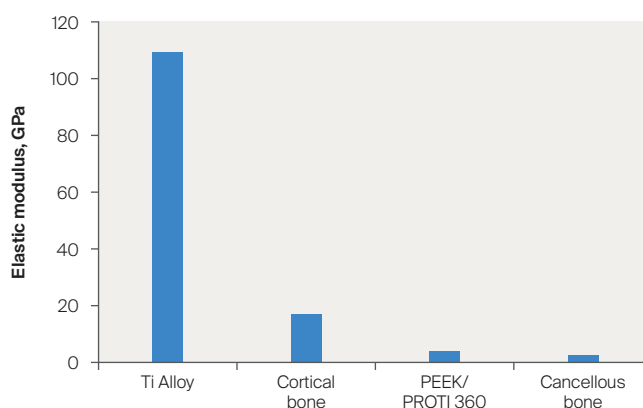


Fig 2 Elastic (Young's) modulus of titanium alloy (Ti-6Al-4V) and PEEK/TiPEEK compared to human cortical and cancellous bone [3, 6].



Fig 1 The PROTI 360°™ family of interbody cages.

The PROTI 360°™ cage surface incorporates roughness at the macro-scale intended to improve friction fit within the disc space (Fig 3) [5]. Additionally, roughness at the microscale and

nanoscale is intended to enhance cell-substrate interactions to support bone growth (Fig 4).

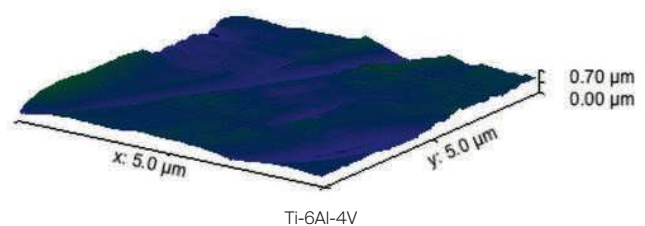
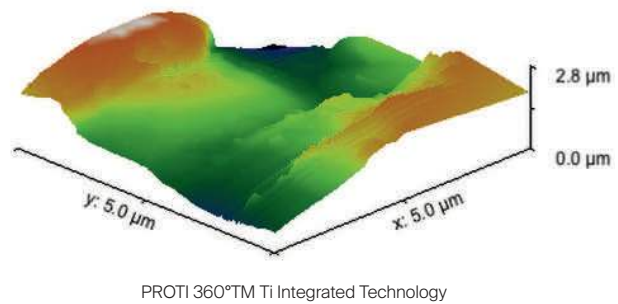
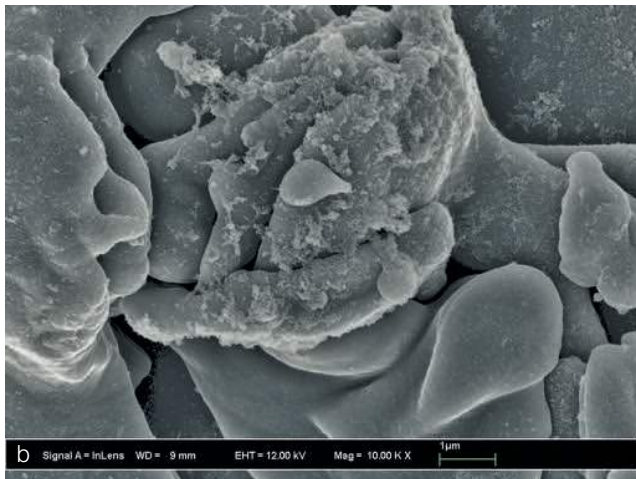
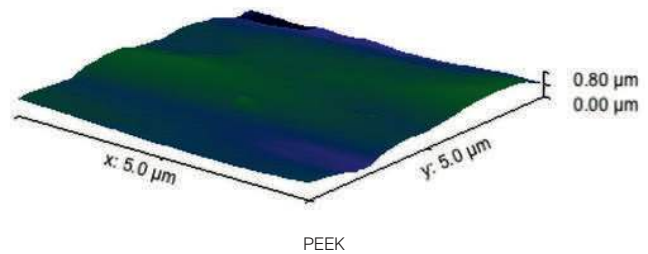
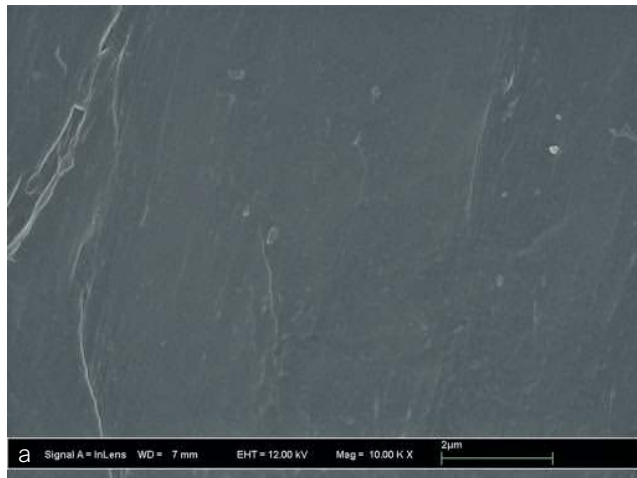
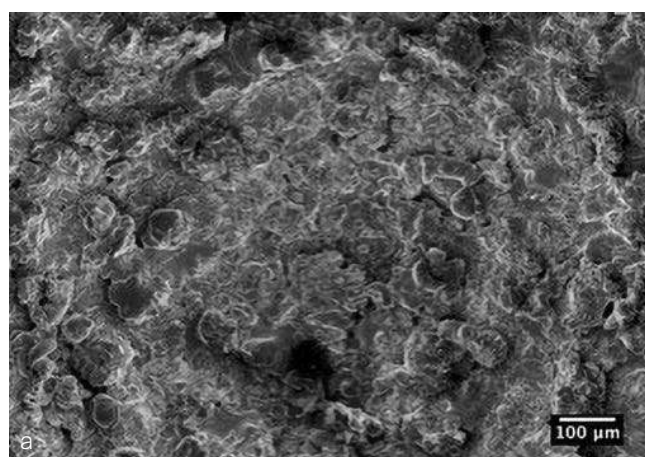
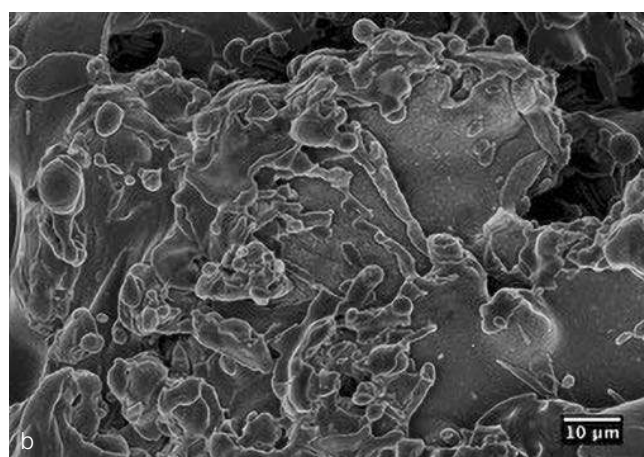


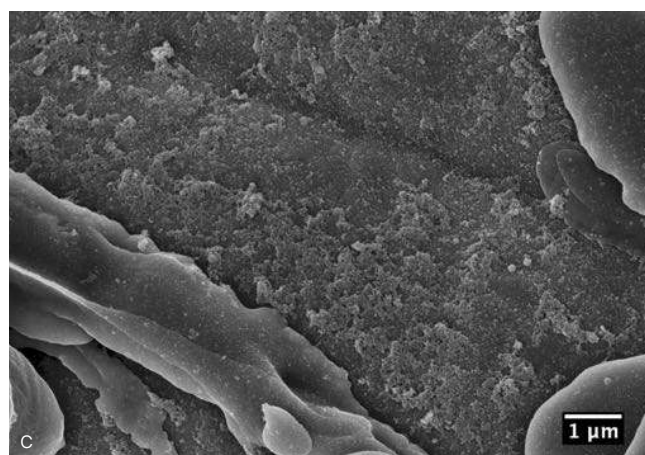
Fig 3a–c Scanning electron micrograph images showing the roughness of the cage surface imparted by PROTI 360°™ Titanium Integrated Technology (b) compared to PEEK (a) and smooth titanium (c).



100 X



1000 X



10,000 X

Fig 4a-c Scanning electron micrograph images showing the roughness of the cage surface imparted by PROTI 360™ Titanium Integrated Technology at the macroscale (a), microscale (b), and nanoscale (c)



Fig 5 Microscopic view of the Ti-PEEK interface. As the Ti is integrated to the PEEK core rather than a pure external coating, the risk of delamination is greatly reduced.

Enhanced bone growth

The PROTI 360°™ cage has an increased surface area with an all-round (360°™) external integrated titanium surface compared to traditional “end plate coating only” cages (Fig 6), which may enhance bony on-growth during the process of spinal fusion. The integrated titanium surface shows significantly higher osteoblast activity at days 14 and 21 compared to both PEEK and Ti [5]. The increased surface roughness increases the in vitro osteoblast population by ~50% within 7 days compared to standard PEEK surfaces [5]. Calcium deposition, which is an indicator of early bone formation, was significantly higher with PROTI 360°™ technology than with both PEEK and titanium alone at days 1 and 7 of device testing [5].

Reduced risk of delamination

The PROTI 360°™ family of implants has design features that prevent delamination, a process in which the titanium layer can separate from the PEEK implant at the interface between the

two materials. The titanium integrated technology is designed to enhance the Ti-PEEK bonding strength and to reduce the risk of delamination upon impaction (Fig 5). The rounded design of the interbody device eliminates external exposed PEEK corners at leading edges as the device is inserted (Fig 6). The thickness of the porous Ti layer and Ti integrated layer is on average 0.2 mm [7]. The manufacturing process for integrated titanium delivers Ti penetration of 223 µm along all surfaces [7].

Radiolucency of PEEK

The PEEK core of the PROTI 360°™ cage has favorable imaging characteristics which support the postoperative assessment of fusion, while the titanium outer layer allows measurement of cage positioning. Clinically, depending on the image quality, plane of view, and patient anatomy, the PROTI 360°™ cage may show a ghost image of the entire cage on fluoroscopic images (Fig 7). Computed tomographic (CT) images show minimal scatter around the implant (Fig 8).

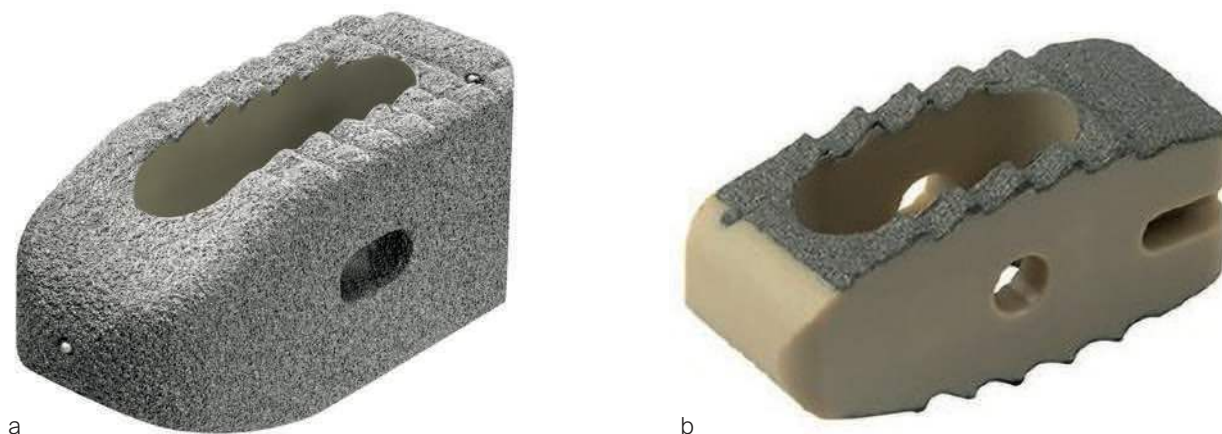


Fig 6a-b The interbody device has a rounded design (a), eliminating exposed PEEK corners at leading edges. In contrast, existing designs (b) have a potential shear plane at the leading edge with PEEK exposed.

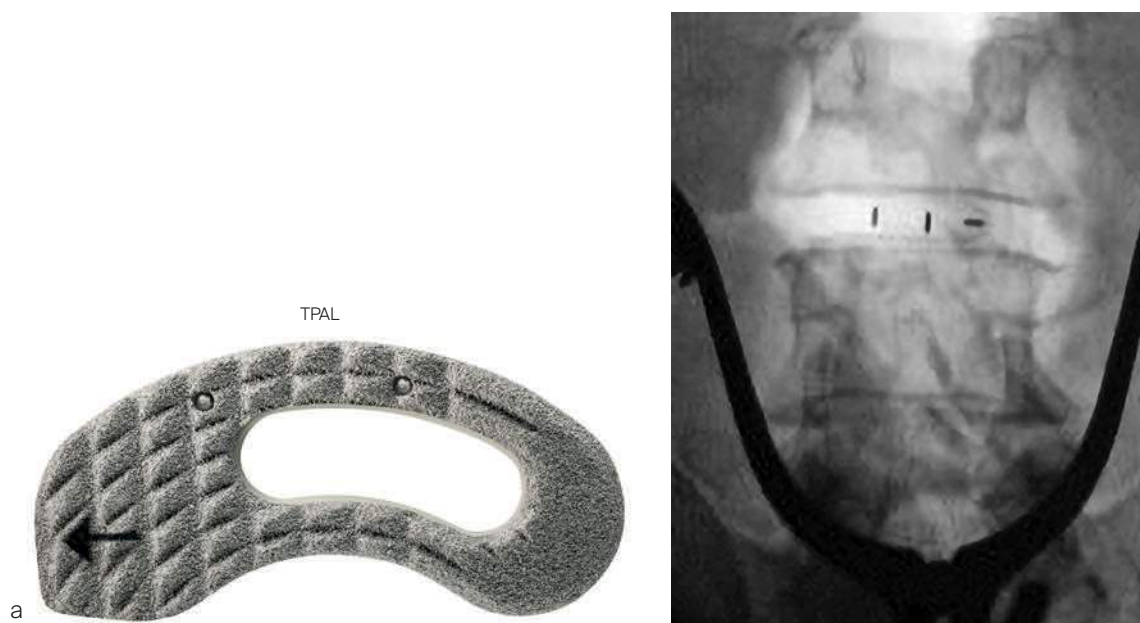


Fig 7a-c Fluoroscopic images showing the appearance of the T-PAL (a), ACIS (b) and CONCORDE (c) PROTI 360°™ cages.

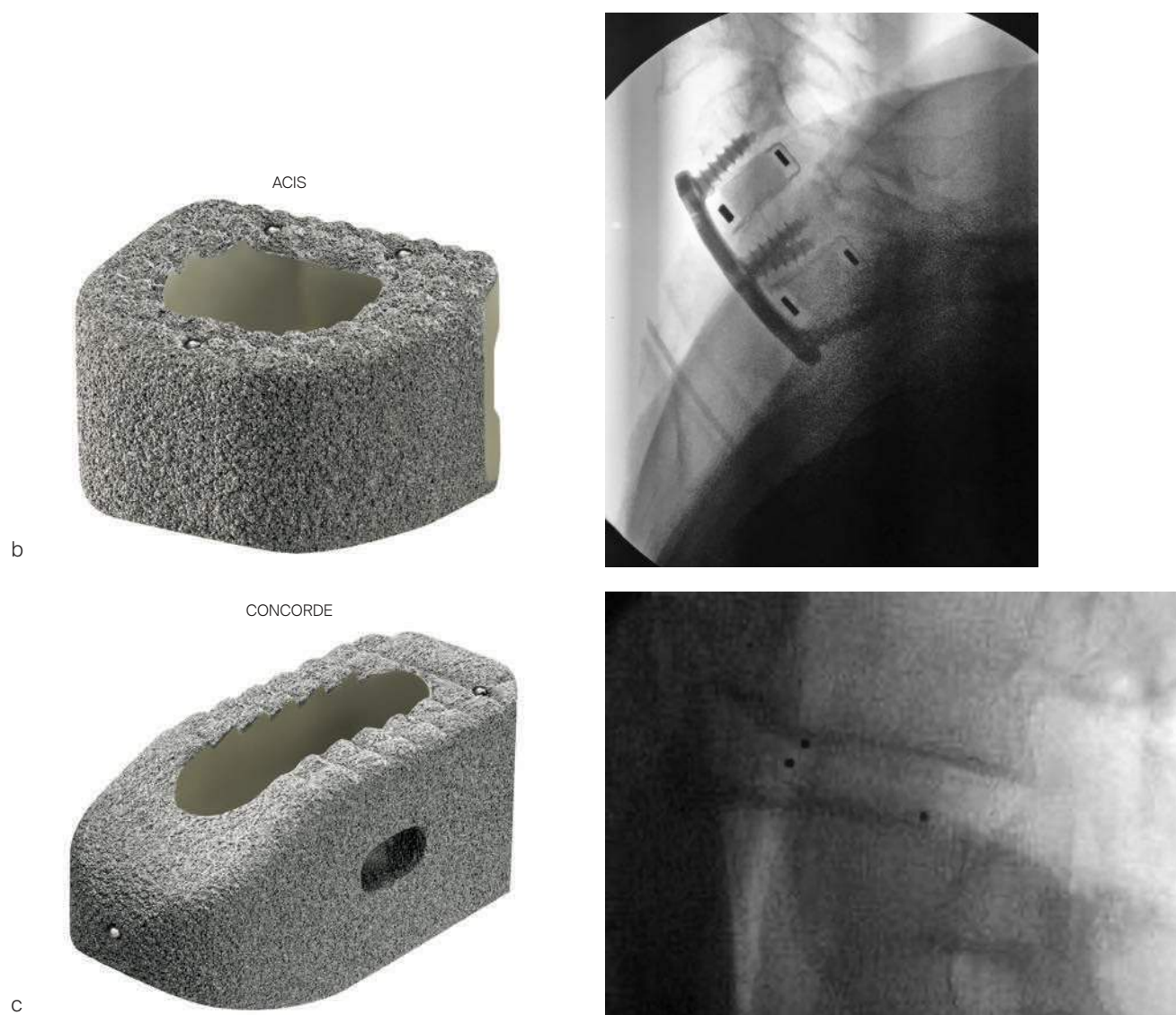


Fig 7a-c (cont) C-arm images showing the appearance of the T-PAL (a), ACIS (b) and CONCORDE (c) PROTI 360°™ cages.

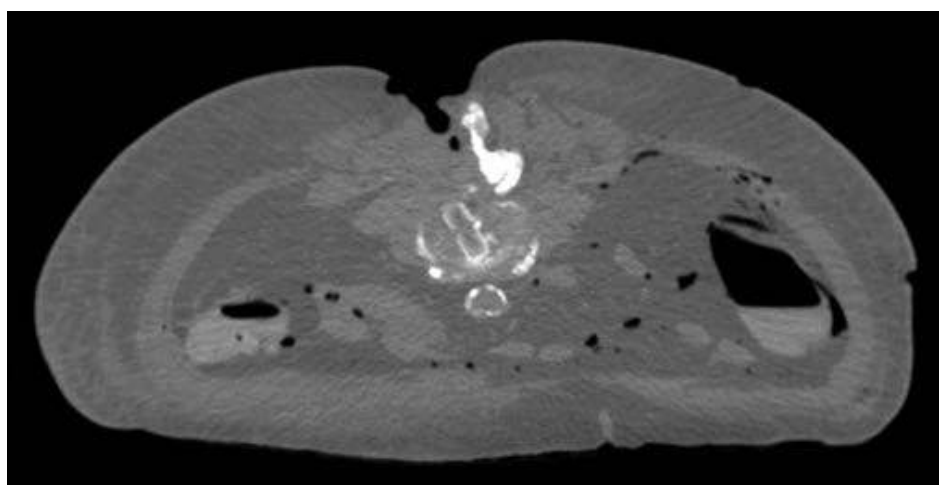


Fig 8 CT image showing the minimal scatter around the CONCORDE PROTI 360°™ implant.

Instrument sets and implants

The PROTI 360°™ cages are available as sterile implants and are compatible with ACIS System (Fig 9a), T-PAL Interbody System (Fig 9c), and CONCORDE Bullet (Fig 9b) instrument sets.

The ACIS implants are available in 5–10 mm heights, in Lordotic Small, Standard, and Large designs and in Parallel Standard or Convex Standard. The CONCORDE implants are available in Parallel and Lordotic designs (7–15 mm heights, 23 and 27 mm lengths). The T-PAL implants are available in the High Curve design (7–15 mm heights, 10 × 28, 12 × 32 footprints).



Fig 9a–c (a) ACIS System instrument; (b) CONCORDE Bullet instrument; and (c) T-PAL Interbody System instrument.

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Symphony Occipito-Cervico-Thoracic System

The Symphony Occipito-Cervico-Thoracic System (Fig 1 and Fig 2) is an enhanced set of instruments and implants for posterior fixation of the upper (cervico-thoracic) spine. The Symphony System consists of polyaxial screws, 3.5 mm and 4.0 mm rods, compatible hooks, cross connectors, lateral offset connectors, and rod connectors designed for posterior stabilization of the upper spine (Fig 3). The implants provide the flexibility required to accommodate variations in patient anatomy.

Symphony is intended for use in posterior cervical fusion (PCF) surgery for the treatment of various cervical spine diseases including myelopathy, kyphosis, radiculopathy, deformity cases, and spinal cord injury. These spine diseases represent a major health concern and are associated with a substantial socioeconomic burden [1]. While treatment options include fusion and non-fusion procedures, the total number of PCF procedures undertaken annually is increasing [1]. The complexity of patient cases treated with PCF is also higher: there is a growing need for longer constructs extending to the thoracic region and PCF is often paired with anterior fusion surgery. Symphony

is designed to reduce the complexity of PCF procedures; to reduce the risk of surgical complications and to improve patient outcomes.

The Symphony System offers a solution for unmet clinical needs in fixation in poor bone quality, deformity correction and revision surgery, while retaining the best features of Mountaineer and Synapse.

Fixation

Poor bone quality is an increasing challenge for surgeons [1], as older patients are increasingly meeting the indications for PCF surgery. Screw failure is a common issue (~ 5.2/patient) in PCF, and patients with poor bone quality are likely to be at greater risk [2, 3]. About 95% of surgeons have observed lateral-mass screw loosening or pull out [2, 3]. The anatomically specific screws and thread forms found within the Symphony System allow for stronger fixation in poor quality bone and may reduce revisions and complications associated with screw loosening or pull out.

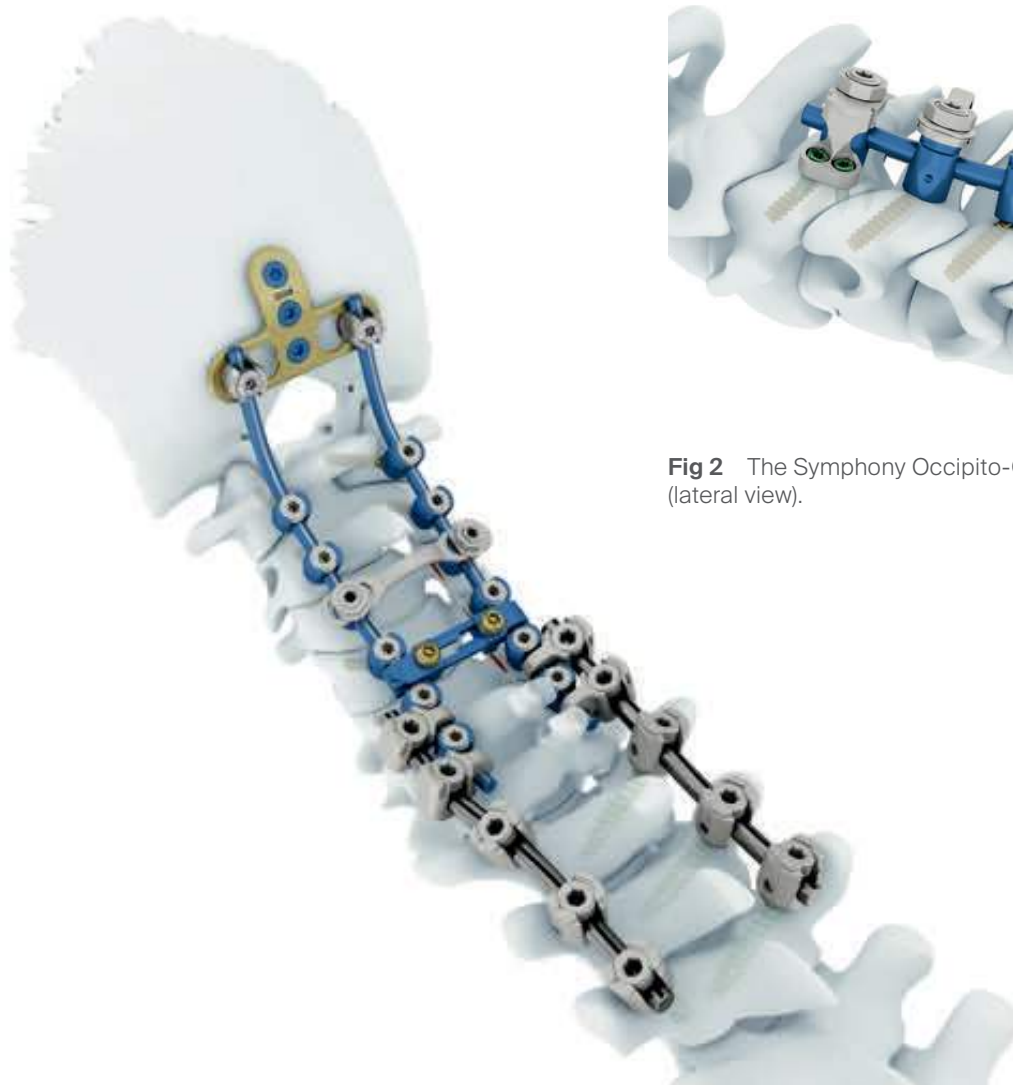


Fig 1 The Symphony Occipito-Cervico-Thoracic System.



Fig 2 The Symphony Occipito-Cervico-Thoracic System (lateral view).

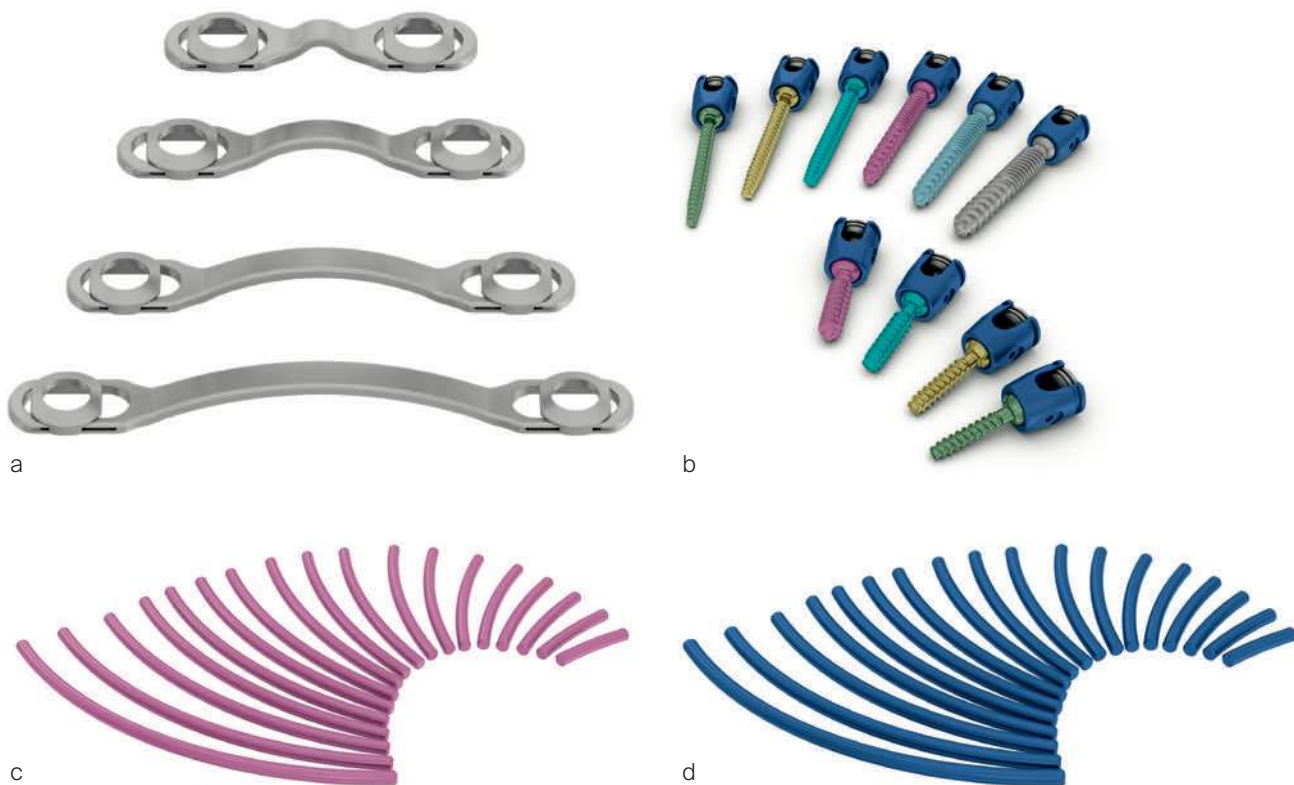


Fig 3a–d Symphony components include cross connectors (a), polyaxial screws (b, upper row), polyaxial lateral mass screws (b, lower row), 3.5 mm rods (c), and 4.0 mm rods (d).

Alignment

In terms of patient outcomes, improvements in regional cervical alignment following deformity correction correlate with an improvement in health-related quality of life (HRQoL) post-operatively [4]. There is a clear need for advanced instrumentation and stronger rods/materials to achieve the desired alignment in the surgical treatment of deformity [4]. Symphony offers stronger and stiffer constructs in the form of 3.5 and 4.0 mm cobalt-chromium rods that are biomechanically superior to titanium equivalents. Furthermore, Symphony offers a single system to cross the cervical-thoracic junction, thereby reducing the complexity of the surgical procedure. Within the Symphony System, screws are available in diameters from 3.5 mm to 5.5 mm, allowing for more stable fixation.

Surgical revision

The number of posterior cervical revision surgeries undertaken globally is increasing (2%–27% at 41.3 months) [5]. Surgical revisions, specifically the extension of previous posterior cervical constructs, are challenging and can be invasive for the patient [5]. Use of the Symphony Universal Connectors allows the size of the surgical incision to be significantly reduced. Furthermore, the Universal Connectors accept multiple sizes of rods (3.5–6.35 mm) and can connect to existing systems. This feature allows existing hardware to be extended rather than removed and replaced, thereby reducing surgical complexity and the duration of the revision procedure. The reduced operating room time offers both improved patient outcomes and economic savings for the hospital system.

Symphony offers a variable and comprehensive set of instrumentation and implants with a sterile packed option. This allows surgeons to handle cases of increasing complexity

while simplifying instrumentation handling by operating room staff and reducing reprocessing costs [6].

Indications

The Symphony System is intended to provide immobilization and stabilization of spinal segments as an adjunct to fusion for acute and chronic instabilities of the cranio-cervical junction, the cervical spine (C1 to C7) and the upper thoracic spine (T1–T3).

Indications include traumatic spinal fractures and/or traumatic dislocations, instability or deformity, failed previous fusions (eg, pseudarthrosis), tumors involving the cervical/thoracic spine, degenerative disease, including intractable radiculopathy and/or myelopathy, neck and/or arm pain of discogenic origin as confirmed by radiographic studies, and degenerative disease of the facets with instability.

The Symphony System is also intended to restore the integrity of the spinal column even in the absence of fusion for a limited time in patients with advanced stage tumors involving the cervical spine, in whom life expectancy is of insufficient duration to permit achievement of fusion.

The Symphony System is compatible with occipital fusion components (plates, rods, and clamps) from the Synapse Occipital-Cervical-Thoracic System and the Mountaineer Spinal System. Additionally, the Symphony System is compatible with Synapse System hooks and rods.

The Songer Wire/Cable System to be used with the Symphony System allows for wire/cable attachment to the posterior cervical spine.

The Symphony System may be connected to the Expedium Spine System and Viper System using connectors and tapered rods. Symphony can also be linked to the USS Spinal System and Matrix Spine System using connectors and tapered rods.

Contraindications

- Active systemic infection or an infection localized to the site of the proposed implantation
- Severe osteoporosis may prevent adequate fixation of screws and thus preclude the use of this or any other spinal instrumentation system
- Patients who have been shown to be safely and predictably treated without internal fixation
- Open wounds

Relative contraindications

Relative contraindications include any entity or condition that totally precludes the possibility of fusion (eg, kidney dialysis or osteopenia), obesity, certain degenerative diseases, and foreign body sensitivity.

References

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New CMF Distractor System

Background

Craniomaxillofacial (CMF) distraction is used for lengthening or bone transport to correct congenital deficiencies or acquired (posttraumatic, post-surgical, or post-infectious) defects in the cranium (Fig 1), the mandible (Fig 2), or the midface. Gradual expansion allows for new bone formation and soft-tissue adaption both in pediatric and adult patients. With existing systems three main issues have raised concerns. The possibility of wrong activation of the system, the inadvertently movement by the system and difficult screw engagement and removal.

The new CMF Distractor is visually like the old system, except that the distraction bodies are approximately 5 mm longer.

Important new features include:

1. New ratcheting mechanism
The new CMF Distractor has a spring clip (detent tab) to avoid inadvertently reversed movement of the distractor. In addition, the new Patient Activation Instrument contains a one-way ratchet clicking when turned in the wrong direction. With these new features the distractor movement is well controlled and if used correctly will produce reliable results.
2. Raised Head Screws
In addition to the regular Plus-Drive Screws provided with the CMF Distractor, new Raised Head Screws are available for easier removal. These Raised Head Screws incorporate both a Hex-Drive and a Plus-Drive in the same screw head, with the Hex-Drive screwdriver having a tapered fit allowing for the same retention force as in the Plus-Drive system.

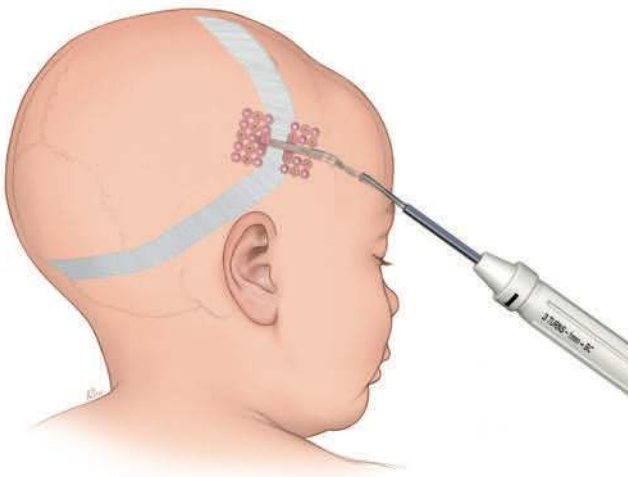


Fig 1 Cranium expansion.



Fig 2 Mandible correction.

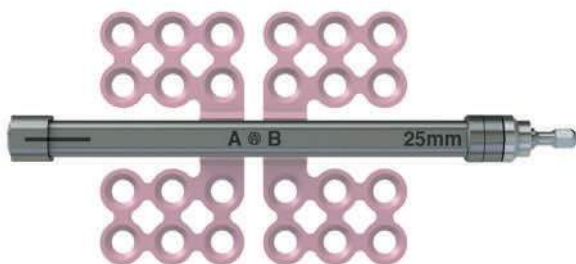


Fig 3 AB Body with footplates attached.

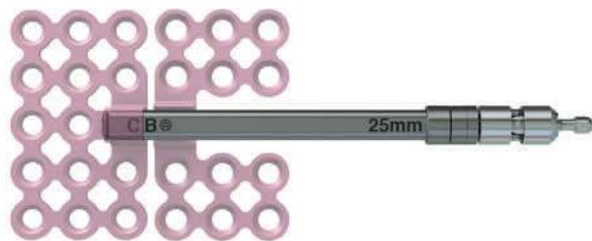


Fig 4 BC Body with footplates attached.



Fig 5 New Raised Head Screws.

LCP Distal Femur Plate for veterinary applications

Background

Comminuted fractures of the proximal phalanx (P1) are common injuries in horses. All breeds and all activities are affected. The degree of comminution varies but many are so highly comminuted that fracture reconstruction is not feasible. Currently, the recommended treatment for horses suffering from a highly comminuted P1 fracture is to immobilize the distal limb in a transfixation cast. However, the prognosis for survival is guarded and complications are common, including progressive arthropathy of the metacarpophalangeal/metatarsophalangeal and proximal interphalangeal joints as well as support limb laminitis.

Plate design

The LCP Distal Femur Plate (DFP) is a precontoured, low profile plate that features combi-holes along the shaft accepting 4.5 mm/5.5 mm cortex screws in the dynamic compression unit portion and 5.0 mm locking screws in the threaded portion (Fig 1). The threaded locking holes in the plate head accept 5.0 mm locking screws and 4.5 mm/5.5 mm cortex screws. The LCP DFP, available in a left and a right version, was initially indicated for distal shaft, supracondylar, intraarticular, extraarticular, and periprosthetic fractures in the human femur. Implants and instruments of the LCP DFP are fully compatible with the 4.5/5.0 mm LCP Systems.

Recently, the LCP DFP (9- and 11-holes, left and right) has been approved for veterinary applications, specifically for comminuted P1 fractures in horses.

- 9-hole plate (236 mm)
- 11-hole plate (276 mm)

The wide and flattened head of the plate has several locking holes which provides a strong fixation in the proximal aspect of the middle phalanx (P2) and the distal aspect of the P1, distal to the area of major comminution. Furthermore, the curved shape allows abaxial fixation into one of the major fragments in P1 or in the medial or lateral condyle of the distal metacarpus/metatarsus when associated with a concomitant condylar fracture. The low profile of the plate permits placement using less invasive fixation techniques.

Clinical cases

The two following cases (both kindly provided by Fabrice Rossignol, Paris, France) demonstrate the surgical procedure which relies on biological osteosynthesis principles with the plate, used as an internal fixator, providing an angle stable construct and durable bridging of the fractured P1. Long-term follow-up regarding biomechanical impact on the distal interphalangeal joint is still required. However, the horses treated thus far have adapted well.

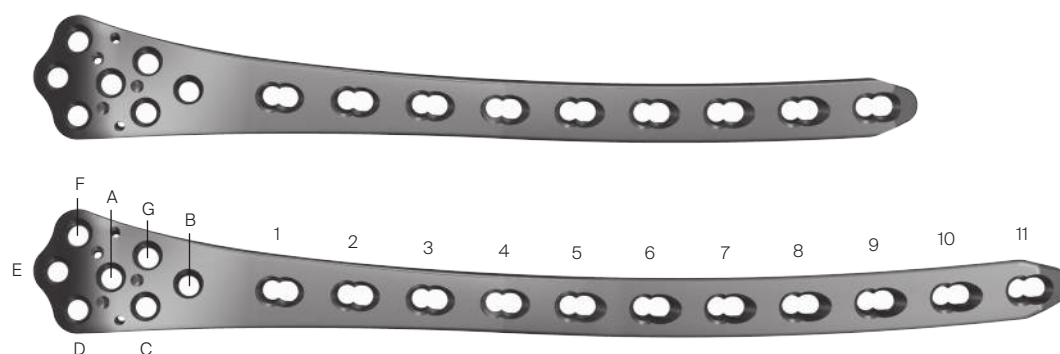


Fig 1 A 9-hole and 11-hole LCP DFP with its hole labeling.

Case 1: Comminuted P1 fracture in a 14-year-old warmblood mare

A 14-year-old Belgian warmblood mare weighing 520 kg was presented with a medical history of severe right forelimb lameness following an unwitnessed paddock injury. Radiographs confirmed a highly comminuted fracture of P1. A distal limb bandage had been applied in an attempt to stabilize the injury before transporting the mare.

Radiographic evaluation at the time of admission confirmed the highly comminuted fracture configuration and revealed considerable collapse of P1 with malalignment and overriding of the fracture fragments (Fig 2). Due to the highly unstable nature of the injury and the presence of multiple sharp fracture fragments, the immediate concern was the potential for skin penetration and conversion to an open fracture. Consequently, the mare was placed under general anesthesia to facilitate indirect fracture reduction through traction on the distal limb. Once alignment was confirmed radiographically, the distal limb was stabilized by application of a fiberglass cast extending distally from the proximal metacarpus and incorporating the hoof.

Following recovery from anesthesia, the mare was placed in intensive care for 24 hours to stabilize her physiological status before surgical fixation. Bridging plate fixation of the comminuted P1 fracture in conjunction with arthrodesis of the metacarpophalangeal and proximal interphalangeal joints was accomplished using an LCP DFP (11-holes). Prior to fixation, articular cartilage was debrided from the articulations using a 4.5 mm drill bit and curettes passed through stab incisions. The frontal plane fracture in the proximal aspect of P1 was reduced and stabilized with 5.5 mm cortex screws placed in lag fashion from dorsal to palmar in a slightly distal to proximal orientation.

The plate was contoured to the desired 15° of dorsiflexion at the level of the fetlock joint to provide an appropriate joint angle (Fig 3a). Three, approximately 4 cm long dorsal midline incisions were performed through the skin and extensor tendon at the level of the proximal end of the plate, the metacarpo-

phalangeal joint, and at the distal end of the plate overlying the proximal interphalangeal joint. Using a combination of sharp dissection and a large periosteal elevator, a tunnel was created between the bone and overlying soft tissues including the extensor tendon. The plate was inserted into the tunnel and appropriate plate positioning, and cortical alignment were confirmed radiographically. A Push-Pull Reduction Device was placed through hole (A) in the head of the plate at the level of the proximal interphalangeal joint to compress the plate onto the dorsal cortices of the phalanges and maintain alignment of the proximal interphalangeal joint. Five 5.0 mm locking screws were inserted in the expanded head of the plate to purchase the distal aspect of P1 and the proximal aspect of P2. To ensure plate-bone contact proximally, two 5.5 mm cortex screws were placed into the distal aspect of the metacarpus (plate shaft holes 4 and 5). The remaining holes overlying the metacarpus were filled with 5.0 mm locking screws; where possible, 4.5 mm cortex screws were placed through the plate overlying large fragments of the P1. Finally, two 5.5 mm cortex screws were placed in lag fashion abaxial to the plate to engage the medial and lateral proximal sesamoid bones (Fig 4). Screws placed outside of the dorsal midline incisions were placed through additional stab incisions.

The incisions were closed routinely (Fig 3b). The distal limb was placed in a cast, and the patient was assisted in recovery. Surgery time, including casting, was 310 minutes.

The cast was changed 2 weeks postoperatively and removed 1 month following the repair. The distal limb was maintained in a Robert-Jones bandage for 1 additional month. Routine hoof care in conjunction with rocker shoes and silicone padding were initiated at the time of cast removal. The mare made excellent progress postoperatively and was fully weight bearing on the repaired leg immediately. Radiographic evaluation 5 months postoperatively confirmed good fracture healing and progression of the arthrodesis (Fig 5). The mare was returned to paddock activity at this time and was fully functional with only mild mechanical lameness, as expected with arthrodesis of the metacarpophalangeal joint.



Fig 2a-d Preoperative x-rays: (a) dorso-palmar, (b) latero-medial, (c) dorso-lateral, (d) dorso-medial views.



Fig 3a-b Placement of the plate above the skin to determine the level of bending (**a**); aspect before suturing (**b**).



Fig 4a-d Postoperative x-rays: (**a**) dorso-palmar, (**b**) latero-medial, (**c**) dorso-lateral, (**d**) dorso-medial views.



Fig 5a-d Postoperative x-rays at 5 months: (**a**) dorso-palmar, (**b**) latero-medial, (**c**) dorso-lateral, (**d**) dorso-medial views.

Case 2: Comminuted P1 fracture in a 10-year-old warmblood gelding horse

A 10-year-old French warmblood gelding weighing 580 kg was presented a few hours after developing a severe left forelimb lameness following an unwitnessed paddock injury. Initial radiographs demonstrated a severely comminuted, minimally displaced fracture of P1 (Fig 6). The distal limb was immediately placed in a fiberglass cast by the referring veterinarian before transporting the horse, which prevented further displacement of the fragments.

The day following admission, the horse was placed under general anesthesia and bridging plate fracture fixation/arthrodesis was accomplished using an 11-hole LCP DFP as described in case 1. Surgery time was 315 minutes.

Postanesthetic myopathy complicated the patient's recovery and necessitated intensive care immediately following surgery. He responded to supportive therapy and improved rapidly. In addition, his comfort level was excellent on his operated leg for the duration of hospitalization. At 3 months postoperatively, clinical evaluation revealed excellent weight bearing on the operated leg

(Fig 7a), with mechanical lameness characteristic of horses with a fused metacarpophalangeal joint. The cosmetic appearance of the distal limb was excellent (Fig 7b–c). Radiographic examination demonstrated excellent fracture healing with ongoing progress of the arthrodesis in both articulations (Fig 8). He was shod with rocking shoes and silicone padding on both front feet to facilitate mobility and to provide hoof support.

Biological bridge plating using the human LCP DFP can provide a better alternative to a transfixation cast for surgical management of highly comminuted fractures with fewer complications and better long-term outcomes. The above-mentioned cases are excellent examples of the utility of the LCP DFP for managing catastrophic P1 injuries in adult horses. The fixation allows an early return to weight bearing on the affected limb and thus mitigates complications, such as support limb laminitis, associated with severe, protracted lameness. Furthermore, it limits the duration of external coaptation minimizing the negative effects of long-term cast application. Finally, arthrodesis of the metacarpophalangeal/metatarsophalangeal and proximal interphalangeal joints prevents chronic pain and long-term disability secondary to osteoarthritis.



Fig 6a–d Preoperative x-rays: (a) dorso-palmar, (b) latero-medial, (c) dorso-lateral, (d) dorso-medial views.



Fig 7a-c Good weight bearing on the operated leg (a) and good cosmetic aspect (b-c).

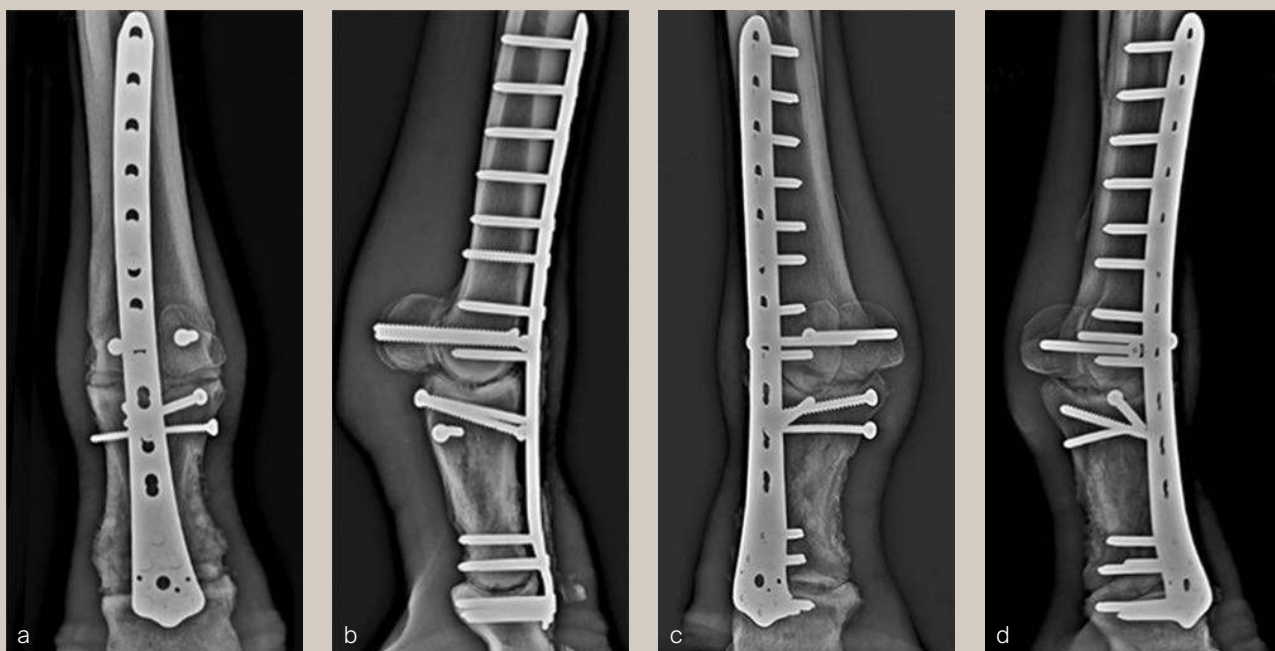


Fig 8a-d Postoperative x-rays at 3 months: (a) dorso-palmar, (b) latero-medial, (c) dorso-lateral, (d) dorso-medial views.

Impact of RIA diameter on femoral bone strength, fracture geometry, and amount of harvested bone graft

Background

Treatment of large bone defects is still related to unsolved problems in orthopedic trauma surgery. Currently, the use of autogenous bone graft harvested from the iliac crest is the gold standard to fill such defects. However, this procedure is associated with complications and postoperative morbidities. Minimally invasive intramedullary reaming with the use of the Reamer-Irrigator-Aspirator (RIA; see also the article 'RIA 2 System: New Generation Reamer-Irrigator-Aspirator in this Innovations magazine) device allows autograft harvesting of large bone graft amounts from the medullary canal of the femur. The aim of this study was to investigate the impact of RIA diameter on femoral bone strength, reaming and fracture geometries, and the amount of harvested bone graft in a human anatomical model.

Methods

Forty-five pairs fresh-frozen human femora were randomized to three paired groups with 15 pairs each. One femur of each pair was reamed with RIA at a diameter of either 1.5 mm (group 1), 2.5 mm (group 2), or 4.0 mm (group 3) larger than its isthmus, whereas its contralateral femur was left intact without reaming.

Next, all specimens were destructively tested in internal rotation under 750 N axial compression to calculate their torsional stiffness and torque at failure (Fig 1). Reaming and fracture geometries were visualized by means of computed tomographic scanning (Fig 2) and amount of the harvested bone graft was determined.

Results

Significant reduction in torsional stiffness was detected after reaming in group 3, but not in groups 1 and 2. Torque at failure was significantly reduced after reaming in each of the 3 groups. In addition, the decrease in cortical thickness within the region of most reaming was significantly bigger in group 3 compared with groups 1 and 2. Finally, collected bone graft amount in group 3 was significantly bigger compared with groups 1 and 2.

Conclusions

Reaming with RIA diameter of 4 mm larger than the isthmus of the femur seems to influence considerably its torsional stability and fracture characteristics; however, it allows harvesting of a significantly higher amount of bone graft.

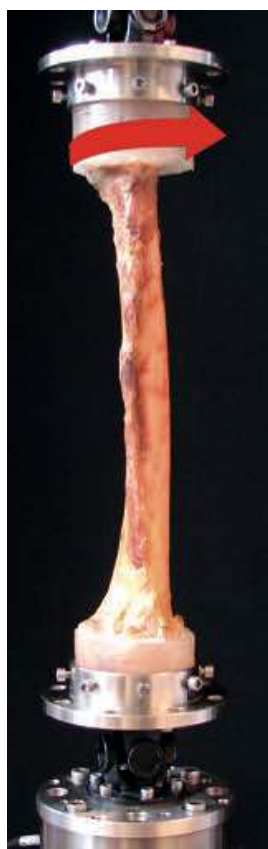


Fig 1 Setup with a specimen mounted for biomechanical testing.

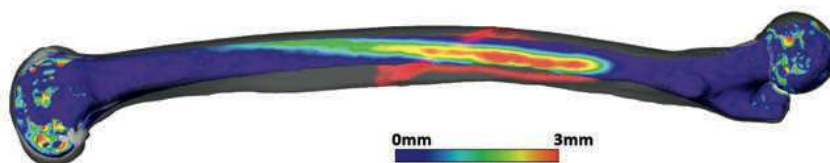


Fig 2 Visualization of the reamed bone in the femoral shaft (rainbow color map) with overlay of the fracture pattern (red) after biomechanical testing.

Computational simulation tools for validated virtual bone and fracture fixation biomechanics

Being increasingly applied in the field of biomechanics, computational modeling via finite element (FE) simulations allows virtual testing of bones and fracture fixations with different configurations under various loading conditions reflecting realistic physiological situations. It can complement or replace experimental testing with its abilities to:

- Accurately describe the biomechanical behavior of the subjects under investigation
- Save time, costs, and human anatomical test material and its surrogate
- Perform parametric investigations via systematic analysis of selected parameters while keeping all other aspects unchanged to avoid the influence of confounding factors
- Analyze many subjects in a semi-automated or fully automated fashion
- Provide insights into details that remain inaccessible in real experiments

The FE simulations are increasingly used and enhance the design process during the development of orthopedic implants. Regulatory authorities, such as the US Food and Drug Administration, have already accepted their use in the course of medical device certification [1].

Prediction of fracture risk is another clinically relevant aspect where computational modeling is utilized with success. By incorporating subject-specific information about bone geometry, structure, and material properties based on computed tomographic data, FE models can predict fracture load more accurately than bone density-related measures at various anatomical locations, including proximal femur, vertebral bodies, and distal radius [2].

In the future, FE simulations are expected to enhance the understanding of fracture fixation biomechanics and failure, and to contribute to improved surgical guidelines, advanced training, and education. The ability of patient-specific modeling and prediction of treatment outcomes in terms of success

or failure are envisioned to open new possibilities. Computational simulations may be utilized in preoperative planning to identify the best individualized treatment method for a given patient. The surgical decision-making process could be aided by defining the specific intraoperative requirements to avoid fixation failure and by alerting the surgeon in case these cannot be addressed, so that alternative treatment options could be considered. Moreover, *in silico* trials are anticipated to partially or fully replace some preclinical and clinical investigations on medical devices, while reducing the number of subjects included. All these applications of computational simulations are foreseen to help reducing the complication rate in fracture treatment.

However, being abstractions of reality with their complexity adjusted to the investigated problem, the creation of FE models and the corresponding analysis require appropriate expertise and thoroughness. Most importantly, the correctness of the results must be ensured. Therefore, a prerequisite for the successful application of these models is their prior careful validation [3], being usually performed via direct comparison with experimental testing.

Considering the contemporary trends in the increased use of computational simulations, the AO Research Institute Davos (ARI) uses complex computational modeling and analysis according to a general approach (Fig 1) in various projects including:

- Virtual biomechanical comparison of different implant fixations
- Systematic investigation of proximal humerus plating [4]
- Prediction of the femoral bone strength and fracture mechanism in sideways falls [5]
- Analysis of prophylactic augmentation effectivity with the use of bone cements [6]
- Evaluation of the biomechanics of modulated bone growth [7]
- Prediction of bone fracture risk in dental implantation surgeries [8]

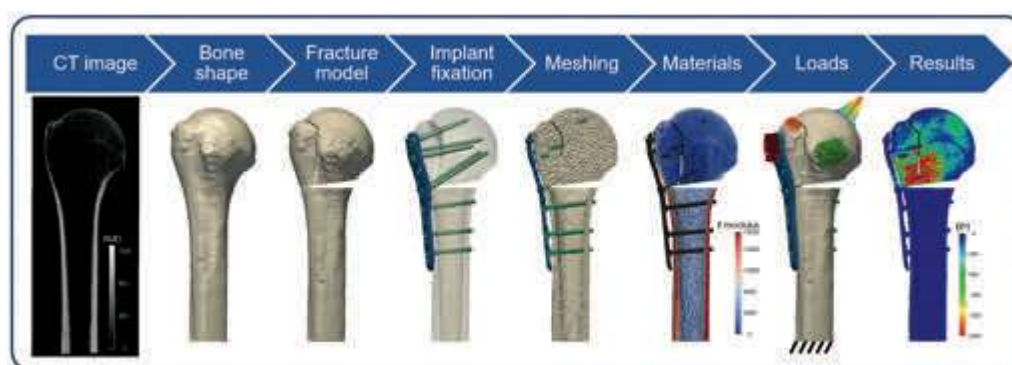


Fig 1 Computational simulation workflow as exemplified for locked proximal humerus plating.

Regarding the systematic investigation of proximal humerus plating, a virtual osteosynthesis test kit has been developed and validated in ARI to investigate various implant-related aspects for this challenging anatomical site. The tool is designed to facilitate efficient and systematic FE simulations of the virtual biomechanical behavior of locking plate fixations on a set of digital proximal humerus models that can be virtually osteotomized to replicate fractures with different level of complexity and stability. The created virtual fracture models can be fixed with locking plates in adjustable implant configurations, and subjected to various experimental or physiological loading scenarios [4] (Fig 2). The underlying FE methodology has been validated by demonstrating that the simulations could accurately predict the experimental cyclic cut-out failure after PHILOS plating of unstable three-part fractures [9]. This prediction has proven to be more accurate than those based on bone density measures [10]. The virtual osteosynthesis test kit has been used to explore various aspects of locking plate fixation, such as plate positioning [11], screw length [12], and configuration [13], screw augmentation with bone cement, and comparison of different locking plates. Clinical validation of the FE methodology is currently ongoing in the frame of a clinical trial with the aim to predict the patient-specific risk of mechanical fixation failure in patients with proximal humeral fracture treated with PHILOS plate. A similar modeling strategy can be developed for other skeletal sites where fracture treatment has remained challenging, such as the distal femur (see also the article Improving the Treatment of Complex Distal Femoral Fractures in this Innovations magazine) and proximal tibia.

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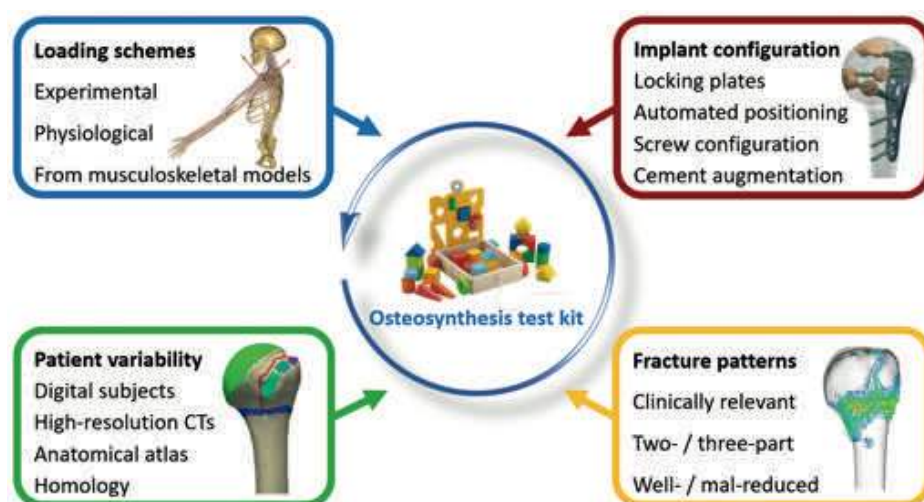


Fig 2 The virtual osteosynthesis test kit concept for the proximal humerus.

Better stability and more predictive fixation with the Femoral Neck System versus two Hansson pins in Pauwels II fractures

Background

Femoral neck fractures account for half of all hip fractures and are recognized as a major public health problem associated with a high socioeconomic burden. Although internal fixation is preferred over arthroplasty for physiologically younger patients, a consensus has not yet been reached about the optimal fixation device.

The Femoral Neck System (FNS)—developed for dynamic fixation of femoral neck fractures—features angular stability in combination with a minimally invasive surgical technique (Fig 1). The implant system was approved by the AO Technical Commission Trauma and launched end of 2017 (see *Innovations magazine* 2017). The placement of its dynamic bolt and antirotation screw, which may slide together over 20 mm, is facilitated by an insertion handle. Alternatively, the Hansson Pin System (HPS) with two parallel pins exploits the advantages of internal buttressing. However, the oblique peripheral placement of the pins, adjacent to the inferior and posterior femoral neck cortex, makes the instrumentation more challenging.

Previous work reported superior biomechanical FNS performance over three cannulated screws in unstable Pauwels III fractures involving inferior and posterior comminution [1]. Considering the pinning HPS principle, higher FNS stability

may be anticipated over the former. However, the preferred HPS application in more stable Pauwels II fractures with calcar support has not been compared with FNS yet. Therefore, the aim of this study was to evaluate the biomechanical performance of FNS versus HPS in a Pauwels II fracture model with simulated posterior comminution.

Methods

Forty-degree Pauwels II fractures AO/OTA 31-B2.1 with 15° posterior wedge were simulated in 14 paired human anatomical femora, instrumented with either FNS or HPS in pair-matched fashion (Fig 2). Implant positioning was quantified by measuring the shortest implant distances to inferior cortex (DI) and posterior cortex (DP) on anteroposterior and axial x-rays, respectively. Biomechanical testing was performed in 20° adduction and 10° flexion of the specimens using a novel setup with simulated iliopsoas muscle tension (Fig 3). Progressively increasing cyclic loading was applied until construct failure. Interfragmentary femoral head-to-shaft movements were determined in terms of varus deformation, femoral neck dorsal tilting, and rotation around neck axis by means of motion tracking. All interfragmentary movements were analyzed and compared between the two implants. In addition, the influence of implant placement on varus deformation and dorsal tilting was investigated.

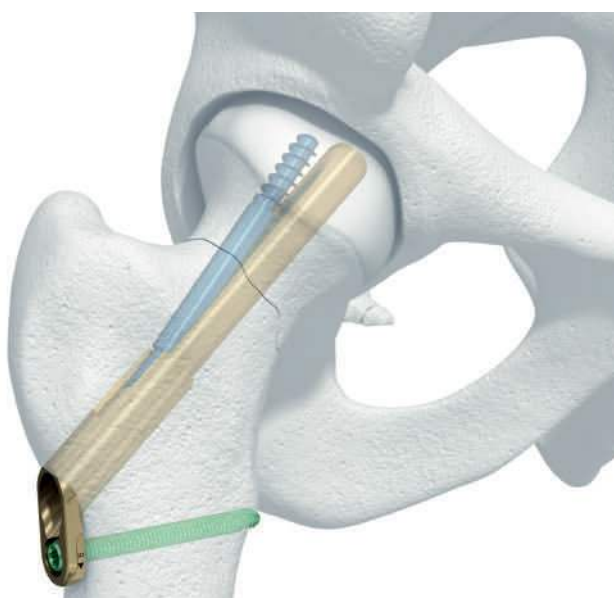


Fig 1 The Femoral Neck System implant for dynamic fixation of femoral neck fractures featuring angular stability in combination with a minimally invasive surgical technique.

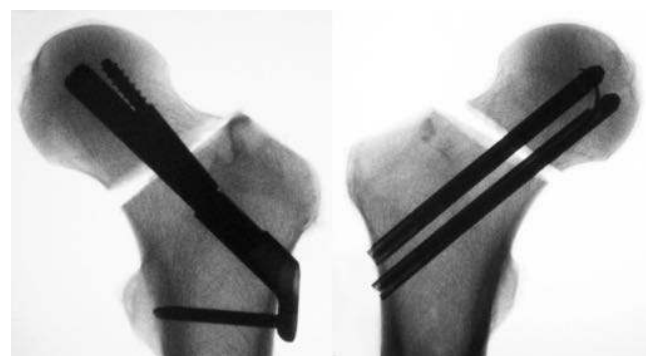


Fig 2 Anteroposterior radiographs of paired proximal femora instrumented with FNS (left) and HPS (right).

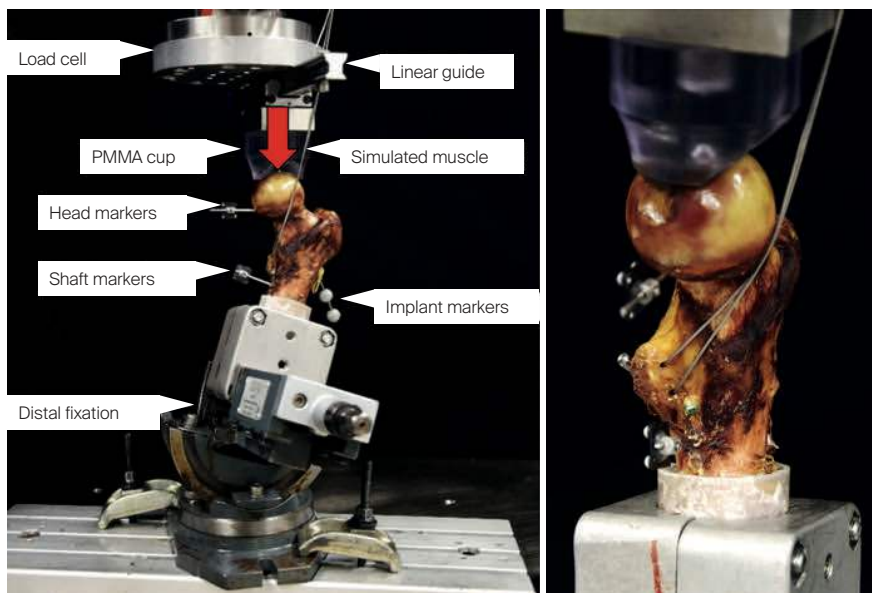


Fig 3 Setup with a specimen mounted for biomechanical testing. Left: anterior view with vertical arrow indicating loading direction; right: posteromedial view showing simulated iliopsoas muscle.

Results

Cycles to 5° and 10° varus deformation were significantly higher for FNS (22490 ± 5729 and 23007 ± 5496) versus HPS (16351 ± 4469 and 17289 ± 4686), $P \leq .043$. Cycles to 5° and 10° dorsal tilting (FNS: 10968 ± 3052 and 12765 ± 3425 ; HPS: 12244 ± 5895 and 13357 ± 6104) and cycles to 5° and 10° rotation around the femoral neck axis (FNS: 15727 ± 7737 and 24453 ± 5073 ; HPS: 15682 ± 10414 and 20185 ± 11065) were not significantly different between the implants, $P \geq .314$. For HPS, varus deformation and dorsal tilting correlated significantly with DI and DP ($P \leq .025$), whereas these correlations were not significant for FNS ($P \geq .148$).

Conclusions

From a biomechanical perspective, by providing better stability against varus collapse and less sensitivity to variations in implant placement, the angular stable Femoral Neck System can be considered as a valid alternative to the Hansson Pin System for treatment of Pauwels II femoral neck fractures.

Reference

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Assessing screw tightness and stripping rates achieved by orthopedic trauma surgeons and researchers

Background

Screws are the most commonly used orthopedic implants. Despite their frequent use, nearly one in four nonlocking screws irreparably damage the surrounding bone because of excessive tightening and stripping [1], reducing construct strength by more than 80% [2]. Screw tightness is controlled manually based on the surgeon's subjective assessment of the required torque. Limited data exist on screw tightness commonly achieved by surgeons and how it is affected by different variables, such as screw diameter. Moreover, no studies exist specifically assessing screw-tightening skills of researchers who are experienced to insert screws in a laboratory environment.

Therefore, the aims of this study were to: (1) identify the achieved screw tightness for orthopedic trauma surgeons and researchers; (2) measure the effect on tightness using different screw diameters in plate fixation or individual screw placement with a washer; (3) measure the rate of bone stripping during screw insertion; (4) assess for any dependence between confidence in screw purchase and bone stripping (yes/no), including the success rate in predicting whether the bone was stripped or not; and (5) identify the impact of using an augmented screwdriver indicating optimum torque.

Methods

Ten orthopedic trauma surgeons who are medical research fellows in the AO Research Institute Davos (ARI) and ten researchers participated in the study. Each participant inserted 60 cortex screws for each of three screw diameters—2.7, 3.5, and 4.5 mm—into artificial bone sheets of 4 mm thickness, 0.32 g/cm³, mimicking cancellous bone. Half of the screws were inserted through correspondingly sized plate LC-DCP and half as individual screws with a washer. Each screw was tightened to what the participants determined as optimal tightness. A digital torque screwdriver was used to record stopping torque, with the participant blinded to its display. A confidence value between 1 and 10 was reported for each screw: 1 for no confidence, and 10 for maximum confidence. Screws were then inserted until the stripping torque—

defined as maximum recorded value—was achieved, allowing calculation of tightness as the ratio between stopping and stripping torque. Three surgeons and three researchers then inserted thirty 3.5 mm screws each through LC-DCP, using an augmented screwdriver indicating when the predicted optimum torque—defined as 80% of the average maximum torque from the previous 3.5 mm screw insertions—was reached. Statistical analysis was performed at level of significance $P = .05$.

Results

Combining all screw diameters and insertion conditions, tightness for unstripped screws inserted by surgeons and researchers was $85 \pm 2\%$ and $78 \pm 3\%$, respectively ($P < .001$; Fig 1). Tightness was significantly less for screws inserted through fixation plates to those inserted through washers for researchers ($P < .001$) but not for surgeons ($P = .129$). Collectively, surgeons stripped 48% of the inserted screws (range: 16–95%), while researchers stripped 22% (range: 3–69%) ($P < .001$). Average reported confidence in screw purchase when the materials were unstripped and stripped were seven and six for surgeons ($P < .001$), and seven and five for researchers ($P < .001$), respectively. Predictive rates for good and bad screw insertion are presented in Table 1. Using an augmented screwdriver did not affect screw tightness but did reduce stripping rates.

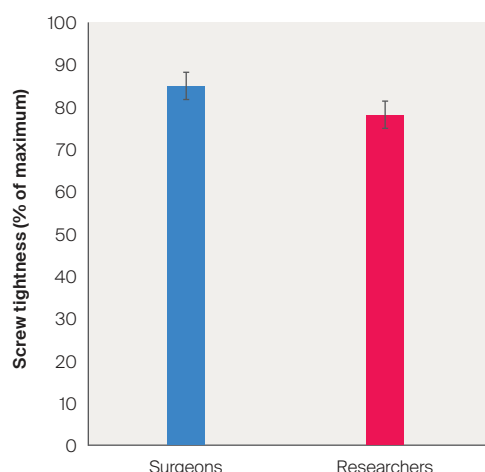


Fig 1 Tightness for unstripped screws of all diameters and insertion conditions.

	Surgeons	Researchers
Rate of correctly predicted good screw insertion (screw had not stripped bone)	58%	89%
Rate of correctly predicted bad insertion (screw had stripped bone)	77%	66%

Table 1 Predictive rates of good and bad screw insertion for surgeons and researchers.

Conclusions

Orthopedic trauma surgeons and researchers achieve different screw tightness under the same conditions, with surgeons applying more tightness to unstripped screws. However, surgeons stripped the material more than twice as often as researchers. Surgeons and researchers altered their reported confidence depending on whether screws had stripped the bone. Surgeons were more likely to detect overtightening by being able to assess better whether a screw had stripped the bone, whereas researchers were better at stating correctly when stripping had not occurred. Using a screwdriver, indicating when optimum torque is reached, reduces stripping rates while not affecting achieved tightness.

References

1. Fletcher JWA, Wenzel L, Neumann V, et al. Surgical performance when inserting non-locking screws—a systematic review. *EFORT Open Rev*. 2019; Epub ahead of print.
2. Fletcher JWA, Ehrhardt B, MacLeod A, et al. Non-locking screw insertion: no benefit seen if tightness exceeds 80% of the maximum torque. *Clin Biomech (Bristol Avon)*. 2019 Jul;70:40–45.

Focus registry study of the Femoral Neck System

Although the Dynamic Hip Screw (DHS) remains the gold standard for the fixation of unstable subcapital and transcervical femoral neck fractures, it requires an invasive approach. In addition, it may cause lateral thigh pain due to implant protrusion. The Femoral Neck System (FNS) was designed to address this issue. Furthermore, it is less invasive and has a smaller baseplate than the DHS. The FNS was approved by the AO Technical Commission for market launch in 2017 (see Innovations magazine 2017). In collaboration with AO Clinical Investigation and Documentation a registry (planned sample size: 112 patients) was started in 2018 with the primary objective to assess the short-term (within 3 months after the surgery) rate of defined surgical and mechanical complications. The maximum follow-up (FU) is 1 year after surgery, if radiological bone union is not achieved at 3 or 6 months or if the patient has persistent or increasing pain on the operated site. The secondary objectives included the collection of patient and surgical details, functional scores, as well as time to union and quality of life. The final study report for this registry is planned for the end of 2020.

Current status

As of March 2019, 95 patients had enrolled in the registry and 48 among them had reached the 3-month FU mark. Preliminary results showed that most patients (> 80%) received either very good or good quality of reduction and roughly three quarters of the patients achieved bone union at the 3-month FU according to the treating surgeon's assessment. Overall, patients showed prominent improvement in both functional and quality of life scores.

Case: 53-year-old man sustained right hip injury (provided by Christoph Sommer, Chur, Switzerland)

A 53-year-old man (active in cycling and other sports) had a fall during road cycling directly on his right hip. He sustained a displaced femoral neck fracture, classified as Garden III, Pauwels II-III (Fig 1). Due to the patient's relatively young age, a head-preserving procedure was chosen (Figs 2–4), knowing the moderate risk of a resulting avascular necrosis (AVN) in the future.



Fig 1a–b Conventional x-rays show a displaced medial femoral neck fracture, classified as Garden III and Pauwels II-III. Decision was made for fixation (young age, no pre-existing osteoarthritis, fit and sport active, biologically younger patient).

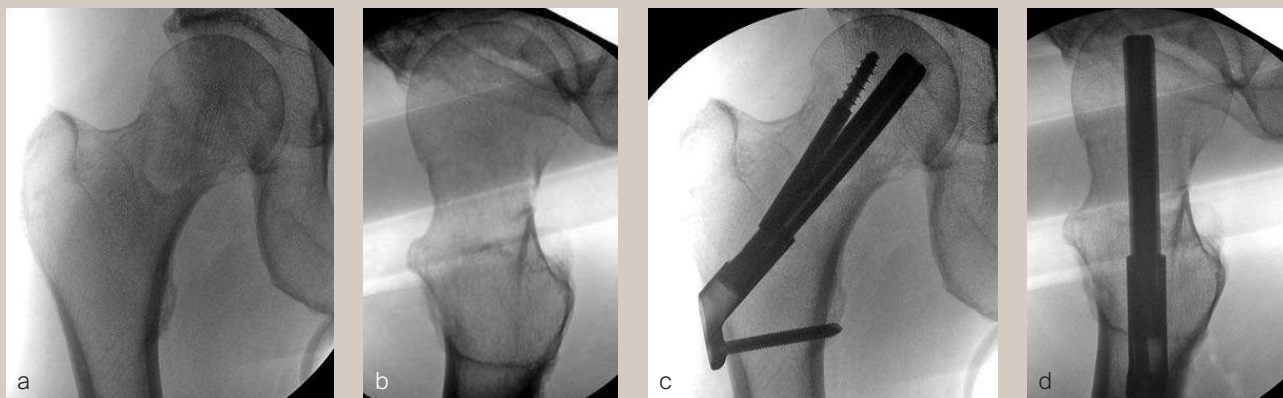


Fig 2a-d Intraoperative fluoroscopic images demonstrate the perfect result of closed reduction in both planes, which was achieved by traction and maximal internal rotation of the leg on a traction table. The FNS is placed nicely in the center of the femoral head, 5 mm below the subchondral zone. The plate is aligned perfectly parallel to the femoral diaphysis, which guarantees a fully central placement of the locking screw.

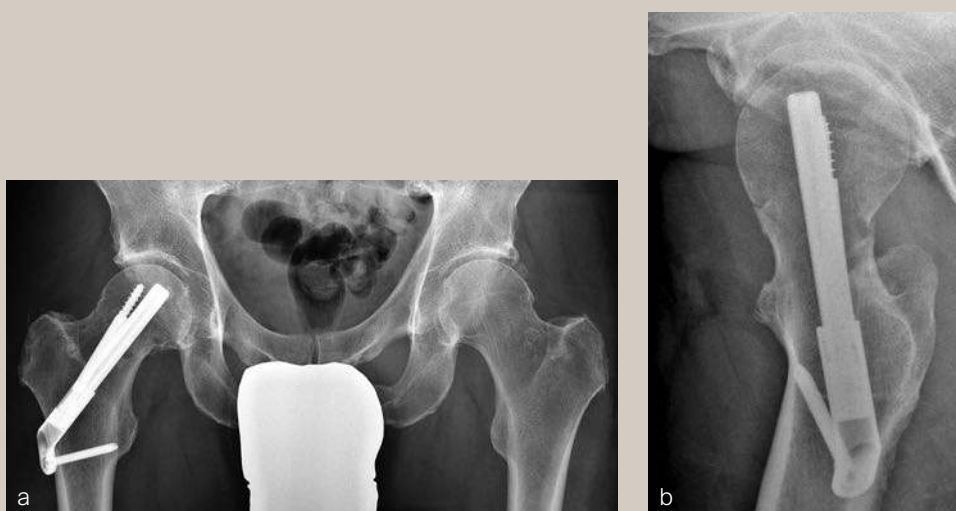


Fig 3a-b Postoperative x-rays document good reduction and ideal placement of the FNS. The patient was mobilized with partial weight bearing of 20–30 kg for the first 6 weeks.

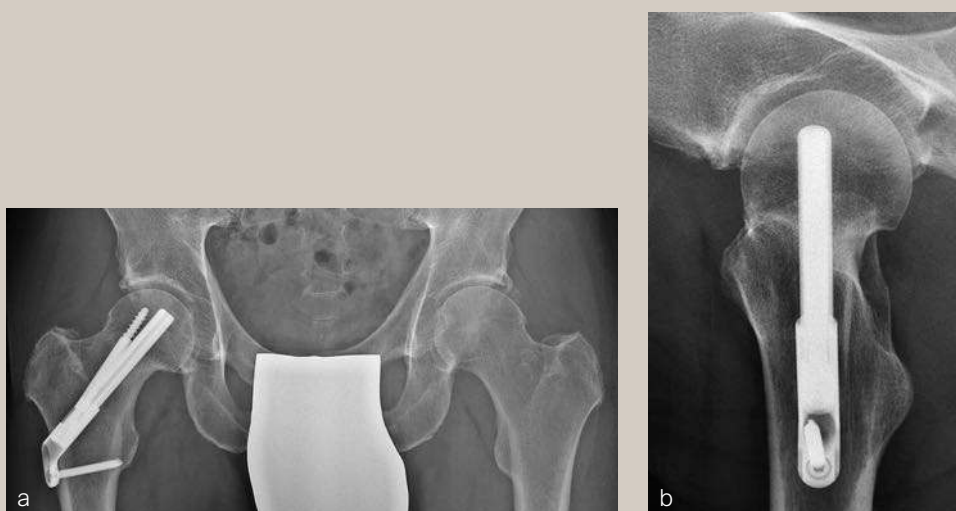


Fig 4a-b Follow-up 6 months after injury. The patient is free of pain walking with only minimal limping when walking fast and longer distances. The x-rays confirm a complete bone healing and no signs of an avascular necrosis.

Manual of Fracture Management—Foot and Ankle

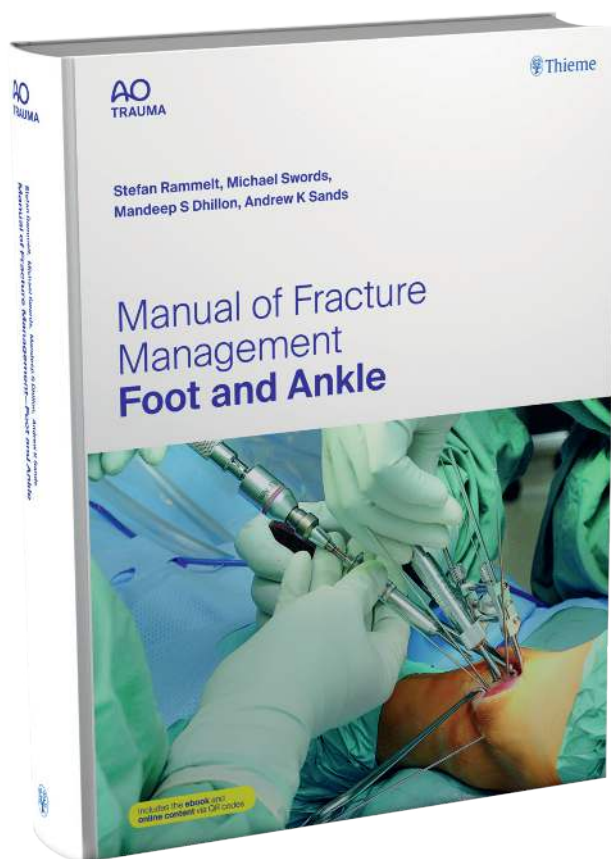
This latest AO Trauma publication *Manual of Fracture Management—Foot and Ankle* examines the techniques and procedures for the management of fractures and dislocations of the foot and ankle. Through a carefully selected collection of 59 cases covering a comprehensive range of foot and ankle surgeries, this book fulfills the need for a practical, hands-on manual for surgeons of all levels, on the management of foot and ankle trauma and fracture management.

The book editors, Stefan Rammelt, Michael Swords, Mandeep S Dhillon, and Andrew K Sands are experts in the field of foot and ankle surgery and are supported by contributions from 48 highly renowned surgeons from 14 countries.

Ideal for both general trauma and orthopedic surgeons, as well as foot and ankle specialists, the *Manual of Fracture Management—Foot and Ankle* includes the following key features:

- 59 detailed cases covering a wide range of topics, including decision making and planning, surgical approach and technique, managing risks and complications, alternative techniques and postoperative rehabilitation
- More than 1,600 high-quality images and illustrations
- Access to the AO online educational offerings including videos, webcasts, webinars, lectures, and more as they become available.

While a single case can be approached in a variety of ways, this book seeks to provide important guidelines that apply to most situations that may arise in foot and ankle fractures. It also provides the reader with the important general considerations applicable to all foot and ankle trauma surgery. AO Trauma is honored to bring you this highly valuable medical text. AO Trauma members are privilege to membership discounts. Further information about this new book is available at Thieme Publishing website: www.Thieme.com.



Learning From Failures in Orthopedic Trauma—Key Points for Success

This new case-based book helps surgeons improve their understanding and prevention of failures.

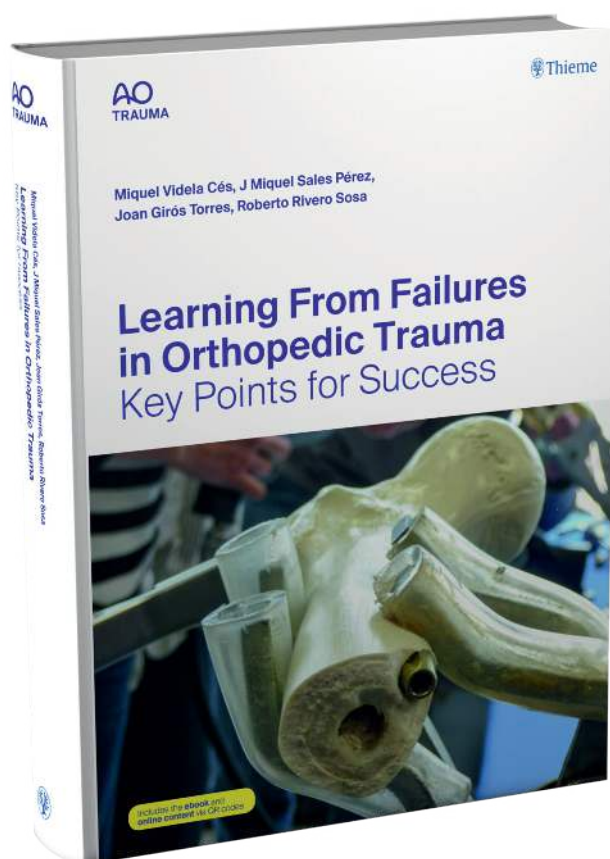
Immense advances in basic research, surgical techniques, practice, and patient care have revolutionized surgery over the last 60 years and made the field with its many subspecialties not only more diverse but also more complex.

The surgical profession places high demands on surgeons who must often make the right decision in a split second. This can easily lead to misjudgments or mistakes, as none is infallible.

Learning From Failures in Orthopedic Trauma—Key Points for Success, recently published by AO Trauma, is the first book of its kind to give surgeons the opportunity to learn from failures without making them themselves.

Based on the original Spanish-language book, *Errores en la Osteosíntesis* by Rafael Orozco Delclós, the publication presents authentic case examples that have been collected and followed up during the past 25 years. It is an essential and valuable resource, as it specifically examines the reason and response to surgical error by factual cases from different anatomical regions of the body; thus, aiding surgeons avoid the most frequent errors in osteosynthesis.

The collection of more than 70 cases failing for a wide array of reasons will help surgeons to recognize and to avoid common failures, start reflecting in action, present failures as positive learning opportunities, and bringing that knowledge to their daily practice.



New AO Technical Commission structure

The AO Technical Commission is the AO's innovation driver. Focused on the introduction of change and new ideas in all areas of its operation, in 2018 the AO Technical Commission launched discussions on how to be more efficient and achieve better outcomes in its four specialties: trauma, spine, CMF, and veterinary surgery. The need and motivation for this comes from the AO Technical Commission's desire to take interdisciplinary collaboration to a new level, to improve its overview of clinical requirements, and to achieve more flexibility in its core structure. These changes are underway and will reach fruition in January 2020.

AO Technical Commission Trauma—pursuing interdisciplinary work

The AO Technical Commission Trauma welcomed its new Chair, Michael Raschke, in July 2018. After a successful onboarding, one of his first tasks was to review the Expert

Groups and Task Forces with the specific goal of identifying synergies. Raschke recognized the complexity of the AO Technical Commission Trauma and one of his top priorities is to enable cross-pollination among the groups and to foster greater interdisciplinary collaboration.

Global Expert Committees (GEC) have been created under the direction of the AO Technical Commission Trauma to facilitate this knowledge sharing (Fig 1). These committees comprise up to 12 key opinion leaders (KOLs). Three GECs will cover the following areas: upper extremity, lower extremity, as well as pelvic and joint preservation. Each group will also include a comprehensive range of expertise in different fields (nailing, plating, external fixation, etc) to support and to initiate discussions about the innovations that the AO Technical Commission Trauma should pursue.

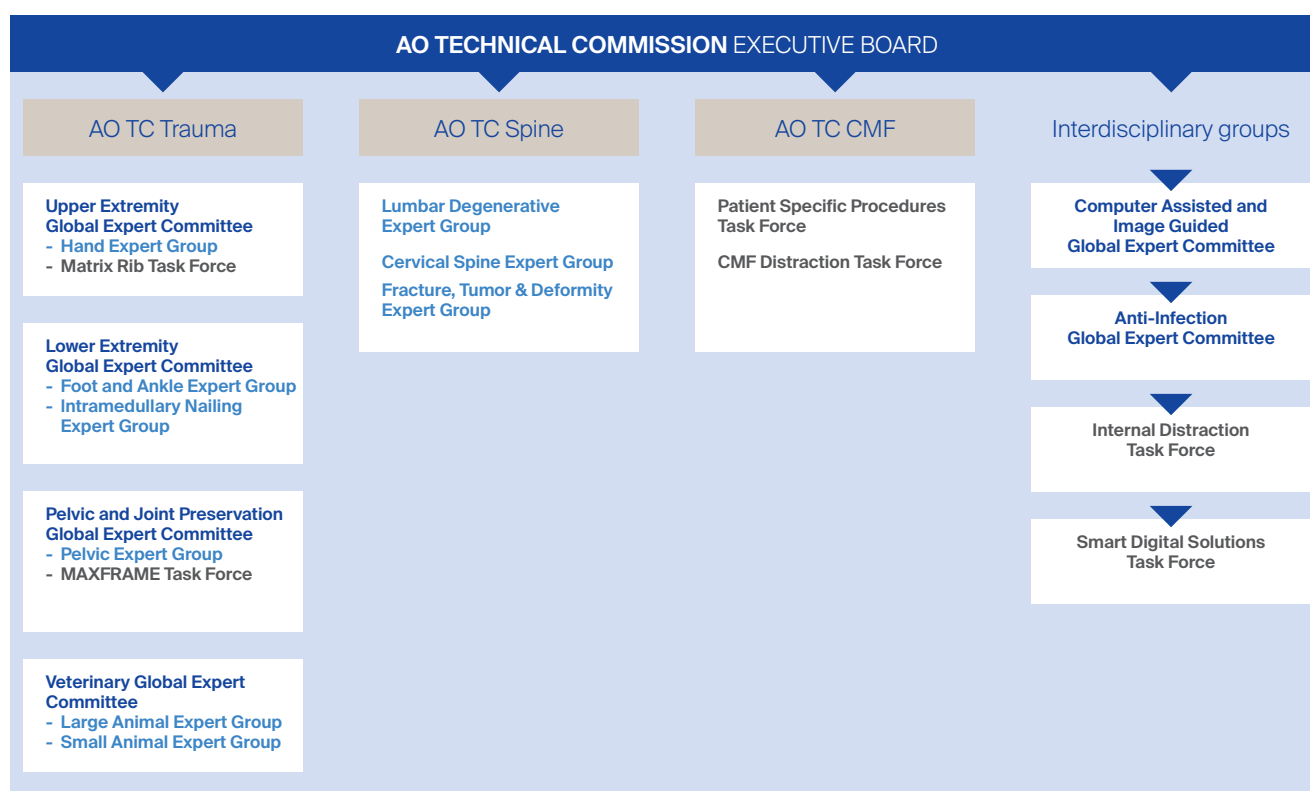


Fig 1 New AO Technical Commission structure, effective as of January 1, 2020.

A fourth GEC is being created for veterinary surgery. Emphasis was placed on the importance of retaining this specialty under the AO Technical Commission Trauma umbrella because of the role played in knowledge exchange between these fields. In addition, the Chair of this GEC will be a guest participant in AO Technical Commission Trauma meetings to ensure this community has a robust understanding of all ongoing innovation projects.

The existing concept of the Expert Groups and Task Forces will be carried forward into AO Technical Commission's new structure. These will continue to include up to five recognized KOLs in a field (ie, foot and ankle or hand) and will form the hands-on groups. These groups will drive new product development. New groups may be appointed by the AO Technical Commission Trauma as new clinical needs are identified. The AO Technical Commission Trauma hopes that the flexibility of the new structure will be a key factor to continued success.

AO Technical Commission Spine—streamlining product development

The AO Technical Commission Spine oversees Expert Groups for Cervical Spine, Lumbar Degenerative and Fracture, Tumor and Deformity. The latter group was formed by the merger of two smaller expert groups in 2018 and provides a platform whereby global KOLs with distinct and varied areas of expertise can collaborate and develop truly innovative surgical solutions, while maintaining a streamlined approach to the project portfolio.

The AO Technical Commission Spine and its Expert Groups leverage the program of annual AO Technical Commission Experts Symposia to generate a steady stream of innovative ideas that are supplied to the product development pipeline. The Symposia allow spine surgeons at all stages of career advancement to discuss clinical cases in specific focus areas, such as deformity or infection, and to identify urgent unmet clinical needs. These requirements for new surgical solutions are further refined within the Expert Groups and presented to the AO Technical Commission's industrial partners as concepts for new product development.

AO Technical Commission CMF—focus on tasks and projects

The AO Technical Commission CMF and its Expert Groups realized that the most active and challenging current projects need input from both existing Expert Groups due to extensive overlaps in development. Previously, these two groups did not coordinate their approach to projects in these overlapping areas. Often, they would discuss the same projects at different times of the year and come to diverging conclusions. Restructuring the AO Technical Commission CMF by merging the two groups into one seemed the obvious solution.

Identifying technical focus areas on which task forces will be appointed to handle tasks and projects relating to specific technologies will make it possible to maximize efficiency and flexibility. In addition, project teams may be formed to work on a specific project in small but highly active groups that will focus on developing solutions for specialized and individual clinical problems.

The AO Technical Commission CMF will start with two task forces to handle ongoing projects. The Patient Specific Procedures Task Force will work on establishing principles and guidelines for the main applications of patient specific implants in CMF and look for new applications. The CMF Distraction Task Force will continue working on the introduction of the new CMF Distractor in the market and will be dissolved after successful implementation.

New technologies or solutions currently being evaluated in *in vivo* studies or by using existing solutions to analyze clinical problems are already on the horizon and will hopefully lead to innovation.

Interdisciplinary GECs and Task Forces

Innovation is a multidisciplinary endeavor, and some fields require the involvement of many KOLs. For this reason, two of the existing groups have progressed to GEC level. These are the Computer Assisted and Image Guided Global Expert Committee, and the Anti-Infection Global Expert Committee.

Two additional hot topics were identified as requiring multidisciplinary efforts, leading to the creation of the Internal Distraction Task Force and the Smart Digital Solutions Task Force. You can find more information in the respective articles in this Innovation magazine.

New partnerships for the AO Technical Commission—delivering innovation in patient care through collaboration with industry partners

Comprising more than 120 key opinion leaders in trauma, orthopedic, spine, CMF, and veterinary surgery, the AO Technical Commission is the key innovation arm of the AO. Its medical members work closely with industrial partners to develop innovative solutions to clinical problems, to undertake clinical validation of new devices and techniques and to approve solutions to be included in AO Courses. Today, the AO Technical Commission's primary industrial partner is DePuy Synthes (DPS). The collaboration between the AO Technical Commission and DPS has been successful and productive to date, with more than 450 new products launched and approved between 1995 and 2019 alone. Recently, the AO Technical Commission has been building new partnerships with different companies, an approach which will further strengthen the delivery of innovative solutions for patient care.

The original AO Technical Commission

The AO Technical Commission was established in 1961, 3 years after the founding of the *Arbeitsgemeinschaft für Osteosynthesefragen* (AO; Association for the Study of Internal Fixation) in 1958. Its purpose was to provide a structure through which surgeons could closely collaborate with industrial partners to develop plates, screws, and nails for the treatment of trauma, and undertake quality assurance for new devices (Fig 1). Because internal fixation for fractures was a tremendous paradigm shift in the early 1960s, close monitoring of the quality and safety of devices was a high priority. All newly developed devices had to be approved by the AO Technical Commission before being taught as standard technique for fracture management. This model of innovation and quality assurance persists today.

Since 1961, the size and scope of the original AO Technical Commission has grown, and additional technical commissions have been established for the surgical specialties of Spine (2003) and CMF (2005). All Specialty AO Technical Commissions are the only bodies within the AO Foundation empowered to approve new technology for inclusion in AO Courses.

The AO Technical Commission originally collaborated with Mathys, Straumann (later Stratec), and Synthes. These industrial partnerships provided essential access to engineering expertise and manufacturing capability, allowing surgeons to bring innovative ideas through to clinical practice. In 2012, Johnson & Johnson DePuy acquired Synthes, becoming DePuy Synthes.

Partnership with DePuy Synthes

The partnership between the AO Technical Commission and DPS was re-evaluated in 2015. Due to changes in the medical device commercial landscape and regulatory requirements, DPS was increasingly challenged to realize all the various concepts and ideas proposed by the medical members of the AO Technical Commission. The Cooperation Agreement signed in 2015 (Fig 2) allowed the AO Technical Commission the opportunity to work with alternative partners if a project proposal was declined by DPS.

New horizons

Since 2015, the AO Technical Commission has developed new workstreams to guide the process of collaboration with "third parties" (alternative industrial partners) in the realization of "off-ramp" projects (projects declined by DPS).

The first step was to clearly define a timeline by which ideas for new projects are accepted or declined by DPS. Throughout the year, ideas for new projects are gathered in expert group meetings and submitted to DPS. Every December, DPS advises the following: (1) whether projects are fully aligned; (2) aligned but not funded due to differing resource allocation priorities; or (3) out of scope (not aligned with the strategic interests of DPS).



Fig 1 Maurice E Müller, one of the founders of the AO and pioneer in osteosynthesis.

If DPS categorizes a project as aligned but not funded or out of scope, the AO Technical Commission has the freedom to seek alternative industrial partners. There is a formal process by which the AO Technical Commission seeks DPS approval to pursue an off-ramp project with an alternative partner and at this stage any existing project documents are handed over to the AO Technical Commission and any issues around intellectual property are clarified.

The second step is for the AO Technical Commission management to produce a business case detailing the scope of each project, the unmet clinical needs addressed by the project, an overview of the project set up (team, budget, and timeline), a cost-benefit analysis, and risk assessment. Possible partners are scrutinized for suitability to undertake the project and scored via a selection matrix, and the partner of “best fit” identified. The business case is then submitted to the AO Foundation Board to gain approval that the AO Technical Commission may sign a Memorandum of Understanding with the selected partner.

If approval is granted by the AO Foundation Board, the third step is to engage in full discussions with the selected partner to develop a full project proposal and start contract negotiations. At each stage of the process, checks and balances are in place to ensure that the AO Technical Commission's valued and longstanding partnership with DPS is not compromised.

In July 2019, the first memorandum of understanding was signed with the Swiss company icotec to develop radiolucent carbon/PEEK instrumentation for the management of metastatic spine disease. A partnership with Hectec is also under discussion to provide and to further develop preoperative planning software for osteotomies.

The AO Technical Commission looks forward to the realization of new opportunities with new partners, building on the established and successful partnership with DPS.



Fig 2 The Cooperation Agreement between the AO Foundation and DPS was signed in 2015 in Chiang Mai, Thailand.

Smart Digital Solutions Task Force

The Smart Digital Solutions Task Force (SDSF) was established under the guidance of the Chair Benedikt Braun from Germany. The inaugural meeting took place in Davos on December 2018. The task force has its origins in an AO Technical Commission's initiative to foster smart sensor technology for patient monitoring. The primary objective of the initiative was to collect relevant data to better understand the fracture-healing processes and patient performance during the rehabilitation period. The medical members of the SDSTF are younger, digitally savvy individuals, and include Peter Richter (Germany), Bernd Grimm (Germany), Meir Marmor (US), and Sureshan Sivananthan (Malaysia) (Fig 1). Andrew Hanflik (US) will be a

regular guest at the task force meetings. The task force is currently working on a narrative review that aims to provide an overview and categorization of current demands, digital solutions, and ongoing activities in patient monitoring in the field of trauma. A workshop on 'Digital Patient Outcomes using Sensors as Wearable Monitors: Opportunities, Methods and Applications' will be held at the ORS Annual Meeting 2020 for the purpose of disseminating their endeavors. The task force members are highly motivated to pave the way toward technologies, such as wearables and implants, which could provide guidance for the patients to adjust their activity levels appropriately to advance healing.



Fig 1 Members and guests of the SDSTF in Frankfurt, Germany, April 2019.

Internal Distraction Task Force

Why was the Task Force formed?

Open fractures with bone loss, tumors, and infected bone are the main reasons for segmental bone defects. They are challenging to treat, especially when their size is larger than about 3 cm. Current orthopedic treatment methods include the induced membrane (Masquelet) technique, the use of bone substitutes, and distraction osteogenesis. The latter relies on segmental bone transport that is mostly performed with an external fixator as a fixation and transport device. However, the use of an external fixator is associated with potential complications, such as pin tract infection, pain, discomfort, and soft-tissue problems. The time of application of an external fixator should therefore be kept as short as possible to reduce these treatment risks. As a result, hybrid techniques were developed using the external fixator for bone transport over a plate or an intramedullary nail that function as stabilization devices. The logical next step in the evolution of better treatment solutions for segmental bone defects were implants and technologies that eliminate the need for an external fixator. In 2016, as the result of clinical need assessments, the Intramedullary Nailing Expert Group (INEG) proposed to DePuy Synthes (DPS) to develop an intramedullary nail for distraction osteogenesis for treatment of segmental bone defects. At that time some other companies offered nails for bone lengthening but not for segment transport, which would have been a novel application. Although the potential benefits and opportunities were well understood, such a nail development could not be started in the collaboration between the AO Technical Commission (AO TC) and DPS because other development projects were of higher priority (based on estimated case volume and expected patient benefit). A segment transport nail was kept on the list of potential future development projects.

Requests for better internal bone transport devices were not only raised by trauma and orthopedic surgeons. In craniomaxillofacial (CMF) surgery there are many indications for distraction osteogenesis: mandible, maxillary, and cranial vault distraction. These surgical procedures are predominantly performed in pediatric patients. Most of the currently available CMF distraction devices rely on mechanical components that are activated outside the patient to operate the internal transport mechanism. Due to limitations of such solutions in terms of patient comfort and infection risk, the Expert Groups of the AO Technical Commission CMF pointed out the importance to develop internal distractors which do not rely on mechanical activation elements running through the skin of the patient.

Internal distraction devices are also used in spine surgery to correct spinal deformities. Traditional growing rods require multiple surgeries to manually distract segments thereby increasing the risk of an infection. Magnetically controlled growing rods overcome this drawback by allowing growth modulation without further surgical interventions to treat early-onset scoliosis in children. However, considerably high complication rates are reported for these devices which underline the need for better solutions.

Recognizing all the above-mentioned unmet clinical needs in trauma, CMF, and spine, the AO Technical Commission Executive Board decided to form a new Internal Distraction Task Force (IDTF) with cross-specialty representation. By choosing such a group composition, the AO TC underlined the importance of bundling the expertise of the different surgical disci-

plines to strengthen innovation in the common attempt of identifying the best treatment solutions.

Composition and goals of the Task Force

Chang-Wug Oh (Department of Orthopedic Surgery, School of Medicine, Kyungpook National University, Daegu, South Korea), medical member of the External Fixation Expert Group, was selected to be the Chair of the IDTF due to his extensive clinical experience in treating large bone defects. Additional medical members of the IDTF are Steffen Rosslenbroich (Orthopedic and Trauma surgeon, University Clinic Münster, Germany), Scott Bartlett (CMF surgeon, Children's Hospital of Philadelphia, USA), and Philip Horsting (Orthopedic and Spine surgeon, Sint Maartenskliniek, Netherlands).

The overall goal of the IDTF is to identify novel "all-internal" distraction devices and treatment methods. In this context, "all-internal" means that there are no device components or cables through the skin of the patient. This comprises not only the structural design of a new implant solution but also its actuation and drive technology. To achieve this ambitious goal, the IDTF will systematically address the following tasks:

- (1) Evaluate current distraction methods in trauma, spine, and CMF to identify their benefits and limitations.
- (2) Analyze how new all-internal distraction devices could solve the identified limitations.
- (3) Screen newest technologies which would allow all-internal device usage in trauma, spine, and CMF.
- (4) Define specific development projects in trauma, spine, and CMF by outlining their project scope.
- (5) Clarify the interest of companies to realize the defined development projects.

First Task Force meeting

The inaugural meeting of the IDTF was held in Frankfurt, Germany, June 8, 2019 (Fig 1). Several experts were invited as guests to share their clinical and technical expertise. Two DPS representatives attended. The meeting started with an analysis of current treatment methods. Numerous potential improvements were identified. The discussions revealed that there are some commonalities among internal distraction procedures that are applied in the different surgical specialties. However, there is also an important difference among the disciplines. For instance, in spine surgery there is a need to span multiple joints for deformity correction while the focus in CMF and trauma is on distraction osteogenesis.

There was agreement that continuous distraction could have distinct advantages over stepwise interventions. Bi-directional operation of a distraction device as well as adjustability of the distraction speed were identified as important functional requirements. The topic of "smart" implants was raised as vision for the future. For example, device feedback on the distraction callus quality or the distraction force could be used to optimize and adjust the distraction process.

The presentation by Philipp Beckerle, Junior Professor of the Robotics Research Institute at the Technical University Dortmund, was received with great interest, since it provided a comprehensive overview of the principles of mechatronic actuation and how these could be utilized for internal distraction applications (Fig 2). There is a large variety of actuators which are categorized based on their physical operating



Fig 1 Internal Distraction Task Force (IDTF) at the inaugural meeting in Frankfurt, Germany, on June 8, 2019.

From left to right: Boyko Gueorguiev (IDTF guest and representative of the AO Research Institute Davos); Michael Raschke (Chair of the AO Technical Commission Trauma); Chang-Wug Oh (IDTF Chair); Scott Bartlett (IDTF medical member); Philip Horsting (IDTF medical member); Dankward Höntzsch (IDTF guest); Steffen Schröter (IDTF guest and medical member of the Joint Preservation and Osteotomy Expert Group); Philipp Beckerle (IDTF guest and representative of the Robotics Research Institute, TU Dortmund); Beat Lechmann (DePuy Synthes representative); Christof Dutoit (DePuy Synthes representative); and Steffen Rosslenbroich (IDTF medical member).

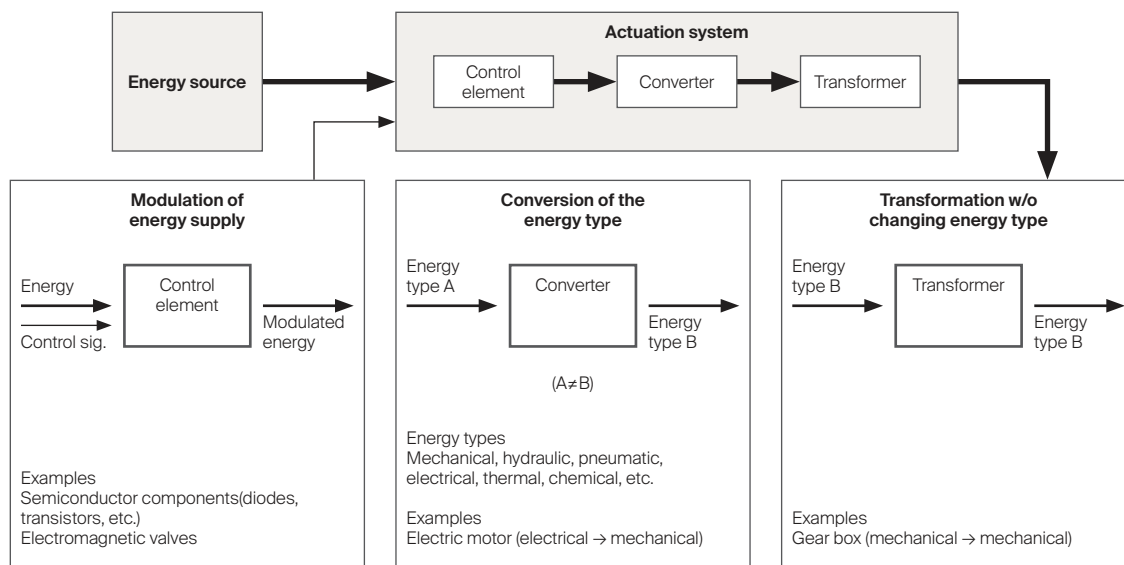


Fig 2 The structure, components, and functions of actuation systems [1]. The overall goal of a distractor, as an actuation system, is to generate a defined movement (distraction) depending on a control signal. For an all-internal distractor solution, the required energy and control signals must be provided without cables or mechatronic components passing through the skin of the patient. The actuation system of the distractor consists of a control element, a converter, and a transformer. The control element modulates the energy according to the control signal. The modulated energy is converted from one energy type to a different energy type. An electric motor, as an example, converts electrical into mechanical energy. The transformer, as the last element of the actuation system, transforms the energy without changing the energy type. A typical example is a gear box which transforms mechanical energy, eg, fast rotation at small torque into slow rotation at high torque. All elements of the actuation system of an all-internal distractor must be appropriately chosen based on the operating conditions, eg, force, distraction, time. A control loop from the transformer back to the control element could be integrated by adding a sensor and a controller (not shown in the figure). The sensor would measure a relevant parameter of the mechatronic system which would, by comparison to a set value in the controller, influence the control element. As a simplified example, the quality of the callus regenerate (determined by, eg, the callus stiffness) could potentially be considered when controlling the distraction.

principle: electromagnetic, hydraulic, piezoelectric, and shape memory alloy actuators, to name a few of them. It was emphasized that the most suitable actuation system can only be identified if the operating conditions are well defined and the surrounding mechanisms are included in the design process, eg, gear boxes. This entails that for an all-internal distractor application it is important to know the required distraction force, distraction distance, and setting time, ie, how fast the actuator needs to respond to a command. Apart from designing the most appropriate actuation system, a reliable technical solution must be found, how the energy and the control signals are provided for its proper function. For an all-internal distractor solution with no cables passing through the skin, these are considerable technical challenges that must be overcome.

At the beginning of 2019 NuVasive Inc announced the launch of an all-internal bone transport system to treat segmental bone defects up to 10 cm in the tibia and femur. This system uses magnets to transfer the required energy and to control the lengthening actuator. Although clinical results of this segment transport nail have not yet been published, the IDTF has the clear understanding that new all-internal distraction solutions for this purpose need to offer more values.

The segment transport nail of NuVasive is expensive. In general, the cost of a treatment device increases with its functional device requirements. The IDTF will thoroughly screen latest technologies in terms of functionality and cost. The latter influences the device use; thereby, the number of patients who benefit from its values.

After definition of the functional requirements, it is also the task of the IDTF to identify potential development partners.

Development partners

DPS has always been the preferred development partner for the AO Technical Commission. By referring to the segment

transport nail as an example, DPS has informed the AO TC that providing all-internal distraction solutions is of company interest. However, due to lack of in-house expertise and limited resources to cover the development work, DPS prefers to explore development collaborations with third parties. In this regard the strategic approach of the IDTF and DPS are aligned. Once a commercial partner is identified, it is up to contract negotiations to define the development and commercialization of the product as well as the involvement of the different stakeholders. It is important to mention that the AO Technical Commission can undertake development projects with other industry partners if collaboration with DPS is not possible.

Synoste, a Finnish medical device company, uses a technology that is based on the shape memory effect to develop implant solutions for bone lengthening and deformity correction. The AO Invest was attracted by the potential of this concept and provided funding to Synoste. The IDTF is interested to thoroughly analyze the use of this technology in future distraction osteogenesis or deformity correction applications. One of the important aspects under consideration is the size of the device.

Outlook

The IDTF will focus in the first couple of meetings on defining the functional design requirements of new all-internal distraction solutions in trauma, spine, and CMF. It is being deliberated to generate questionnaires to obtain broader clinical feedback on the treatment demands by using the AO Foundation network. An interdisciplinary approach is chosen by bringing medical and technical expertise together to foster innovation. For this purpose, the IDTF will invite experts as required.

Reference

1. **Rinderknecht S, Nordmann R, Herbert Birkhofer H.** *[Einführung in die Mechatronik für den Maschinenbau]*. Düren, Germany: Shaker Verlag GmbH; 2018. German.

AO TC Experts Symposia drive innovation

The AO TC Experts Symposia play a central role in ensuring that AO TC approved devices and surgical techniques fulfill the demands for which they have been developed. This quality assurance is facilitated by the exchange of challenging clinical case experiences. Potential strengths and weaknesses of treatment solutions can be identified and analyzed to refine current solutions and to trigger new developments. The topics of the symposia are chosen based on their clinical importance. They often cover areas which are controversially discussed among healthcare professionals to gain more clarity about the best clinical practice. The participants of the AO TC Experts Symposia are invited based on their medical expertise and innovative, out of the box mindset. The symposia are held across the globe to consider and to address regional aspects. In the highly complex and dynamic healthcare world, technological advances and regional, social characteristics have extensive impact on treatment selection and efficacy. The exchange of clinical experience is the driving motor to improve currently existing treatment methods and to develop completely new solutions. As such, the AO TC Experts Symposia deliver a powerful momentum to clinical needs-driven innovation.

Since their initiation in 2006, the AO TC Experts Symposia have been held to cover mainly trauma topics. Due to the successful event format they are now also organized in the CMF and Spine specialties.

The following is an overview about the symposia that was held since the last edition of the Innovations magazine.

First AO Technical Commission Spine Experts Symposium

In September 2018, the AO Technical Commission held the 1st AO Technical Commission Spine Experts Symposium, in Montreal, Canada. Ten faculty and 22 participants from 11 countries participated in this one-and-a-half-day event. The symposium was structured in five sessions during which participants and faculty discussed 30 case presentations (Fig 1). The case-based exchange of clinical experiences revealed various challenges in patient treatment, which the AO Technical Commission has committed itself to address. Two prizes were awarded for the most interesting case presentations: Qian Bangping from China received the prize for his presentation of a difficult cervical deformity correction case. Moyo Kruyt from Netherlands won the award for his case presentation on early-onset scoliosis.

After the event, the symposium chair Maarten Spruit (Chair of the AO Technical Commission Spine) concluded: "The AO TC Experts Symposia are ideal opportunities for surgeons of various levels of experience to enter in case-based discussions around 'hot' topics in musculoskeletal surgery. These discussions have the potential to reveal clinical needs and treatment gaps. The key for success is to use these important findings as input for new development projects". The effectiveness of the transition from brainstorming to product development depends on careful planning, documentation and systematic analyses: "In the AO Technical Commission Spine, we focus on thorough and precise clinical need definitions. Subsequently, the relevant AO TC Expert Groups take this source of information as a basis to initiate development projects. This approach is probably the best way to help solve clinical problems and improve patient treatment", Spruit explained.

13th European AO Technical Commission Trauma Experts Symposium

Pol Rommens, former medical member of the Pelvic Expert Group, chaired the symposium at the Medical University Mainz, Germany, in October 2018. Having been the chair of previous trauma symposia, he shared his experiences with these events: "Renowned trauma experts attend the AO TC Experts Symposia. They discuss new solutions for surgical challenges which we encounter in our daily practice. There is an open, honest and respectful discussion among key opinion leaders which is a prerequisite for improving patient treatment. Sometimes, even traditional implants and techniques, as the 95° angled blade plate, are revisited and move into our focus of interest again."

The symposium was attended by ten faculty from four countries and 43 participants from 20 countries. The symposium program, which attracted also seven representatives from DePuy Synthes, consisted of four sessions which were titled: (1) Calcaneus: open or minimal invasive? (2) Corrections of malalignment with external fixation. (3) Angled blade plate—a traditional implant for revision surgery in proximal femoral fractures. (4) Double plating osteosynthesis at the distal femur. Each session was started with a lecture of the faculty to introduce the topic. Subsequently, the stage was opened for participants to present their difficult cases, which were preselected by a faculty panel.

Maximilian Hartel (Trauma and Orthopedic surgeon at the University Clinic Hamburg-Eppendorf, Germany) won the prize for the most interesting case presentation by leading the participants through a complex distal femoral fracture case which was treated with double plating (Fig 2). As an additional reward he was invited to participate in an AO TC Expert Group meeting to provide input for currently running AO TC development projects. Reporting about his experiences, Maximilian Hartel said: "The AO TC Expert Group concept ensures a high level of professionalism. It is very much appreciated that the Expert Groups are open to involve new surgeons like me, to bring in new ideas and insights in the development process to come up with better treatment solutions. I have always enjoyed the opportunity to exchange ideas with other surgeons and to discuss the implementation process with development engineers. Of interest for me are the detailed medical and technical thought processes which lead to specific designs, thereby pushing the limits of technical feasibility."



Fig 1 Agnita Stadhouder (Amsterdam UMC, Netherlands) during her case presentation about the use of a vascularized fibular graft for correction of severe dystrophic neurofibromatosis scoliosis in the thoracic spine.



Fig 2 From left to right: Michael Raschke (Chair of the AO Technical Commission Trauma), Maximilian Hartel, case presentation winner, and Pol Rommens (Chair of the 13th European AO Technical Commission Trauma Experts Symposium).

Making sure that the AO TC Experts Symposia are open to talented young surgeons creates a vital channel between established experts in their field and up-and-coming generations. These AO TC events offer creative surgeons to take the first steps on their pathway into the AO TC innovation powerhouse.

13th Asia Pacific AO Technical Commission Trauma Experts Symposium

Merng Koon Wong, medical member of the AO Technical Commission Trauma and former chair of the Asia Pacific Expert Group, chaired the symposium in Kuala Lumpur, Malaysia, in March 2019. In his opening speech he emphasized: "Performing surgery is not just about inserting implants according to the surgical technique guide. The success of it rather depends on skills in fracture reduction, temporary fixation, and final fixation. The AO TC Experts Symposia are a platform where cutting-edge surgical techniques including tips and tricks are showcased and discussed. Findings and potential improvements can be shared across continents."

Ten faculty from seven countries led 34 participants from ten countries through the symposium program (Fig 3). There were four highly interactive case discussion sessions: Proximal Tibia Fracture Fixation, Intramedullary Nailing Problems, Intracapsular Hip Fractures, Malunion, and Deformity Correction. Xiadong Chen from Shanghai, China, was the winner of the most interesting case presentation.

In the intracapsular hip fracture session, the evaluation of the clinical performance of the Femoral Neck System was received with special interest. About 2400 cases have been performed with this implant system in Japan, since it was approved by the AO Technical Commission end of 2017 (see Innovations magazine 2017). Clinical case examples revealed that special attention must be given to appropriate plate positioning along the femoral shaft. The Lower Extremity Expert Group addressed this point by adapting the instrumentation steps of the surgical technique guide.

All above-mentioned AO TC Experts Symposia underlined once more the vital function of this event format to bring AO surgeons together in a shared spirit of camaraderie to pursue one common goal—to improve patient care. We thank all symposium chairs and participants for their efforts and enthusiasm in making the AO TC Experts Symposia successful.

The first AO Technical Commission CMF Experts Symposium is scheduled for November 13–14, 2019, in Tampa, United States, and will be chaired by Daniel Buchbinder, Chair of the AO Technical Commission Executive Board.

The AO Technical Commission plans the following symposia in 2020 (dates are subject to changes):

- 4th Latin America AO Technical Commission Trauma Experts Symposium, March 6–7, 2020, Sao Paulo, Brazil
- 14th Asia Pacific AO Technical Commission Trauma Experts Symposium, April 3–4, 2020, Seoul, South Korea
- 15th European AO Technical Commission Trauma Experts Symposium, September 2020, St Petersburg, Russia
- 2nd AO Technical Commission CMF Experts Symposium, November 2020



Fig 3 Participants of the 13th Asia Pacific AO Technical Commission Trauma Experts Symposium.

AO TC Meet the Experts sessions 2018

The Meet the Experts sessions of the AO Technical Commission (AO TC) offered the 2018 AO Davos Course participants the opportunity to be informed of the most recent AO TC approved medical devices as well as hot topics in trauma and orthopedic surgery. Expert surgeons with direct involvement in the development of new implants and instruments explained during lectures and practical demonstrations their clinical use and clinical benefits for patient treatment. As in the past, the AO TC Meet the Experts concept was an appealing format to explore innovative devices and surgical techniques which have not yet been included in the AO course programs because of their novelty.

In previous years, the AO TC Meet the Experts events took place in the Café Chamonix at the Congress Center, a shielded environment with its merits in terms of broadcasting live events but had the disadvantage of being separated from other course activities. With the implementation of a new concept for the Davos course appearance in 2018, the AO TC stage was relocated to the AO World area which established high visibility to all course participants (Fig 1). The audio-visual equipment was well integrated into the new stage setup. Five cameras captured the activities on the stage and provided close-up views of the implants and instruments on large monitors on both sides of the stage.

For the first time, all Meet the Experts sessions were streamed live and attracted on average 300 online viewers.

The following is a short summary of all topics that were presented during the 2 weeks at the Davos course.

Advances in femoral nailing

Paulo Barbosa and Christopher Finkemeier (Fig 2), medical members of the Intramedullary Nailing Expert Group, presented features of the newly developed Femoral Recon Nail System (see also Innovations magazine 2018). This nailing system offers surgeons the opportunity to select, based on their preference, either a nail for a piriformis fossa entry point or a nail for a trochanter tip entry point. These nails are specifically designed to enhance anatomical fit by reducing the nail radius of curvature to 1.0 m. The presenters explained the various proximal and distal locking options provided by the nail which increase implant stability and which address various femoral fracture types. The audience was updated on the innovative instruments that facilitate the surgical technique and support the surgeon in achieving precise implant placement. The practical demonstration largely addressed the tips and tricks for proper fracture reduction, which remains the key to successful fracture treatment.



Fig 1 New appearance of the AO TC Stage in the AO World area close to the entrance of the Congress Center.



Fig 2 Paulo Barbosa (left) and Christopher Finkemeier highlighted the values of the recently introduced Femoral Recon Nail System.

Femoral Neck System (FNS)—a new technique for minimal invasive fixation of femoral neck fractures

Karl Stoffel and Christoph Sommer (Fig 3) from the Lower Extremity Expert Group presented a new implant system specifically designed for minimally invasive fixation of femoral neck fractures—the Femoral Neck System (FNS) (see also Innovations magazine 2017). This innovative implant is a fixed-angle gliding fixation device that allows for controlled collapse of the femoral neck while simultaneously restricting rotation around the head-neck axis. Due to the telescoping mechanism of the head element, consisting of a bolt and an antirotating screw, there is no lateral implant protrusion which could lead to subsequent soft-tissue irritation. After explaining the main advantages of the FNS features, the presenters led the audience through the surgical technique in a practical demonstration that highlighted procedural efficiency. Both experts shared clinical cases and illustrated important surgical steps based on intraoperative imaging.



Fig 3 Karl Stoffel (left) and Christoph Sommer shared their clinical experiences with the Femoral Neck System—a new technique of minimal invasive fixation of femoral neck fractures.

Augmentation of the PHILOS plate

Franz Kralinger (Trauma and Sports Department, Wilhelminenspital, Vienna, Austria) and Stefaan Nijs (medical member of the Upper Extremity Expert Group (Fig 4) presented the rationale for cement augmentation of the PHILOS plate. Screw penetration and secondary loss of reduction are potential complications of proximal humeral plate fixation, especially in patients with osteoporotic bone. Cement augmentation through fenestrated screws, leading to cement clouds around the screw tips, has been shown to strengthen the implant anchorage in the bone. Surgeons may decide intraoperatively if augmentation should be performed. The presenters gave a detailed explanation of the surgical technique of screw augmentation. They underlined the importance of performing a leakage test with contrast dye to assure that no cement is injected into the joint. Based on clinical experience, implant removal of augmented screws is not a concern. The presentation concluded that augmentation is a safe technique that enhances proximal humeral fixation stability.

Evolution of craniofacial distraction

The AO CMF surgeons Richard Hopper (Chair of the Craniofacial Expert Group) and Adi Rachmiel (Department of Oral and Maxillofacial Surgery, Rambam Health Care Campus, Haifa, Israel (Fig 5) presented a comprehensive overview on the evolution of craniofacial (alveolar, mandible, midface, and cranial) distraction. They explained both external and internal distraction devices that developed over time as new technologies emerged. Since internal devices are located underneath the skin, they are usually associated with a high patient satisfaction. However, external devices are still used in complex cases, as they offer high versatility and functionality. The audience were informed of the different treatment concepts ranging from single vector to multi-vector distraction as exemplified by the curvilinear distraction system for correction of mandibular deformities. From an intervention perspective, surgeons need to be attentive to the timeline of the distraction procedure. Session attendees learned about state-of-the-art treatment concepts for vector control and molding of the alveolar, differential movements of the midface to improve patient appearance and function, control of sleep apnea by mandible movement as well as orchestrated interventions for cranial pressure. Several clinical cases illustrated the effectiveness of the treatment methods.



Fig 4 Stefaan Nijs (left) and Franz Kralinger explained the advantages of cement augmentation when treating proximal humeral fractures with the PHILOS plate.



Fig 5 Richard Hopper (left) and Adi Rachmiel explained the potential of craniofacial distraction as this treatment method evolved over time.

Guidance in planning, design, and use of patient-specific implants

Alexander Schramm (medical member of the Computer Assisted and Image Guided Surgery Expert Group) and Pit Voss (Department of Oral and Maxillofacial Surgery, Medical University Freiburg, Germany (Fig 6) gave a presentation on planning, design, and use of patient-specific implants (PSIs) in orbital and periorbital reconstructions, mandibular reconstructions, and orthognathic surgery. Recent advances in digital planning and innovative approaches to design and manufacture patient-specific surgical guides and implants mean that complex surgical procedures can be performed in a highly reproducible manner. Clinical results of waferless maxillary positioning underline the potential of this new digital approach. The advantages of high predictability and accuracy, independent of the surgical experience, as well as reduced operating room time may outweigh the disadvantage of the high costs which are currently associated with the use of PSIs. The technique of using patient-specific surgical drill guides, osteotomy guides, and 3-D implants is especially powerful in orbital and mandibular reconstructions after large bone resections in tumor surgery, as illustrated by several case examples shared by the presenters.

Introducing the LCP Pancarpal Arthrodesis Plate family

This veterinary topic was presented by Michael Kowaleski (Chair of the Veterinary Expert Group) and Eva Schnabl-Feichter (University of Veterinary Medicine, Vienna, Austria (Fig 7). Online participants could ask questions to the expert presenters via moderator Bruno Peirone (Department of Veterinary Sciences, University of Turin, Italy). The LCP Pancarpal Arthrodesis Plate family comprises three plate sizes for treatment of hyperextension injuries of the carpal joint in skeletally mature dogs between 7 kg and 40 kg. The presenters explained the plate-specific design features. One of these is that the plate thickness tapers proximally and distally to improve soft-tissue coverage and to gradually decrease plate stiffness toward the plate ends. This reduces the risk of metacarpal bone fractures. The surgical technique to position and to apply the plate with the appropriate order of screw insertion was presented to achieve the desired compression at each joint level. A practical demonstration on an artificial bone model illustrated the most important surgical steps of this procedure to the session participants. The session closed with the presentation of clinical cases.

If you have missed a topic that would have been of interest to you? Note that all Meet the Experts sessions are available for online viewing by accessing the AO Videos channel under <https://aovideos.aofoundation.org/> and selecting AO Foundation and AO Technical Commission.



Fig 6 Pit Voss (left) and Alexander Schramm gave a comprehensive overview on the workflow to use patient-specific implants in craniomaxillofacial surgery.



Fig 7 Michael Kowaleski (left) and Eva Schnabl-Feichter presenting the advantages of using the new LCP Pancarpal Arthrodesis Plate and in a practical session demonstrated its proper use.

Portrait: Benedikt Braun

Benedikt Braun, trauma and orthopedic surgeon, joined the AO family when he accepted the position of the Chair of the AO Technical Commission's newly formed Smart Digital Solutions Task Force (SDSTF).

Benedikt was born in 1987, the eldest of four siblings, in Homburg, a German town about 20 km from the French border. When he was 10 years, his family moved north to Niederrhein, where his father, also a trauma surgeon, headed a department at the clinic in Kleve. Since his mother, an anesthesiologist, was also in the medical profession, it might have seemed inevitable that Benedikt would also choose a medical career.

However, by the age of 14 years he had made a name for himself as a talented young musician, playing the flute. After winning national competitions repeatedly and playing at large concert venues, such as the Tonhalle Düsseldorf, he considered studying music. In preparation for this he began taking additional piano lessons with a university professor from Düsseldorf. After receiving a bottle of wine for Christmas, his piano professor once said ironically "No matter how much wine you give me I still wouldn't be able to cope with how badly you play." This outspoken but heartfelt comment prompted young Benedikt to consider applying his talents in a different direction. Nonetheless, he and his piano professor formed a fruitful flute-piano duo which led them to many concert engagements well throughout Benedikt's subsequent university time. But it was then that his thoughts turned back to medicine.

Because of his mediocre skiing skills, in 2006 he suffered a meniscus injury that spared him from military service. He enrolled to study medicine in Aachen straight after high school, and what had started as a stopgap quickly became a calling. The pragmatism required by trauma surgery was something he found particularly inspiring. During his university days, Benedikt was accepted as a scholar of the German National Merit Foundation, Cusanuswerk, Dean's List and of North Rhine-Westphalia. He completed several internships abroad, including one at the Hospital for Special Surgery, NY, USA, and almost every year, he spent time in St Augustin, Florida, USA, with the late Dr Warren Kluger (Fig 1). He was a general and vascular surgeon by training but a true old-school do-a-bit-of-everything surgeon and was friends with Benedikt's high-

school host family. Alongside Benedikt's father, Dr Warren Kluger inspired Benedikt to pursue a career in surgery by demonstrating the necessary work ethic.

As he was nearing the end of his studies, Benedikt was uncertain about his next steps. Through a series of coincidences, he ended up back home. I first had the pleasure of meeting him after a talk at DKOU in Berlin, shortly before he applied for a position back in his hometown, Homburg.

He began his residency at the Saarland University Hospital (www.uniklinikum-saarland.de/de/einrichtungen/kliniken_institute/chirurgie/unfallchirurgie) in Homburg immediately after graduating from medical school in 2013. Education there covers the entire spectrum of traumatology and orthopedic surgery; consequently, Benedikt also boasts wide-ranging interests.



Fig 1 Young Benedikt and Dr Warren Kluger.

Nevertheless, he says traumatology of the lower extremity is his focus, as he regards the feet the foundation of the human body. "If patients have problems with their feet or are unable to walk, it can be of equal importance to them as having an impaired function of the hand—after all, it is our oldest and still primary means of transportation." In 2018, he completed a short fellowship in foot and ankle surgery with Dr Andrew Sands in New York (Fig 2; medical member of the AO Technical Commission Trauma and Dr Roy W Sanders of Tampa, Florida, and since August 2019, he is consultant surgeon in Homburg.

In addition to his clinical work, Benedikt has always been passionate about research. He believes that hardware, instruments, and techniques are already highly developed; thus, achieving major improvements in these fields requires tre-

mendous efforts. Although current technical solutions in traumatology are diverse and plentiful, many already existing general solutions have not yet been specifically used for trauma surgery. He is convinced that there is still a lot of room for improvement and optimization in the healthcare system today.

The use of new interdisciplinary technologies holds considerable potential for bigger developmental leaps than have been achieved to date. It was gratifying to have the chance to share my enthusiasm for implementing innovative research projects to improve patient care with someone as talented and driven as Benedikt. Several years ago, the AO Technical Commission launched a strategic initiative to foster smart sensor technology to obtain more information about fracture healing and patient performance during rehabilitation.

As one of my mentees, while he was a junior physician, Benedikt became involved in AO Technical Commission research projects that involve pressure measuring insoles that use wireless technology to monitor patients during their postoperative rehabilitation period (Fig 3). Examples of his valuable contribution include a validation study and several clinical studies in this area which even led to simulation assisted interfragmentary movement prediction based on the patient's gait.

Benedikt is regularly involved in the annual AO Trauma Pelvis course in Homburg and in summer 2019 he submitted his professorial dissertation. Talking to him, his natural enthusiasm and gift for inspiring his students to further explore trauma and orthopedic surgery come across almost immediately. He is involved in lectures on the lower extremity and a practical seminar. He also offers an elective subject with case discussions for students who are interested in gaining a deeper understanding of traumatology. This course has been very well received and as a result he was recognized by the medical department in 2018 with the annual teaching award. Furthermore, he is actively involved in working with the young surgeon committees of both the German Surgical Society (DGCH) as well as the professional society (Berufsverband der Deutschen Chirurgen) organizing sessions, lectures, and instructional courses for students and young surgeons.



Fig 2 Together with Dr Andrew Sands of the AO Technical Commission Trauma.



Fig 3 Benedikt reporting about the first clinical study results with the pressure measuring insole at the AO Technical Commission Patient Monitoring Workshop in 2016.

His primary motivation for working in trauma surgery is clinical practice: “Being able to help an acutely injured patient, and establishing mutual trust, is indeed an incredibly rich experience.” Benedikt says that barely any clinical professions offer regular 9-to-5 working hours. He feels that traumatology is not necessarily worse than other medical disciplines for achieving a balance between your private and professional life. Irregular shifts and travel can be demanding, but a lot depends on the clinic, your own approach, and your personal circumstances. Benedikt emphasizes that the team and spirit in Homburg are excellent and that he feels honored to work with them. His goal is to also create such a productive work atmosphere in the SDSTF. His family backs his endeavors and he is particularly fortunate that his wife, Eva-Marie, is a tremendous support. She often provides him with beneficial advices, and while she is an OB/GYN physician by training her knowledge of trauma surgery is impressive.



Fig 4 Roped up with his father descending over a deeply crevassed glacier.

Away from work, he enjoys traveling, hiking, and moderate mountaineering. Benedikt and his wife constantly strive to achieve more and reach higher altitudes. He has started doing smaller glacier tours (Fig 4) and recently succeeded in realizing a long-cherished dream by climbing Mount Kilimanjaro together with his wife (Fig 5). Music continues to play an important role in Benedikt's life: he practices the flute regularly, but these days considers himself a better listener than player.



Fig 5 Benedikt with his wife at Uhuru peak (Kibo/Kilimanjaro), the highest point of Africa and highest freestanding mountain at 5895 meters.

Week 1	Week 2
	Sunday 08, 12:00–12:45 Patient Specific Procedures in CMF - State of the Art Daniel Buchbinder
Monday 02, 12:15–13:00 RIA 2: The Next Generation Reamer-Irrigator-Aspirator Brent Norris, Martijn Poeze, Hans-Christoph Pape	Monday 09, 13:15–14:00 How to Plan and Perform CMF Distraction Alberto Rocha Pereira, Stephen Dover
Tuesday 03, 12:40–13:40 AORcon: Introduction to AORcon Complex Exercises Bas Masri, Robert Hube	Tuesday 10, 12:15–13:00 Application of the LCP Distal Femur Plate in Comminuted Fractures of the Proximal Phalanx in Horses Fabrice Rossignol, Jeffrey P Watkins, Christoph Lischer
Wednesday 04, 13:00–13:45 Fracture Related Infection: New Consensus on Diagnosis and Treatment Willem Metsemakers	
Thursday 05, 12:15–13:00 Minimal Invasive Rib Stabilization Mario Gasparri, Stefan Schulz-Drost	
Friday 06, 11:45–12:30 Elastic Nailing for Children's Fractures: How to Avoid Complications Theodor Slongo, Unni Narayanan	
Schedule of the AO TC Meet the Experts sessions in 2019.	

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