IBRA International Bone Research Association

FLASH 2019

Edition 1

Editorial

The turn of the year 2018/19 brought a couple of improvements and changes for IBRA:

While the inclusion of proximal humerus fractures completed the upper-limb segment in 2018, this year offers a more diverse setting of foot & ankle educational levels. Beside the already well-perceived advanced courses, basic and master courses are going to join IBRA's course offerings in Japan and Switzerland in 2019.

The IBRA membership includes a new level which opens opportunities for newcomers who would like to get a first impression of our organization or for health professionals who don't lead the scalpel.
Beside the full and premium (lifetime) membership, a basic membership is now offered and can easily be joined through a few clicks on our web page.

As regards the web page: by the turn of the year, IBRA shifted to the new, more international domain IBRA.net to welcome these years' new engagements, especially in the USA (and for all other countries we serve already). Since January, IBRA's scientific networking has run with a respective top-level-domain.

Our new president, Prof. Dr. Rainer Meffert assumed office from Prim. Dr. Wolfgang Hintringer, who did a great job for the past four years and guided IBRA into new spheres. A big THANK YOU for your excellent commitment! Giving our readers a brief impression about Rainer Meffert, we start this Flash with an interview on his background, his ideas for IBRA, and some little insights into his personal life.

IBRA Administration Team

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Interview with the new IBRA President Prof. Dr. Rainer Meffert

Prof. Dr. med. Rainer H. Meffert
Director of the Surgery Department II
Clinic and Policlinic for Trauma, Hand, Plastic and Reconstructive Surgery
University Hospital Würzburg

1984-1991 Medical Studies, University of Münster, Germany
1986 Kantonspital Basel, Switzerland (Hand surgery)
1988 University of Iowa, USA (Trauma surgery)
1990 University College London, Great Britain (Internal medicine)
1991 Northern General Hospital, Sheffield, Great Britain (Orthopaedics)
1991-1993 Unfallkrankenhaus Hamburg
1993-1998 Marienhospital Herne, Ruhr Uni Bochum
1998 Bundeswehrzentralkrankenhaus Koblenz
1998-1999 Johns Hopkins University, Baltimore, Maryland, USA
1999-2007 Senior physician at the University Hospital Münster, Germany
since 01/2007 Full professor of trauma surgery at the University Hospital Würzburg, Germany (1st Professorship in Bavaria, Germany)
2017 President of the Vereinigung Bayerischer Chirurgen (Association of surgeons in Bavaria)
2018 President of the International Bone Research Association (IBRA)

Elected by the Board of Directors in 2013, Primarius Dr. Wolfgang Hintringer from Vienna, Austria served as president of IBRA from July 2014 to December 2018, when he passed the leadership to Prof. Dr. Rainer Meffert from Würzburg, Germany. During his presidency IBRA has grown significantly in quality and quantity of educational courses, yet standardized in educational contents. Many geographic and cultural borders have been crossed for the purpose of exchanging expertise and extending knowledge. IBRA was very blessed by his presence and unique character and is lucky to keep him in his new role as past-president for the coming 2 years. Thank you very much, Wolfgang Hintringer, and welcome Rainer Meffert!

Prof. Meffert, you are the head of the Department of Trauma, Hand, Plastic & Reconstructive Surgery at the University of Würzburg, an experienced researcher, a renowned surgeon, and a great teacher. And for more than 10 years, you have been a highly engaged IBRA member. Based on your experiences, what are the main strengths of IBRA?

The main strength of the IBRA is to accumulate a community of competence, tolerance, experience, focused on a field of high functional demand on complex anatomy. IBRA members are open-minded and curious to exchange their experience and skills with others. Most of us do feel more like friends than like competitive colleagues.

Throughout your academic career you have studied, worked, and taught in many countries (like England, the USA and in several other countries with IBRA).
Where are the opportunities you see in international cooperation and networking?

Before I can answer on changes in international cooperation and networking in the future, I should look back on my personal career. Early during my medical studies I took the opportunity to work in Switzerland, in Great Britain for 8 months, as well as in the United States. It was highly interesting for me to learn about the attitude and behavior of doctors in different health systems and different societies. Years later, when I finished my residency in general surgery and after I completed my military service in the central trauma hospital in Koblenz, Germany, I spent one year at John Hopkins University in Baltimore, USA.

I joined a professional research team in the biomechanical laboratory with chief professor Edmund Chao, one of the godfathers of modern medical biomechanics. He taught me how to analyze papers, work professionally, and plan studies and (animal) experiments. In long, sometimes controversial discussions, he gave me new insights into research work – a lesson I learned for my later career. And I am still convinced that the personal exchange of knowledge, experience and also skills is a key to improving your own work and abilities. Maybe you might think I am old school if I tell you that the personal interaction and time spent together is much more valuable than Internet networking such as webinars or others. Of course, there is no communication without email, WhatsApp or other social media to easily stay in touch and keep up relations. However, there must be some personal components to make it real. Therefore, we all need to do some travelling and visit our friends in other countries and continents to really understand their way of thinking and working.

IBRA just started educational events in China, Japan, and is going to open an office in the United States of America. What is your vision for the cooperation with surgeons in the Far East and in North America?

Surgeons in the Far East and North America are very specialized and focused on special areas in surgery. Therefore the teaching will have a very high level of theoretical and practical background and we will exchange our experience with experts. I am very much looking forward to not only meeting the colleagues in the Far East and North America in meetings and congresses but also in operative workshops as we have started with the Master Courses in Cologne. I am very confident that our colleagues at the highest level of specialization will appreciate this way of teaching. However, both markets and also medical societies may not be open-minded in general, so therefore we have to carefully find out what they use as their current techniques, and I am pretty confident we will find excellent doctors, who will join our faculty team later on.

Prof. Meffert Speaker at the Int. Orthopaedic Forum

In a previous publication in 2007 (idw-online.de) you mentioned that the know-how from plastic surgery and traumatology will advance hand surgery on new levels? Are there any developments over the past 10 years you could share with us?

Hand surgery is a very fine field where traumatology meets plastic surgery on a microsurgical level. In our department, we currently have 7 plastic surgeons and 21 trauma surgeons to fulfill all tasks of a level one trauma center including a replantation service. Not every plastic surgeon or trauma surgeon is interested in stepping into the field of hand and micro surgery. However, it is so important to learn these techniques in order to achieve the best possible trauma care. In the last 10 years, we have achieved a very high level of experience in combined osteosynthesis bone reconstruction simultaneously to free perforator flap soft tissue coverage. In the field of hand surgery, there has been a lot of progression in anatomically designed implants such as fully axial angular stable mini screws and plates that can achieve the highest ability to allow early functional treatment in hand traumatology.
Also different future techniques including new self-anchoring materials have been investigated and the development of hand surgery is continuing.

Our surgeons at the University Hospital incl. students

At the last IBRA General Assembly, you took over the IBRA presidency. What goals would you like to achieve? If colleagues ask you about the benefits of being an IBRA Member, what would you tell them?

First I would like to thank the Board of Directors of the International Bone Research Association for electing me as the next period president of the IBRA. It´s evidence of true trust I have received and I do highly appreciate

the nomination. The IBRA have it in mind to share their fine expertise in trauma and hand surgery with colleagues from other countries and societies. Therefore, I find it very interesting to gain more contact with the Asian market and medical society. It was a great opportunity to travel to Xián, China, last year and give talks but more importantly and interestingly to see their hospitals, their organizations and their attitude in treating patients. And their confidence, that we may improve treatment in other countries with our knowledge, however, we shall not forget, how much we can learn from them. Having said that, I believe we will generate an extensive international faculty more resulting in more controversial discussions on a high level of experience. This is exactly what our members expect to train our academic thinking, allowing other treatment options than the ones we have learned and widening the own horizon. Any of our IBRA members will be able to share these discussions on the workshop table as well as during and after theoretical sessions. And before you include a new operation technique in your own repertoire of techniques in future, you like to be sure to expect superior results by understanding these techniques and having trained them in workshops. And with a growing number of IBRA members, I still hope we can manage to maintain a friendly atmosphere in our courses and workshops. This truly distinguishes the IBRA from other societies.

What are your experiences with the IBRA scholarship program?

The IBRA scholarship program is a logical add-on to our courses. While you attend our workshops and symposiums, you will have the opportunity to spend more time with highly experienced surgeons presenting these techniques in Europe. It gives us the chance to travel to the United States, to South America or even to Australia, and vice versa people from overseas might be interested in spending time with us in our hospitals. I am very positive that the scholarship program has a high impact on our society. On the other hand, newly developed implants meets critical evaluation over time. Therefore, I hope we will have enough studies investigating benefits and drawbacks in the clinical setting.

Prof. Meffert + visiting Surgeon

What would be topics to discuss at the regulars' table with you? What are the hobbies that shape Rainer Meffert beyond work?

If you want to discuss topics at a "regulars' table" with me you can find a lot of topics in my professional field of trauma surgery. From a tip of a finger to the heel of your foot, wherever you have trauma in the musculoskeletal system, our department will take care of it. So I can follow all these discussions if there is interest. On the other hand I do have (at least) some hobbies I appreciate doing beyond work. I love to go alpine skiing, which I do every year with my family, with my colleagues from my department as well as with faculty members of the university. So, at least 3 weekends a year I spend on my skis in the mountains. I also love to go mountain biking in my holidays, be close to nature, and work-out. Furthermore, when time during holidays allows it, I love traveling to different countries to explore the nature and share quality time with family, friends and colleagues.

Meffert Family on Tour

My last trip was a family trip going through South Patagonia in Chile, a truly nice experience to visit the most southern city (Punta Arenas) of the world. Celebrating Christmas 2018 in the middle of the Atacama Desert was a new experience far from a normal Christmas. So ask me about travelling, I would like to hear your stories and to share mine with you.

Thank you very much for the interview, Prof. Meffert

Course Composition: Basic – Advanced – Master

IBRA offers a variety of course levels for surgeons in different stages of their career.

Basic courses are designed for surgeons during their residency or sub-specialty training. Their goal: offering state-of-the-art approaches in clinical diagnosis, treatment and rehabilitation. Coming from a variety of hospitals and clinics, the faculty offers a wide range of perspectives nourishing the participants with varieties of approaches, techniques, and experiences.

Advanced courses are for specialists with deeper expertise in their field. Starting from evidence-based treatment options, expert opinions – especially in operating procedures of challenging cases – are getting more important. As such, chairpersons and faculty provide examples for case discussion and exchange.

Master courses require superior expertise in the respective sub-specialty, and such as they are ideally for heads of departments and experienced researchers. While all participants are considered experts in their field, chair persons and faculty are moderators of most intriguing cases – theoretically in case presentations as on practical grounds. Participants are invited to bring tricky cases for scholarly debate.

Some important features of all courses are highly specialized faculty members, transdisciplinary approaches to relevant related academic disciplines (such as biomechanics and engineering), and the level-specific practice on challenging cadavers from sawbone to pre-fractured specimen.

The following overview of relevant parameters shaping the course composition offers assistance in finding your most relevant level:

	Basic Courses	Advanced Courses	Master Courses
Target audience	*Recommended for residents and physicians in sub-specialty training.*	*Recommended for senior surgeons and consultants.*	*Recommended for heads of departments and senior surgeons.*
Main specialty of the event	*The course offers the basics in clinical diagnostics, treatment and follow-up. The focus is on state-of-the-art surgical techniques.*	*Starting with classification of the injury or deformity, the faculty members share their preferred approach, treatment, and follow-up of cases with advanced difficulty.*	*An interactive seminar and hands-on workshop, addressing trauma and reconstruction with representative cases and discussions. International faculty present latest innovations and trends both in lectures and surgical demonstrations to the participating senior surgeons.*
Role of faculty (theory & practice)	*Teachers and instructors*	*Models and advisors*	*Moderators and facilitators*
Presentations	*Lectures/cases with discussions, economic considerations*	*Case discussions*	*Impulses (challenging cases, research)*
Objective (theory)	*Learning state-of-the-art interventions*	*Dealing with challenging cases*	*Challenging good practices (impulses beyond)*
Transdisciplinary contents	*Presentation on basic biomechanics, providing background information to all hands-on skills*	*Presentation on advanced biomechanics, engineering, sports orthopaedics*	*Presentation on innovations and ongoing developments*
Introduction of exercises	*Videos (commented by faculty)*	*Videos and occasionally life operations*	*Case discussion of group with radiologic findings*
Practical Exercises	*Instructed by faculty*	*Advised by faculty*	*Facilitated (moderated) by faculty*
Quality of Specimens	*Sawbone/fresh frozen cadaver*	*Fresh frozen/pre-fractured specimen (if indicated in exemplary cases)*	*Pre-fractured specimen*

IBRA – Research and Education Committees

The IBRA Research & Education Committees (REC) are platforms supervising quality assurance and encouraging professional expertise. They put emphasis on promotion of individual academic and professional careers beyond geographic and cultural borders. The three Research & Education Committees focus on the body segments head, upper limbs and lower limbs.

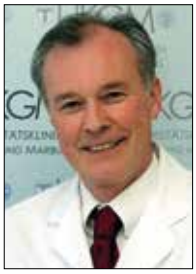
Core tasks of the IBRA Research and Education Committees are:

- Supervising continuous medical education (CME) quality standards of the various course offerings.
- Evaluating course participants' needs for further improvement of educational conduct.
- Assessing scholarship applications for IBRA training centers and confirming accepted candidates.
- Assessing and advising potential (multi-center) research studies of IBRA training centers.

Each Research and Education Committee is composed of surgeons often representing various IBRA Training Centers of the respective body segment. A MedTech representative complements the committee in terms of current trends in education and research.
The Research and Education Committees meet twice a year – usually January and September for timely decision-making toward scholarship applications (deadlines for scholarship applications are January 10 and September 1).

The IBRA Research & Education Committee Head consists of the following members:

Andreas M. Neff, Marburg, Germany (Chairman)
Oliver Ploder, Feldkirch, Austria
Tim Lloyd, London, United Kingdom
+
Claudio Darms, Medartis, Basel, Switzerland



The IBRA Research & Education Committee Upper Limbs consists of the following members:

Christoph Pezzei, Vienna, Austria (Chairman)
Lars Peter Müller, Cologne, Germany
Adam Watts, Wrightington, United Kingdom
+
Matthias Walter, Medartis, Basel, Switzerland



The IBRA Research & Education Committee Lower Limbs consists of the following members:

Victor Valderrabano, Basel, Switzerland (Chairman)
Christian Plaass, Hannover, Germany
Mario Ulises Herrera Perez, Tenerife, Spain
+
Lukas Regniet, Medartis, Basel, Switzerland



Distal Radius Corrective Osteotomy - When and How?

Roman Wolters, Hermann Krimmer

Despite all the improvements in the surgical management of distal radius fractures due to optimized osteosynthesis materials, and despite a distinctive understanding of fracture morphology, a distal radius fracture that has healed in malalignment is still a challenging complication. This article provides an overview of the various types of malalignment and their options for surgical correction.

INTRODUCTION

A distal radius fracture that has healed in malalignment is still a challenging complication. The resulting discomfort ranges from pain, motion restriction, and loss of strength in the region of the wrist to a difference in external appearance, silver-fork deformity, and development of posttraumatic arthrosis. Since the consequences are sufficiently well-known nowadays, the current trend is toward performing corrective surgery as early as possible. Even in the case of clinical pictures like Madelung's deformity and congenital deformation in the region of the distal radioulnar joint, a distal radius correction can be indicated. The aim of this is to reduce pain and prevent early arthrotic changes.

INDICATIONS

Distal radius fracture that has healed in malalignment

The improvement in preoperative diagnosis by performing preoperative computed tomography (CT) as standard for intra-articular and complex distal radius fractures, with 3D reconstruction where necessary, has led to a better understanding of fracture morphology.

In addition, further development of osteosynthesis material with numerous fixed-angle special plates – to fit the particular fracture morphology – is helping to enhance postoperative outcome and avoid secondary dislocations.

In the case of postoperative malalignment the strategy used in the past was based on waiting for complete osseous consolidation before corrective osteotomy. Nowadays there is no wait for complete healing because it is now known that a correction of alignment as early as possible leads to a rapid improvement in discomfort while consequential damage in the form of posttraumatic arthrosis or the development of a complex regional pain syndrome (CRPS) can be avoided [1, 2].

• Note
Correction of alignment should be performed as early as possible.

An existing CRPS sustained by malalignment usually improves after correction of alignment.

Corrective osteotomy is always indicated in the case of extra-articular fractures after total healing in malalignment involving dorsopalmar and radioulnar inclination and in the case of radial shortening [3]. In addition, in the case of intra-articular malalignment the indication always depends on the development of offset in the region of the articular surface.

ABBREVIATIONS

CT	Computed Tomography
CRPS	Complex Regional Pain Syndrome
DRUJ	Distal Radioulnar Joint
EPL tendon	Extensor pollicis longus tendon
FCR tendon	Flexor carpi radialis tendon
MRI	Magnetic Resonance Imaging
VAS	Visual Analog Scale

Coexisting malalignments in the region of the distal radioulnar joint (DRUJ) and an ulnar impaction syndrome resulting from radial shortening often cause ulnocarpal pain.

However, the radiological image does not always have to correlate with the clinical picture:

- In relatively young patients, the focus is on preventive effects such as the avoidance of posttraumatic arthrosis, alongside clinical discomfort..
- In elderly patients, on the other hand, the focus is on the discomfort so if the patient is largely pain-free the indication for corrective osteotomy should be determined with caution.

If CRPS is present, malalignment must be ruled out radiologically because it can cause and sustain the clinical picture.

If corresponding clinically relevant malalignment has been ascertained, after osteosynthetic management or after conservative treatment, corrective surgery should be performed as early as possible (Fig.1).

Fig.1 X-ray of a wrist with a distal radius fracture that has healed in malalignment with a dorsal tilt of 30° and an ulna plus situation of 2mm.
a PA x-ray image
b Lateral x-ray image.

Posttraumatic Growth Disorders

In posttraumatic growth disorders of the radius (Fig.2) considerable length deficits often occur as a result of early closure of the epiphyseal plate. Due to the soft tissue situation in such cases it is not advisable to perform a one-stage procedure. A two-stage procedure taking the form of distraction osteotomy is preferable. When length compensation has been achieved, a change of method with internal fixed-angle plate osteosynthesis is performed. This ensures good adaptation of soft tissue and avoids excessive bone grafts (see also Fig.9).

Fig.2 X-ray of the wrist of a 14-year-old female patient wrist ulna plus of 2 cm and increased palmar tilt of the radius to 30°.
a PA x-ray image.
b Lateral x-ray image.

Madelung's Deformity

Madelung's deformity (Fig.3) is a growth disorder of the distal radius, predominantly in the female gender. Vickers and Nielsen [4] were able to prove that the cause is abnormal ligamentous structures (Vicker's ligament) that inhibit growth in the region of the ulnar epiphyseal plate of the radius. Based on our own experience, in some cases intraoperative examination also exhibits abnormal muscular tissue that extends to the carpus, bridging the palmar ulnar epiphyseal plate of the radius.

If the disorder is diagnosed at an early stage, the abnormal ligamentous structures can be resected in order to eliminate the obstruction. However, if the diagnosis is only made at a later stage, there is usually the typical malalignment with increased radial inclination accompanied by tilting of the ulnar articular surface of the radius toward palmar (see Fig.3). That causes proximalization of the lunate bone between the radius and the ulna, with dorsal malalignment of the ulnar head.

If a substantial malalignment already exists, there is the option of radial corrective osteotomy. If corrective surgery is performed when the patient is a young adult, this usually leads to a considerable pain release, an improvement in external appearance, and a reduction in secondary arthrotic changes.

However, if the patient is already older than 35 – 40 years upon diagnosis, corrective osteotomy is often no longer indicated on account of the long period of adaptation to the malalignment. In such cases, salvage procedures represents the preferable treatment [5].

Fig.3 X-ray of a wrist with Madelung's deformity.
a PA x-ray image.
b Lateral x-ray image.

Congenital Incongruence of the Distal Radioulnar Joint

Congenital incongruence of the DRUJ is usually accompanied by an ulna minus variant with deformation of the radioulnar articular surface. This frequently leads to painful impingement, evidence of which can be clinically assessed by positive compression test at the DRUJ.

In magnetic resonance imaging (MRI) there is often contrast agent enhancement in the region of the DRUJ, which is seen as a sign of chronic irritation. The deformation might be regarded as pre-arthrosis because it often subsequently leads to arthrosis in the DRUJ.

• Note
Congenital incongruence of the DRUJ can lead to early arthrotic changes if it is not treated.

Therefore, in addition to the clinical effect due to pain reduction, the indication for corrective osteotomy follows a preventive effect to avoid the development of arthrosis.

Clinically, forearm rotation is painfull with no restriction of motion.

Fig.4 X-ray of a wrist with congenital incongruence of the DRUJ.
a PA x-ray image.
b Lateral x-ray image.

The aim of corrective osteotomy involves restoration of the neutral position with correction of the sigmoid notch which leads to decompression of the DRUJ and is achieved by reducing the tension in the interosseous membrane [6] (Fig.4).

DIAGNOSIS

Clinical examination with documentation of the range of motion and grip strength measurement using a dynamometer to compare sides are mandatory, assessment of pain and wrist score unnecessary.

Prior to planning and performing corrective osteotomy, there must be not only x-ray images in PA and lateral projections available but also a current CT scan. Proper analysis of malalignment is often only possible with a CT scan. Offsets in the region of the articular surface can only be reliably assessed on a CT scan.

Furthermore, prior to performing the corrective osteotomy it is necessary to radiologically rule out any severe arthrosis in the region of the radiocarpal articular space and in the region of the DRUJ because advanced arthrosis can represent a contraindication for corrective osteotomy.

• Note
A current CT scan must be available prior to performing corrective osteotomy.

If there is any suspicion of congenital malalignment, x-ray images must be made of the opposite wrist.

In the case of Madelung's deformity the opposite wrist should also be x-rayed in 2 planes because the clinical picture is often on both sides.

SURGICAL PROCEDURE

Posttraumatic Malalignment

Extra-Articular Malalignment

Corrective osteotomy for dorsal malalignment used to be performed via a dorsal approach and for palmar malalignment it used to be performed using a palmar approach.

However, in a correction that is performed from dorsal it is difficult to conduct an exact adjustment of anatomical positions. That is why the team led by Lanz preferred a palmar approach at an early stage with distal pre-mounting of the correction plate [7, 8]. When fixed-angle implants with two-row distal support had been developed, this procedure became standard.

In Lanz's procedure the palmar approach is extended distally in a Y shape to enhance the overview. If no significant shortening exists, the approach is, as for distal radius fracture, between the flexor carpi radialis (FCR) tendon and the radial artery. In the event of radial malalignment with distinct shortening, on the other hand, the approach is radial to the radial artery in order to be able to subperiosteally detach the 1st – 3rd extensor tendon sheath and avoid obstruction of the correction by soft tissue.

Fig.5 Intraoperative opening of the 3rd extensor tendon sheath.

The 3rd extensor tendon sheath is always open in order to avoid secondary rupture of the extensor pollicis longus (EPL) tendon due to sharp osteotomy edges or hematoma formation (Fig.5).

Following exposure of the palmar distal radial surface the correction plate is pre-mounted distally with 3–4 screws. The first screw to be introduced is a cortical screw and with the other fixed-angle screws the screw head is not inserted completely. If there is pronounced dorsal tilt, the distal screws may have to be predrilled toward proximal in order to avoid an intra-articular screw position. In doing so, the plate is mounted at the desired correction angle (see below).

On the correction plate we use (Correction Plate from Medartis), the distal plate edge runs parallel to the articular surface of the radius.

Since in the case of severe malalignment the watershed line can often no longer be identified, plate position may have to be checked with an image intensifier.

If there is a loss of inclination in the PA plane, the pre-mounted plate must protrude proximally toward ulnar. When corrective osteotomy has been performed, the plate comes to rest on the radial shaft proximally and then centrally.

To correct dorsal tilt the plate must protrude proximally from the radial shaft after pre-mounting. Whereby the angle between the plate and the radial shaft is the desired correction angle.

• Note
In distal pre-mounting, the PA and lateral plane correction angles must be taken into account.

To fix the correction angle the Medartis company (Medartis AG, Basel, Switzerland) offers special instrumentation that is positioned in the plate shaft and ensures accurate angular adjustment (Fig.6).

The pre-mounted plate is removed again. Under fluoroscopic control the osteotomy plane is now established. It can be marked with a Kirschner wire. It usually corresponds to the former fracture plane.

• Caution
It is absolutely essential to make sure the osteotomy is performed just proximal to the DRUJ, in order to avoid damaging the articular surfaces of the DRUJ.

For the osteotomy the extensor tendons are protected with a Hohmann bone lever that is introduced subperiosteally. To avoid thermal necroses a fresh saw blade should always be used.

When the osteotomy has been performed, the plate is mounted in the occupied holes again and then the plate is reduced against the radial shaft, resulting in accurate restoration of the articular surface angles. In the shaft region the plate can be fixed temporarily using blunt reduction forceps.

The correction position is now checked with fluoroscopy. Care must also be taken to ensure correct length compensation in the neutral position or a slight minus position (–1mm) of the ulna. Introduction of a nonunion retractor to the osteotomy gap facilitates length compensation, especially in the case of relatively long distances.

Then the plate holes are filled in the shaft region.
In relatively rare cases of malalignment with palmar tilt of the articular surface of the radius it is usually possible in the osteotomy to leave the dorsal cortical bone alone.

Then the malalignment can be corrected by palmar folding open of the osteotomy using an „open book technique".

Since correction nowadays is performed using a fixed-angle plate with two-row distal support as standard, an osteotomy gap of 6–8mm can be left without any interposition of iliac crest cancellous bone, provided the bone quality is good.

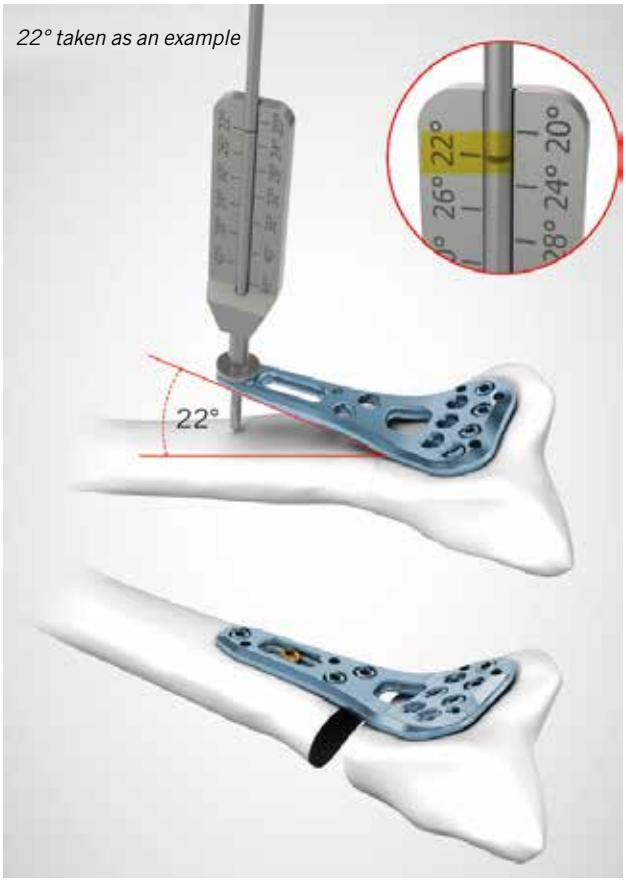


Fig.6 Instrumentation for setting the desired correction angle (courtesy of Medartis AG, Basel, Switzerland).

In the case of major defects a cancellous or corticocancellous iliac crest graft should be interposed, being held in place with a plate screw. Alternatively, bone substitute material or allogenic femoral head bone can be interposed.

In the case of anatomical alignment of the distal radius (correct inclination of the articular surfaces) an ulnar shortening osteotomy is a good alternative for simple radius shortening because it can be performed under control and reliably using the now standard fixed-angle ulnar shortening plates.

Following 4-week immobilization of the wrist in a thermoplastic splint, an x-ray checkup is performed and approval is given for functional follow-up treatment where applicable (Fig.7).

Intra-articular Malalignment

If intra-articular malalignment requires a direct view of the articular surface, it can be achieved by performing correction from dorsal. As with dorsal fracture management, the approach is via the 3rd extensor tendon sheath and subperiosteal exposure of the dorsal radius with a direct view of the articular surface. The osteotomy is performed in the former fracture plane under vision using a thin sharp chisel.

• Note
In the dorsal approach the correction osteotomy can be performed with a direct view of the articular surface.

Alternatively, it is possible to perform an arthroscopy-assisted correction [9, 10].

When the osteotomy has been performed, K-wires can be introduced like a joystick to facilitate adjustment of the correction position. The correction outcome can then also be temporarily fixed in place with Kirschner wires. Osteosynthesis is performed using screws or plates, depending on the fracture situation (Fig.8).

Growth Disorders in the Region of the Radius

In the case of posttraumatic growth disorders due to premature complete or partial closure of the epiphyseal plate, often substantial longitudinal defects arise which cannot be surgically compensated in a one-stage procedure. In such cases a two-stage procedure is indicated.

• Note
For relatively large longitudinal defects a two-stage procedure is indicated.

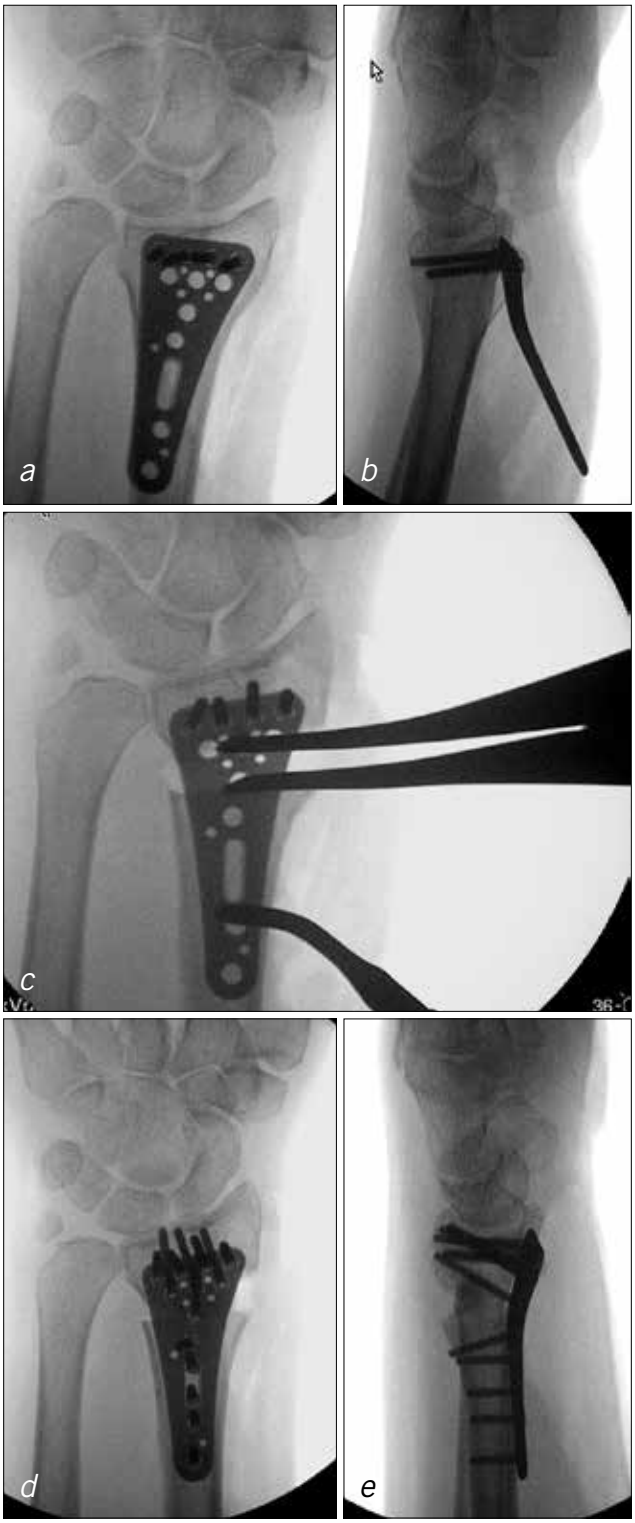


Fig.7 Palmar correction following distal radius fracture (preop. see Fig.1).
a PA projection: intraoperative plate fixation protruding at the desired correction angles.
b Lateral projection: intraoperative plate fixation protruding at the desired correction angles.
c Length compensation with nonunion retractor.
d PA projection: After correction with restoration of the articular angles at the radius and longitudinal compensation of ulna –1mm.
e Lateral projection: After correction with restoration of the articular angles at the radius and length compensation of ulna –1mm.

In the first operation a distraction fixator (e.g., Hoffmann fixator, Fig.9 a, c) is mounted. Here it is crucial to mount an additional Schanz screw with a connecting rod at right angles to the distraction plane in order to prevent palmar tilting of the distal radius portion during distraction. Osteotomy is then performed proximal to the distal Schanz screws and proximal to the DRUJ.

After one week, distraction commences with approx. 0.5 mm per day. The distraction phase can take weeks or even several months before the desired length compensation has been achieved. In a second operation the defect zone is then bridged by plate osteosynthesis and the fixator is dismounted (Fig.9 d, e).

Congenital Malformations

Madelung's Deformity

In the correction of Madelung's deformity the aim is ulnar elevation of the distal radius accompanied by rotation toward dorsal. The correction is performed via the above-described palmar approach. The abnormal ligamentous or muscular portions already described are resected. In the osteotomy care must be taken to ensure that the osteotomy plane on the ulnar side is just proximal to the deformed radioulnar joint. The radial cortical bone can usually be left alone to improve guidance.

The distal radius is now folded open with the aid of an osteotomy retractor using an „open book technique". Since dorsal rotation of the radial articular surface has to be performed at the same time, the anatomical excessive palmar tilt must be corrected by using a palmar correction plate which ist straight.

Following adjustment of the desired correction position the reduction outcome can be temporarily fixed in place with a Kirschner wire. After fluoroscopic control the reduction position can be fixed using the palmar fixed-angle straight plate.

Since correction osteotomy for Madelung's deformity usually involves young patients, defects with a width of up to 1 cm can be left alone without interposition of a cancellous bone block (Fig.10).

Congenital Incongruence in the Region of the Distal Radio-ulnar Joint

In the case of congenital incongruence of the DRUJ the aim of correction osteotomy is to restore the shape of the sigmoid notch and to perform decompression of the DRUJ.

Fig.8 Correction of intra-articular offset formation following distal radius fracture.
a Preoperative coronal CT scan of the wrist.
b Preoperative sagittal CT scan of the wrist.
c Postoperative coronal CT scan of the wrist following correction from dorsal with screw osteosynthesis.
d Postoperative sagittal CT scan of the wrist following correction from dorsal with screw osteosynthesis.

The osteotomy takes the form of double osteotomy with shortening, taking out a radially wide bone wedge. Care must be taken to ensure that the distal osteotomy plane is proximal to the sigmoid notch. Correction is achieved by straightening up. With a simultaneous radial shift (or ulnar shift of the radial shaft) this results in reduced tension of the interosseous membrane and consequently decompression of the DRUJ.

• Note
Correction for congenital incongruence of the DRUJ corresponds to a closed wedge osteotomy with shortening and radial shift

After repeat distal mounting of the plate the osteotomy can now be closed and the screw holes in the shaft region can be filled after a fluoroscopic check. If decompression of the DRUJ

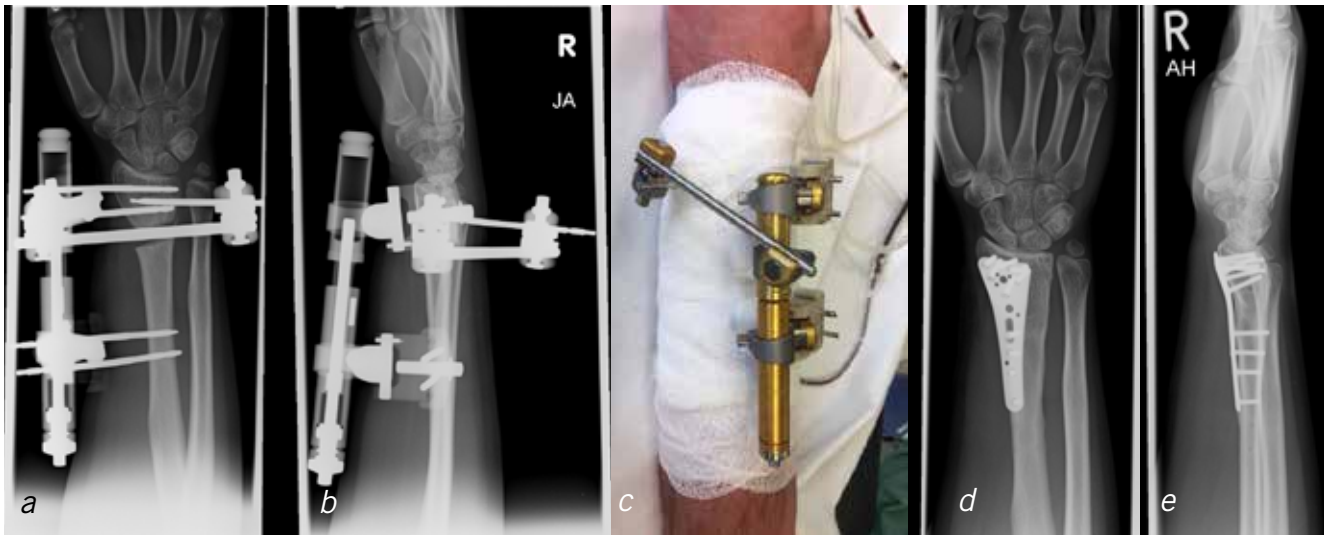


Fig.9 Correction of substantial radial shortening (preop. see Fig.2).
a PA image: distraction fixator in situ.
b Lateral image: distraction fixator in situ.
c Take note of mounting with additional transverse rod.
d PA image: procedural switch to palmar plate osteosynthesis following length compensation.
e Lateral image: procedural switch to palmar plate osteosynthesis following length compensation.

Fig.10 Correction of Madelung's deformity.
a Preoperative PA x-ray image.
b Preoperative lateral x-ray image.
c Postoperative PA x-ray image.
d Postoperative lateral x-ray image.

is also necessary, the distal end of the radius is shifted toward radial. Care must be taken to ensure that the osteotomy edge on the ulnar side does not impinge the ulnar shaft.

In the selected plate position a planned radial shift must be taken into account so that the plate does not project radially after a shift in the shaft region (Fig.11).

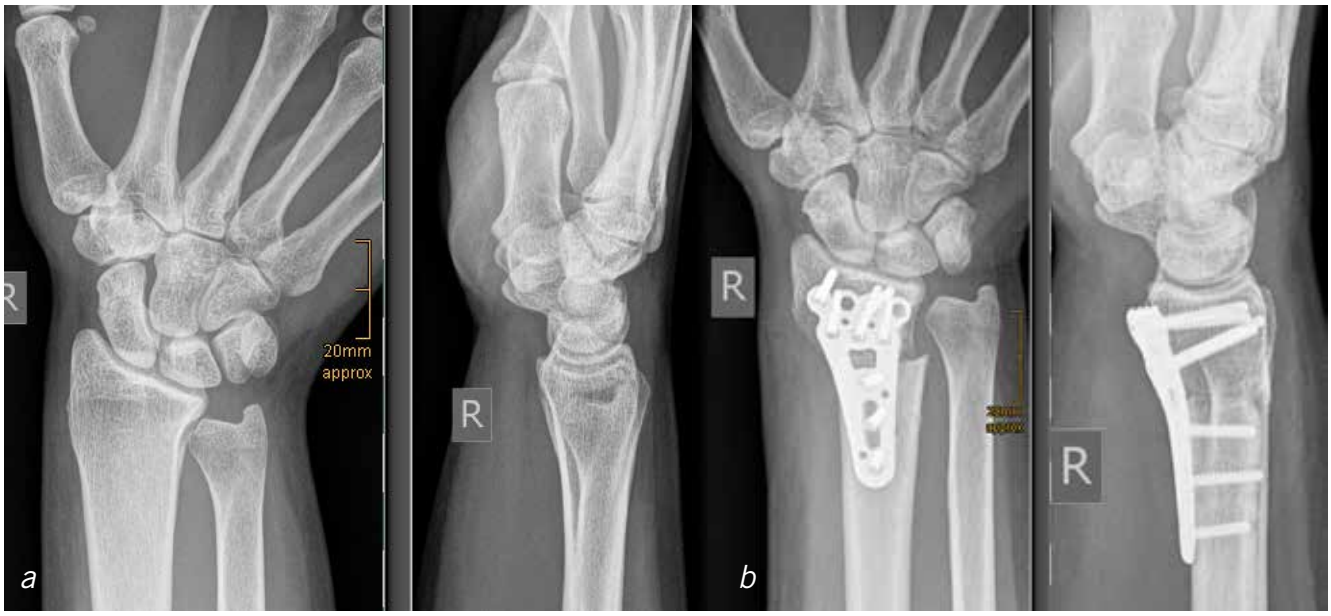


Fig.11 Correction for congenital incongruence of the DRUJ.
a Preoperative PA and lateral x-ray images.
b Postoperative PA and lateral x-ray images.

ADDITIONAL INFORMATION

Preoperative 3D planning

Preoperative 3D planning of correction osteotomy is a relatively recent development over the last few years. A CT scan is made of the side to be operated on and a CT scan is made of the opposite side for reference purposes. The malalignment is now analyzed under computer control. The required templates are made using a 3D printer. This method was developed, inter alia, by the Materialize company. In some cases the required correction plates can also already be custom-made [11]. The method is to be recommended especially in the case of complex and intra-articular malalignments. The benefit is reliable predictability of postoperative outcome.

Tab. 1 Overview of the various malalignments and their correction options.

Type of malalignment	Correction procedure
Extra-articular malalignment	Palmar approach
	Distal pre-mounting of the palmar plate prior to osteotomy, taking into account the malalignment to be corrected
Intra-articular malalignment	Dorsal approach with direct view of the articular surface
	Fixation of correction position with dorsal plate or screws
Posttraumatic longitudinal growth disorder	2-stage procedure with distraction fixator
	Procedural switch to palmar plate osteosynthesis when the correction position has been reached
Madelung's Deformity	Palmar approach
	Fixation of the correction position with palmar plate
Congenital incongruence of the DRUJ	Palmar approach
	Distal pre-mounting of the palmar plate before osteotomy
	"Closed-wedge" osteotomy with shortening and radial shift
	Fixation of the correction position with palmar plate

KEY MESSAGES

- Despite all the improvements in the management of distal radius fractures, healing in malalignment is a challenging complication.
- Since the resulting discomfort is known, i.e., pain, motion restrictions, and possibly posttraumatic arthrosis, correction osteotomy performed as early as possible is indicated.
- In most cases the correction is performed using a palmar approach.
- If a CRPS is being sustained by existing malalignment, correction osteotomy should be performed despite the CRPS.
- In the case of other clinical pictures as well, e.g., Madelung's deformity, congenital deformities of the DRUJ, and growth disorders in the region of the radius, existing discomfort can be sufficiently treated by radial corrective osteotomy.

KEYWORDS

Radial Corrective Osteotomy, Indications, Surgical Procedure

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CONFLICT OF INTEREST

H. Krimmer: Member of the development team at Medartis (Basel), financial support for congress attendances with own papers.
R. Wolters states that there is no conflict of interest.

SCIENTIFICALLY RESPONSIBLE PURSUANT TO CERTIFICATION REGULATIONS

Prof. Dr. med. Hermann Krimmer, Ravensburg, is scientifically responsible for this article pursuant to certification regulations.

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The IBRA International Conference **"All we know about radius"** in Prague, is intended not only to describe basic procedures with the evidence-based support but also to show and discuss a much larger range of problems for everyone treating the Radius. The factors like anatomy, type of fracture, delay from injury, age, location of pathology, and different treatment options, will be presented and debated. Also complications and false treatments will be presented and possible treatment options will be shown.

April 12 – 13, 2019 – Prague, Czech Republic

More Information: https://www.ibra.net/Events/-/2019/4

Medartis 3.5 Proximal Humerus Plating System Initial Assessment: A Revolutionary New Development!

Mohammad Waseem

INTRODUCTION

These few pages deal with the new Medartis 3.5 proximal humerus system. I have used this system for 4 years. We believe that the new locking blade plate construct provides an alternative to the readily available PHILOS plate. It outperforms the PHILOS plate with regards to the DASH score and also provides a better support to medial calcar with improvement in head shaft angle. It allows the shape of the head to be maintained and better outcomes as shown below.

There are similarities between this and other systems you might be using or be familiar with. I have used them all and this comes with more options for the surgeon to reconstruct proximal humerus. This, like most systems, does not fix everything and is not failure proof but an improvement in most areas.

ANATOMICAL

A right and left construct with holes for cuff and soft tissue repair allow better fixation. A posterior flange allows improved hold of greater tuberosity fragment. The twist allows the surgeon to avoid damage to the Deltoid insertion. This is true where longer plates are used.

BIOMECHANICAL

The system offers variable locking with Trilock system to aim screws at the best angle. The blade plate allows you to fix fracture dislocations adequately and maintains medal calcar angle to improve outcome and preserve blood supply.

SURGICAL

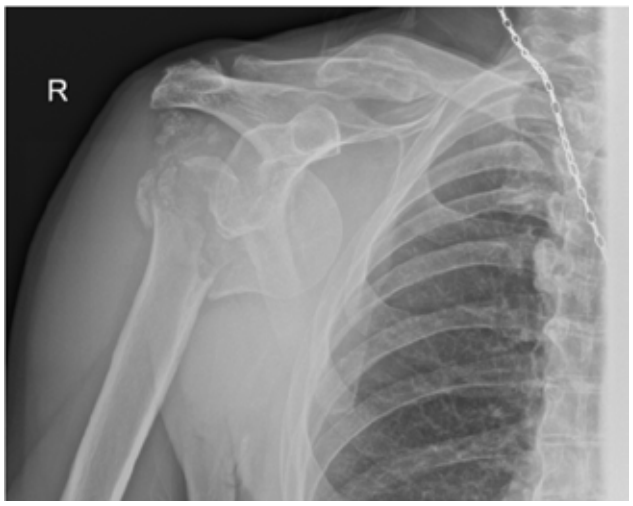
This plate has all the advantages of the other systems above and a few more of its own. It preserves blood supply, reconstructs the humerus to its anatomical shape. The blunt tip screws and two angles of blade plate 40 and 50 degrees add a lot to the surgeon's armament and fixing capability. The removal is also easy; we have performed 5 of these with no major issues.

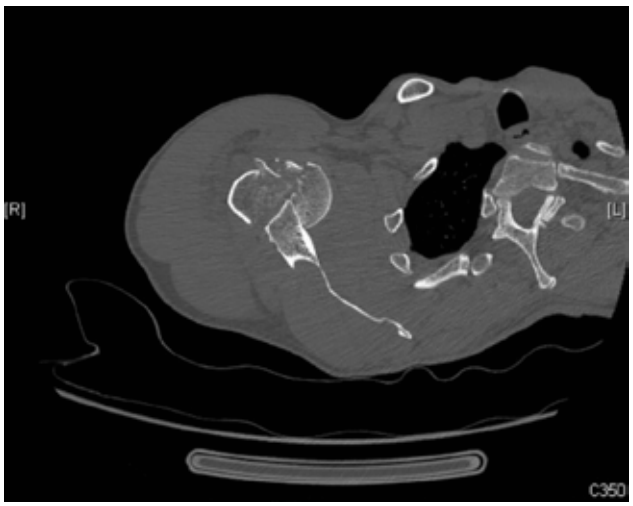
Our initial results over the first 42 months show that there is a better outcome in the first twenty-five patients were treated with the Medartis Proximal Humeral Plate 3.5 for complex proximal humeral fractures. Two senior surgeons, using this "locking blade plate", operated on all the patients. The patients were regularly assessed clinically, and plain radiographic evaluation was performed for fracture healing, avascular necrosis, and implant failure. Clinical outcome was measured using Oxford shoulder scores and DASH (Disability of the arm, shoulder, and hand) scores.

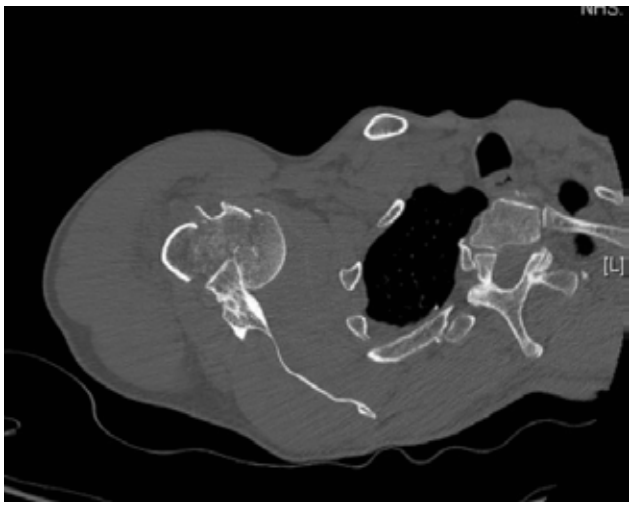
Results: There were eight male patients (Mean Age: 59 yrs.) and seventeen female patients (Mean Age: 64 yrs.). 42% were two-part, 32% were three-part, and 26% were four-part fractures. Mean Oxford shoulder scores: 37 (PHILOS 41.8) and Mean DASH scores: 22.5 (PHILOS 30.2). There were no cases of non-union. There was an average improvement in neck shaft angle by 12 degrees. Three plates were removed after fracture healing for complications of impingement only.

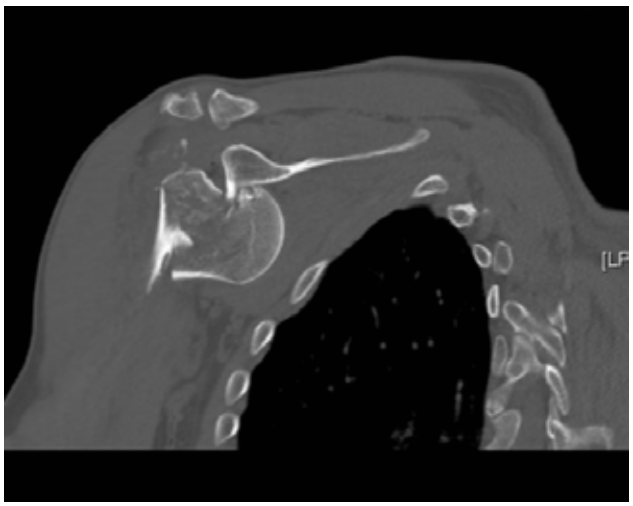
Conclusion: We believe that the new locking blade plate construct provides an alternative to the other readily available humeral plating and nailing systems. It outperforms the PHILOS plate with regards to the DASH score.

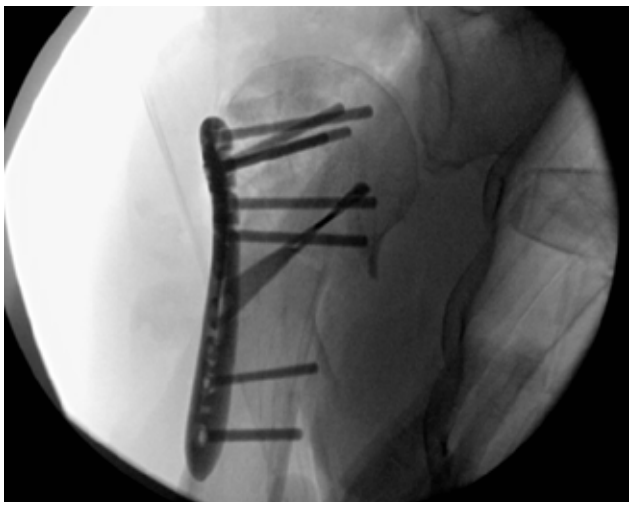
Proximal Humerus Case Study 05/29/2014
62 Right hand dominant Male



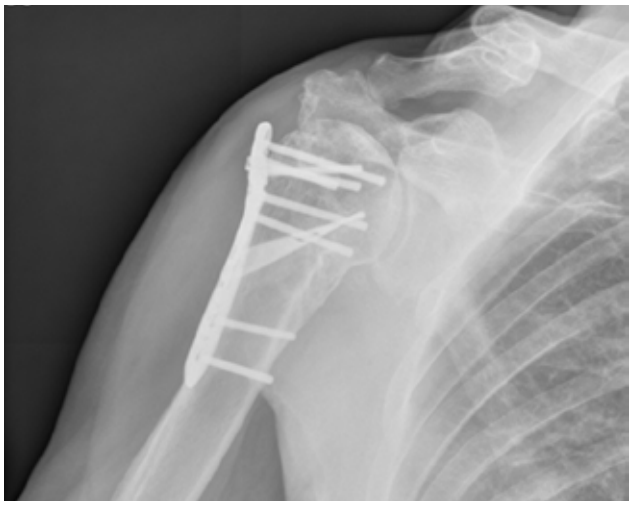








Images from Monday 08/01/2018 presented with opposite shoulder pathology. Full range of motion still working. Extremely pleased with the result. Blade plate allows remodelling around the fixation over 3 years.



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Managing Chronic Ruptures of the Achilles Tendon

Sergio Tejero, Estefanía Prada

INTRODUCTION

The Achilles tendon, the largest and strongest tendon in the human body, is nevertheless one of the tendons which most commonly suffers a complete tear[1]. Ruptures are particularly common in middle-aged men who participate in sport only occasionally. However, up to 25% of these acute injuries are misdiagnosed, and present as chronic injuries[2]. The chronic rupturing of an Achilles tendon can be defined as a rupture where diagnosis or treatment is delayed for more than 4-6 weeks[2]. Most surgeons agree that chronic ruptures should be managed operatively. The aim of surgery is to restore and maintain the length of the Achilles tendon to enable propulsive gait through the gastroc-soleus muscle complex[3][4].

PATHOPHYSIOLOGY

Retraction of the proximal stump results in shortening of the intact proximal gastrocnemius-soleus complex[5]. This reduces its biomechanical efficiency as well as the contractile force the muscle can develop. The overall effect is weakened ankle plantar flexion and hence a flat-footed, non-propulsive gait on the affected side together with a limp[6][7].

DIAGNOSIS

Diagnosis is based predominantly on medical history and clinical examination. When a patient has a chronic rupture, the pain and swelling have often subsided and the gap between the tendon ends has filled in with fibrous tissue. In addition, active plantar flexion, although weak, may be possible through the action of the tibialis posterior, flexor hallucis longus, flexor digitorum longus, and peroneal muscles. These residual functions may make it difficult to confirm the correct diagnosis through clinical examination alone. High-resolution ultrasound and magnetic resonance imaging are helpful in preoperative planning or as a diagnostic tool[6][7].

TECHNIQUE

The choice of surgical technique depends on the size of the rupture gap: defects of less than 2 cm can usually be mobilized and repaired with end-to-end anastomosis; defects of 2 to 6 cm require an Achilles tendon advancement procedure, performed as a V-to-Y lengthening, although further augmentation with a flexor hallucis longus (FHL) tendon transfer is possible in certain cases; for defects of more than 6.5 cm we use an Achilles tendon allograft reconstruction if insertion is affected by tendinopathy.

Repair involves an extensive incision on the medial-posterior calf. The sural nerve may be trapped in scar tissue after

Fig.1
Inverted "V" is marked on the midline in the most proximal portion of the myotendinous junction.

Fig.2
Lengthening of the tendon.

the rupture and should be carefully dissected and protected. A scar pseudo-tendon is frequently identified within the rupture gap, and this should be resected along with the non-viable ends of the tendon. The true tendon gap should then be measured with the knee flexed at a 30 degree angle and the ankle plantarflexed to 20 degrees, to match the resting tension of the unaffected side.

V-Y lengthening

We often use an inverted "V" incision through the tendinous portion only of the myotendinous junction of the gastroc-soleus-Achilles complex. We place the apex of the V on the midline, in the most proximal portion of the myotendinous junction (Fig. 1). In our opinion it is very important to carefully apply traction in order not to detach the tendon from the muscle. The V incision in the tendon is then repaired, creating an inverted-Y configuration. The long arm of the inverted Y is the length that the tendon has been elongated—equal to the length of the measured gap (Fig. 2). We consider augmentation when the lengthening is over 5 cm and when there is extensive tendinopathy proximal to the Achilles insertion (Fig. 3)[8].

FLEXOR HALLUCIS LONGUS AUGMENTATION

FHL transfer to the calcaneus could be considered when augmentation is needed for Achilles reconstruction after V-Y lengthening[9][10]. The FHL muscle usually extends distally down to the level of the tibiotalar joint, making it easy to identify (Fig. 4). Care must be taken to avoid injuring the medial neurovascular bundle (tibial nerve and posterior tibial artery) which is immediately medial to the FHL muscle and tendon. The tendon diameter is measured (Fig. 5), and a corresponding-sized bone tunnel is drilled into the posterior tubercle of the calcaneus directly anterior to the attachment of the distal stump of the Achilles tendon.
We create the bone tunnel with a size-specific cannulated drill bit over the Beath pin. Traction can be applied to the suture to hold the tendon within the bone tunnel at the appropriate tension (Fig. 6). The ideal tension holds the ankle at the same resting tension as that on the contralateral side. We fix the tendon into the bone tunnel using an interference screw of the same size as the bone tunnel. In our opinion, suturing the muscle belly of the FHL to the back of the Achilles tendon at the level of the Achilles repair provides a vascular bed for the relatively dysvascular level of the ruptured Achilles tendon.

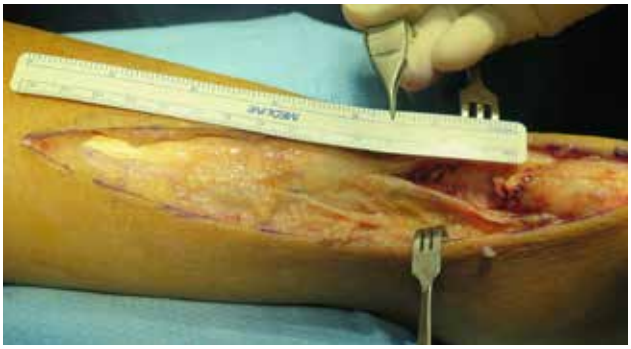

Fig.3
Extensive tendinopathy associated to a chronic Achilles rupture.

Fig.4
Dissection of the Flexor Hallucis Longus (FHL)

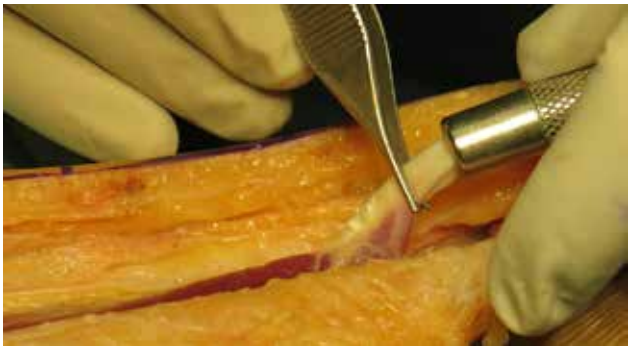

Fig.5
Measurement of the FHL

Fig.6
Traction of the FHL to measure the tension.

ALLOGRAFT

We use a bone-tendon Achilles allograft for reconstruction when the defect is more than 6.5 cm and the insertion of the Achilles tendon is affected by extensive tendinopathy (Fig. 7). The native calcaneus is prepared for the insertion of a calcaneal bone block. A microsagittal saw is used to make a quadrangular defect approximately 1.5 cm long x 1.5 cm wide x 1.0 cm deep on the footprint of the Achilles insertion (Fig. 8). The calcaneal bone block of the allograft is then cut to match the defect created in the native calcaneus in a press-fit manner. The bone block is gently impacted into the calcaneus defect until the Achilles tendon lies adjacent to the bone. We prefer not to put a screw through the allograft. The graft is then tensioned and repaired to the native Achilles tendon (Fig. 9). No formal results have yet been published for this procedure, but no rejection of the allograft has been observed and no transmission of disease to the host has been reported in the literature[11][12].

Fig.7
Extensive atrophic tendinopathy

Fig.8
Quadrangular defect created on the footprint of the Achilles insertion

POSTOPERATIVE CARE

A below-the-knee cast is put on for two weeks and the patient is encouraged to bear as much weight as possible on the operatively-treated limb as soon as they can. At two weeks, the cast is removed and a lower leg anterior splint is applied, enabling the ankle to fully plantar flex but not dorsiflex, and allowing inversion and eversion. At six weeks, the anterior splint is removed, and the patient gradually returns to their normal activities. Recovery can take as much as nine to twelve months[6] .

Fig.9
Tensioned Achilles allograft.

COMPLICATIONS

Compared with acute injuries, chronic injuries are associated with a higher rate of postoperative infection and more prolonged recovery. Plantarflexion weakness, sural neuritis, and deep-vein thrombosis are other potential complications that could appear in this context.

CONCLUSIONS

- Chronic rupture of Achilles tendon is diagnosed four to six weeks after the original injury.
- Local tissue, local tendons, and allografts can be used to reconstruct the tendon, and end-to-end repair is possible if the gap is < 2 cm.
- Compared with acute injuries, chronic injuries are associated with a higher rate of postoperative complications.

Fig.10
Achilles V-Y reconstruction and FHL to calcaneus augmentation in a 39-year-old male patient.

Fig. 11
Clinical photo 12 months after the reconstruction.

Fig. 12a
Preoperative picture of a 45-year-old patient with chronic Achilles tendon rupture.

Fig. 12b
Clinical photo 12 months after the Achilles allograft reconstruction.

Fig. 13a
X-ray (2 weeks after the Achilles reconstruction with allograft.

Fig. 13b
X-ray (6 months after).

IBRA ADVANCED COURSE LOWER LIMBS

Painful defects and injuries of the foot and ankle are among the most frequent musculoskeletal orthopaedic diseases. Their operative care always presents us with medical and technical challenges. Strategy and method, the right osteosynthesis procedure as well as the appropriate materials are crucial elements for the postoperative function of the foot and ankle, and thus for the welfare of the patients.

June 21 – 22, 2019 – London, United Kingdom

More Information: https://www.ibra.net/Events/-/2019/6

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Low-condylar fractures of the distal humerus treated with cannulated headless compression screws

Andreas Harbrecht , Michael Hackl, Kilian Wegmann, Lars-Peter Müller

INTRODUCTION

Osteoporotic fractures of the distal humerus represent a great challenge to trauma surgeons. These low-energy injuries are commonly complete intra-articular fractures with severe comminution of the capitulum. Coronal osteochondral shearing of the fragments typically results in a characteristic fracture line distal to the olecranon fossa making it difficult to reconstruct these injuries by means of double plate osteosynthesis [1, 2, 3, 4].

Facing patients with the above-mentioned fractures, a decision must be made if primary osteosynthesis can be performed or primary joint replacement is necessary. In case of an active elderly patient, open reduction and internal reduction should be aimed for whenever possible as total elbow arthroplasty requires a strict, life-long limitation of postoperative weight bearing. Preoperative counseling of the patient is crucial and has to include the possibility of intra-operative decision-making as to whether osteosynthesis is feasible or total elbow arthroplasty is required [5].

Fig.1
a) CT scan of a distal humerus fracture AO Typ 13 C3/Dubberley IIIB, left arm in sagittal, coronary and axial reconstruction.
b) X-rays six weeks after surgery sole screw osteosynthesis with cannulated headless compression screws in a.p. and lateral ray path.

Surgery is performed with the patient in a supine position. A Bryan-Morrey approach is used and the elbow is surgically dislocated to achieve best possible exposure of the articular surface of the distal humerus. In most cases, the collateral ligaments do not have to be released to achieve dislocation as both condyles are usually fractured leading to pronounced joint instability.

Common double plates do not extend far enough down to the articular surface and thus cannot be used to sufficiently reconstruct these complex fracture patterns. Open reduction can be performed by using cannulated headless compression screws instead. Fracture fragments are temporarily reduced by reduction clamps and K-wires. The K-wires are overdrilled and the appropriate length of the compression screw is measured. 4 mm should be subtracted to avoid intra-articular impingement of the screws.

The cannulated headless compression screws are inserted over the K-wire and the wire is then removed. Typically more than five screws are needed to achieve sufficient stability.

The focus during surgery should lie on the anatomic reconstruction of the medial trochlea and the lateral capitulum. Fractured pieces in the center of the joint are not as important to be reattached as long as the load-bearing radial and ulnar columns are reconstructed. Re-insertion of the collateral ligaments must be performed after the successful refixation of the fracture. Oftentimes the collateral ligaments are augmented by use of internal bracing to restore ligamentous elbow stability. In cases of pronounced instability, a hinged external fixator can be applied for primary stability and proper postoperative physiotherapy. If a fixator was primary installed in the acute fracture situation by us or the primarily attending hospital, then pins are not removed during surgery, rather simply disconnected and later reconnected as the last steps of the operation.

Anterior transposition of the ulnar nerve is usually performed. Meticulous closure of the wound is mandatory to minimize the risk of postoperative infection. Due to the poor bone quality, a careful postoperative treatment protocol is required to avoid loss of reduction.

The clinical outcome of these complex injuries is difficult to predict. However, permanently restricted flexion and extension is common with good restoration of pronation and supination [6]. In order to avoid necrosis, it is important that all fractured pieces are reattached properly to the distal humerus to achieve revascularization [7]. Necrosis is a relevant risk and the patient must be informed ahead of surgery. In those cases, secondary total elbow arthroplasty can become necessary.

The above-mentioned procedure of open reduction and internal fixation using cannulated headless compression screws represents a viable treatment option for osteoporotic distal humerus fractures in active elderly patients to avoid joint replacement.

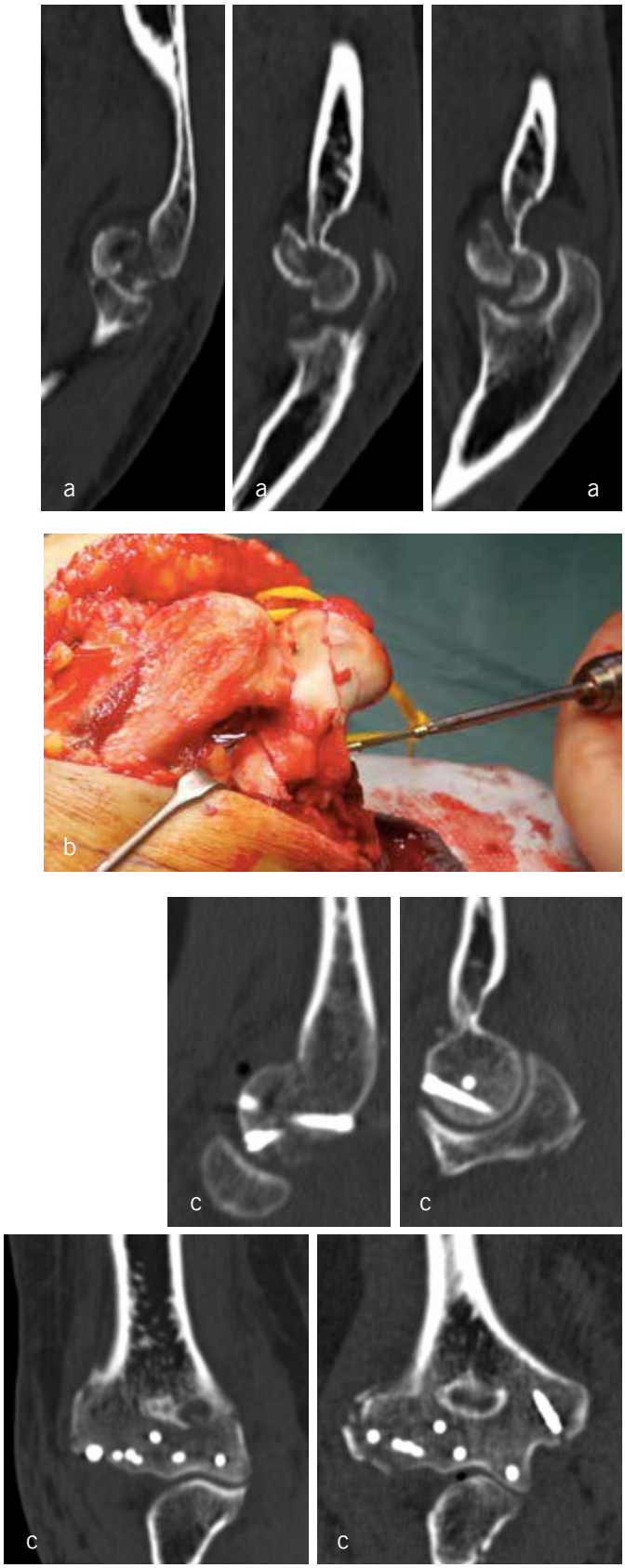

Fig.2
a CT scan of a distal humerus fracture right arm in sagittal reconstruction.
b situs view with an exposed trochlea humeri, osteosynthesis is performed with cannulated headless compression screws.
c CT scan 6 weeks after surgery sole screw osteosynthesis with cannulated headless compression screws in sagittal and coronary reconstruction.

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Fractures of the Condylar Process – Surgical Treatment Versus Conservative Treatment

Andreas Neff, Marburg

INTRODUCTION

Appropriate treatment of "condylar process fractures", which, accounting for about 25% – 35%, are the most frequent mandibular fractures, continues to be discussed controversially, but over the last two decades it has undergone crucial further developments. According to current consensus, when an indication is being established it is useful to differentiate according to fracture localization and other factors relevant to prognosis and treatment, e.g., age, displacement, dislocation and clinical picture with mobility restrictions, status of the dentition, occlusal disturbances. Last but not least, the patient's compliance and wishes have to be taken into account when establishing an indication.

While according to the current (though weakly) evidence-based study situation (RCTs and meta-analyses) the basic issue of "surgical versus conservative" for fractures with displacement and/or dislocation is nowadays regarded as having been clarified, at least for condylar base fractures and condylar neck fractures, in favor of surgical treatment, the focus of debate is now on a selection of optimal approach and the type of surgical management (type and number of plates, screws, pins, etc. used for osteosynthesis). Also, there is wide consensus that fractures in childhood (deciduous dentition and early mixed dentition phase) and condylar process fractures with minimal displacement or none at all (height loss less than 2 (-4) mm) are best managed with primary conservative treatment after completion of the mixed dentition phase. While conservative treatment of relevantly displaced and/or dislocated fractures usually aims for an outcome that is as "satisfactory" as possible, with functional adaptation by remodeling, surgical management aims to achieve comprehensive restoration of anatomical and physiological articular function with as few complications as possible. Different fracture locations call for differentiating osteosynthesis methods that relate to the particular site and approaches that are optimally matched to them. Since condylar process fractures are thus no longer subjected to generalized conservative treatment, "according to standard", so to speak, in a differentiating surgical procedure the therapeutic requirement nowadays is to select from the many different methods available the best one for the individual case, which can vary enormously. The basic aim of surgical treatment should be restoration of full function in as short a time as possible, with few complications, and with minimal traumatization of tissue.
The topic area "fractures of the mandibular condylar process" is designed to enable those who have to deal with condylar fractures to assess indications for surgical/conservative fracture management according to current standards and provide an overview of the now commonly used surgical procedures and approaches, relative to the different condylar process fracture locations, including the associated complications, pitfalls, and risks.

CLASSIFICATION

The classification of condylar process fractures (cf. Tab. 1) is characterized by a large number of competing and ambiguous classification proposals, so generally speaking, "nomenclatorial chaos" prevails, especially in an international context. Based on therapeutic and prognostic aspects the following are criteria that are recognized as being relevant for classification:

- Localization of the fracture
- Type of displacement
- Type of dislocation
- Fragmentation (none, minor, major)

In order to standardize the hitherto highly unstandardized fracture localization definition criteria, according to current European consensus (shared by SORG, AO, and IBRA) fractures are classified as condylar base, condylar neck, and condylar head (Fig.1).

The specifying localization of a condylar fracture acquires therapeutic importance when it comes to the selection of osteosynthesis and approach because condylar neck fractures proximal to the base of the condylar process are, judging from experience, more accessible to surgical

management than fractures of the higher (juxta-articular) condylar neck. Condylar head fractures are currently divided up into fractures with vertical loss (previously types B and C) and ones without (previously type A). (Fig.2)

In addition, condylar process fractures are also split up into fractures without displacement, fractures with displacement, and dislocation fractures, in which the condylar head has left the articular fossa (Tab. 1). In the case of displaced fractures of the condylar neck and the condylar base the small fragment often rotates in an anterior direction due to pulling of the lateral pterygoid muscle, and usually also deviates to medial. The fracture surface of the small fragment is usually lateral to the large fragment, and more rarely medial to the large fragment (the latter especially in the case of neck fractures). If the condyle-to-fossa relationship is canceled out, albeit with largely intact capsules and ligaments, this is referred to as a pseudodislocation fracture.
With dislocation fractures of the extracapsular region of the condylar neck the condylar head completely leaves its socket with the articular capsule tearing apart, and in this case the tissue trauma correlates with increasing depth of the course of the fracture. Here the most frequent type is dislocation toward medial.

With all condylar process fractures that involve displacement or dislocation, the large fragment is displaced through the loop of the masseter and medial pterygoid muscles toward cranial and dorsal because vertical support is lost in the joint. Consequently, there is bound to be a reduction in the vertical height of mandibular ramus (Fig.3). For an up-to-date, radiologically accurate description and classification of condylar process fractures based on the above criteria, see www.aofoundation.org/aocoiac and references.

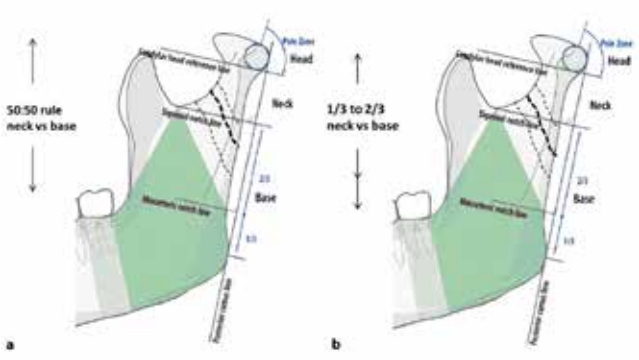

Fig 1: Classification of condylar base and neck fractures according to AOCOIAC
(open source and Neff et. al. 2014, Craniomaxillofac Trauma Reconstr)
a) SORG classification 2005 with 50:50 rule at Loukota's line
b) AO/SORG/IBRA classification 2014 with 1/3 to 2/3 rule with regard to the Loukota line defining neck (at least 1/3 above) vs base fractures (at least 2/3 below Loukota's line).

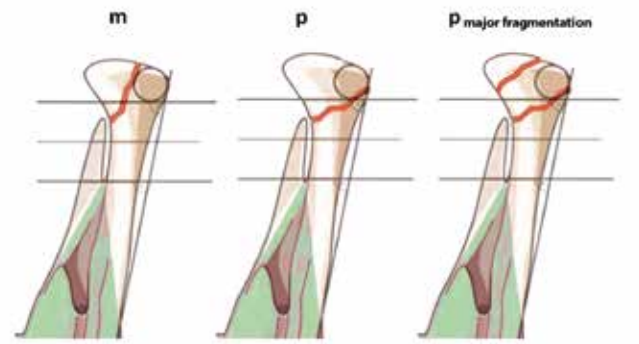

Fig.2: Classification of condylar head fractures according to AOCOIAC
(open source and Neff et al. 2014 Craniomaxillofac Trauma Reconstr)
left hand side: head fracture type m medial to the pole zone without loss of vertical height.
middle part: fracture type p within or lateral to the pole zone with loss of vertical height.
right hand side: major fragmented fracture, combination m and p, the fracture is defined according to the most distal fracture line p.

Fig.3: Trifocal mandibular fracture with median fracture and loss of vertical height due to bilateral condylar base fractures with sideward displacement. Note fragmented fracture at the posterior border left hand side, defining a major fragmentation.

To establish an appropriate indication it is now essential to conduct three-dimensional imaging, e.g., using computed tomography with an axial and coronal beam, or dental volume tomography as the diagnostic method of choice. For preoperative planning, 3D representations and the orthopantomogram (height of the fracture) are helpful.

PRINCIPLES OF CONSERVATIVE (NON-SURGICAL) TREATMENT

Traditionally, conservative fracture treatment is chiefly based on splints or archbars, and subsequent mobilization or - especially in the case of fractures with direct joint involvement - also primary functional treatment is usually classified as conservative. Activator treatment, in the form of exclusive functional therapy, usually takes three to six months for fractures of the mandibular condyle, and longer periods are possible. It is easy to appreciate the long duration of treatment considering the destruction of tissue in condylar fractures. Especially in the case of juxta-articular fractures it is always preferable to conduct active mobilization at an early stage in order to prevent immobilization damage. The most feared complication, especially in fractures with direct joint involvement and in dislocation fractures, is ankylosis, scarred fixation or bony fusion of the two juxta-articular fragments, which is particularly observed in the case of children and inadequate functional treatment.
Conservative fracture treatment employs various splint and wire ligatures chiefly attached to the teeth, and prosthetic splints are not so common nowadays; the use of a hypomochlion is controversial and not evidence-based. The treatment objective is to establish normal occlusion. In conservative treatment the maxilla and mandible are provided with a splint or archbars (Fig.4) and initially immobilized by mandibulomaxillary fixation (MMF) or intermaxillary fixation (IMF) and then mobilized with slack elastic rubber cords. This immobilization therefore approximately corresponds to conservative treatment of other mandibular fractures, whereby the duration of (previously usually rigid) mandibulomaxillary fixation was reduced continuously.
The previously common, generalized reference to a period that was binding for all condylar process fractures, however, would appear to be of little use. On the contrary, the duration of rigid fixation must relate to the individual case and be oriented toward localization (capsular involvement/juxta-articular versus abarticular) and toward individual fracture geometry/fragment contact so it varies between immediate mobilization/short-term immobilization over a period of one to a maximum of two weeks for juxta-articular and dislocated fractures, and about three to basically up to six weeks (by analogy with corpus fractures) for, e.g., low condylar base or ramal fractures with an intact condyle-to-fossa relationship. The basic rule here is that immobilization damage in fractures with capsular involvement must be avoided by introducing mobilization as early as possible.

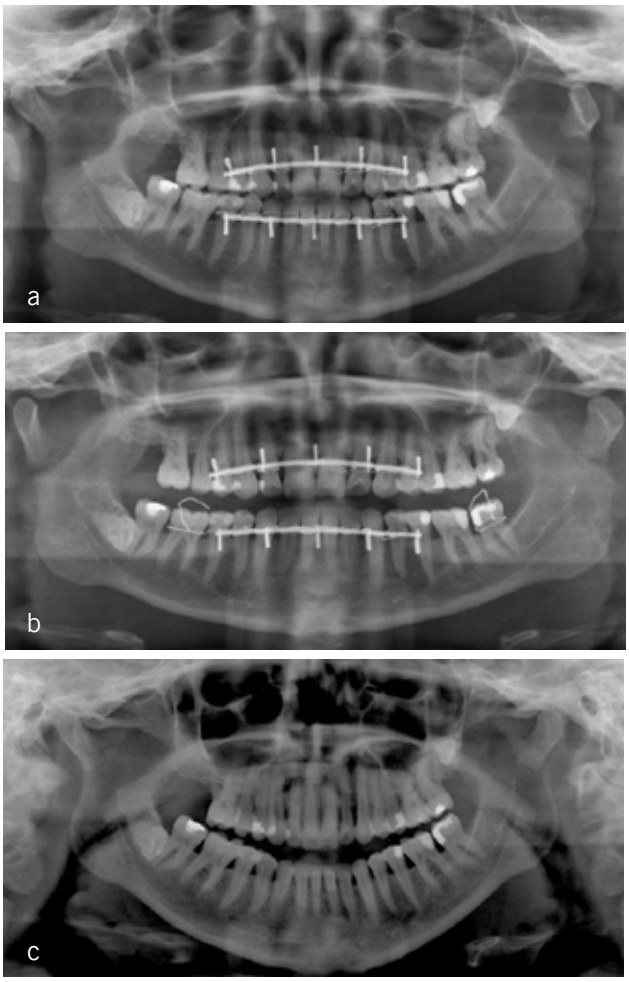

Fig.4: Bilateral condylar fracture treated conservatively
a) by MMF and archbars
b) after release of MMF premature posterior contact and anterior open bite, so bilateral hypomochlion (see wire ligatures) for distraction and again MMF to compensate for vertical loss
c) fractures healed in malposition with consecutive open bite deformity (posterior molar contact only).

TREATMENT PRINCIPLES OF SURGICAL FRACTURE MANAGEMENT

According to review literature, irrespective of fracture localization there is always an indication for surgical management in the case of vertical dimension instability, i.e., basically with all relevantly displaced/dislocated fractures (the degrees of angulation and height reduction that used to be applied as indication criteria now only play a subordinate role accordingly, representing a parameter that merely provides orientation). However, if there are no relevant occlusal disturbances, only minimal symptoms, and an acceptable range of motion, it is possible to adopt a primary expectant, conservative early functional procedure.

The situations that used to be cited as relative surgical indications now tend to be regarded as confirmed indications:

- if there are also mid-face fractures and no vertical support is provided via the mandibular joints;
- if there are medical grounds that would not justify mandibulomaxillary fixation;
- in the case of bilateral condylar process fractures, including ones of an edentulous mandible;
- if there are other fractures, especially of an edentulous or inadequately dentate mandible.

The healing process depends not only on accurate fragment reduction but also on other individual factors, especially fracture localization, the occlusal situation, any pre-existing degenerative joint diseases/discopathy, and, last but not least, postoperative muscular activity on the part of patients (e.g., bruxism, forced mouth opening training, etc.). In this context, different fracture localizations require not only different osteosynthesis methods but also differentiating treatment methods and approaches that relate to the individual fracture site. For surgical management it is possible to consider a large number of different methods; systems are subject to ongoing further development, and especially for condylar base fractures there is a wide range of special reinforced condylar plates and 3D plates available to cope with the high biomechanical loading conditions in the condylar region. Plate position aims to ensure three-dimensional stabilization of tension lines (gapping, bending, torsion) both at the rear margin of the articular process and parallel to it, as well as another one toward the sigmoid notch, whereby at least two screws should be anchored in the proximal fragment. Single plate osteosynthesis usually no longer meets the biomechanical requirements. 3D plates allow good stability while reducing the number of screws required for the proximal fragment.

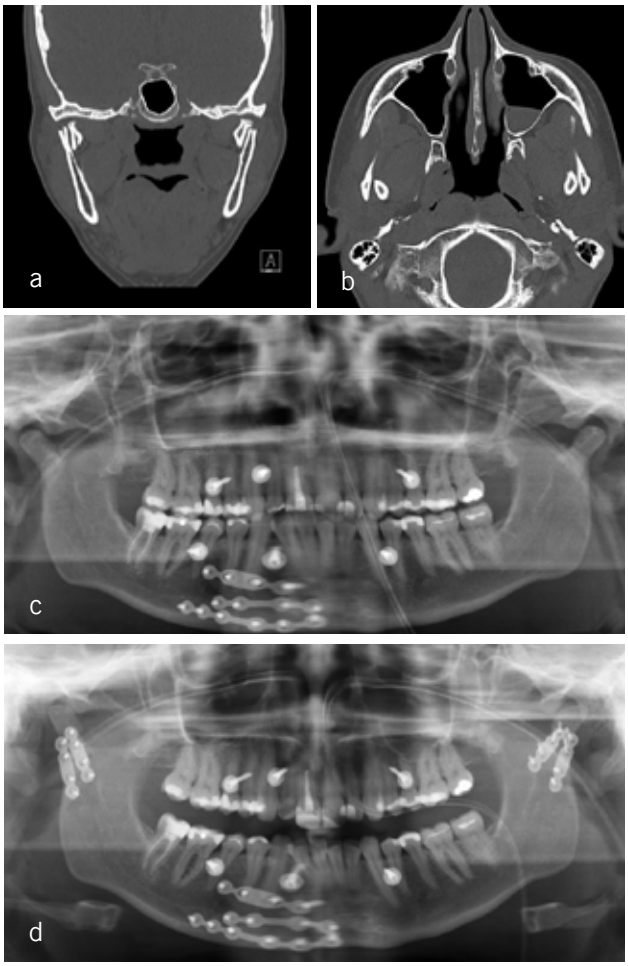

Fig.5: Case series bilateral condylar neck fracture, surgically treated by ORIF
a) medially displaced condylar neck fractures bilaterally, CT coronal view preop
b) CT axial view preop
c) OPT preop after ORIF of the paramedian fracture right hand side
d) OPT control after ORIF via transparotid approaches with angular stable reinforced double plates (Trilock condyle plates)

Overload-induced fatigue failure of osteosynthesis materials occurs especially following imprecise reduction (often as a result of inaccurate plate adaptation) and resorption at the fracture surface. The latter in turn is attributable to insufficient stability, often exacerbated by the absence of callus formation where the condylar process is very slender and interfragmentary support is minimal. As limited exposure and visualization in this highly challenging area quite frequently represent an obstacle to precise adaptation of the plates to the bone, locking plates therefore offer their potential advantages especially in the condylar process region, as they can compensate for this essential drawback associated with conventional plates (Fig.5).

Titanium miniscrews, titanium small fragment screws (1.8mm) (Fig.6 + 7), and monocortical or cannulated lag screws are mainly used nowadays to stabilize fractures of the condylar head. While load-bearing use of microplates or miniplates is not to be recommended considering biomechanical and functional aspects, resorbable pin systems (2.0mm) and newly introduced magnesium screws (2.7mm) have also been used recently in order to avoid otherwise urgently recommended metal removal in the capitulum region. In contrast to titanium screws, which have been followed up over longer terms (> 5 years), however, no long-term follow-up data are available so far for resorbable materials and also some unfavourable intermediate results have been reported.

APPROACHES TO THE HIGH CONDYLAR PROCESS AND CONDYLAR HEAD REGION

Surgical approaches for high condylar neck fractures and condylar head fractures are the traditional approaches to the mandibular joint region (preauricular and retroauricular approaches, possibly the transparotid or anteroparotid approach). For condylar neck fractures and multiple fractures it may be useful to apply a combination, e.g., with a retromandibular or transparotid/anteroparotid approach or for lower neck and base fractures preferably an angular/high submandibular approach.

COMPLICATIONS

One relevant complication is injury to the facial nerve during surgical management of condylar process fractures, especially - but not exclusively - via an extraoral approach. The marginal branch (angular and retromandibular approaches (Tab. 2) or the frontal branches (preauricular and retroauricular approaches (Tab. 3.) are usually affected, whereas the zygomatic branches are more at risk in the case of anteroparotid/transparotid approaches. While the risk of permanent lesions to the seventh cranial nerve is classified as relatively rare (i.e., less than 1%), the rate of temporary palsies is cited, depending on experience, as having a high variable frequency between 0–48% (angular / retromandibular approach) and 0–30% (retroauricular / preauricular approach) respectively. According to a recent meta-analysis (Al Moraissi et al., 2018) the angular approach with lesion rates below 1% has to be rated as the most favorable, at least for basal fractures and deep neck fractures.

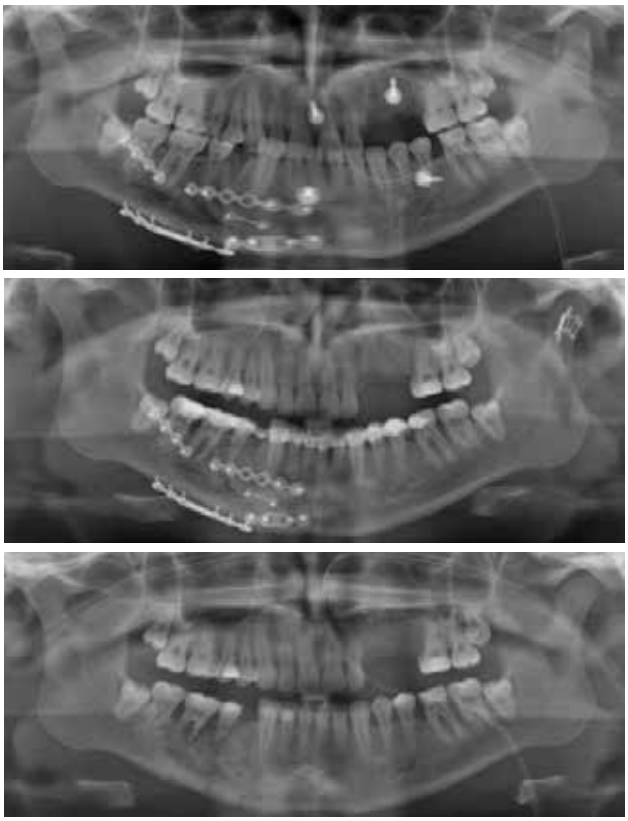

Fig.6: Case series condylar head fracture left hand side and multifragmented fracture mandibular body right hand side, ORIF with two positional screws and microplate osteosynthesis (middle, cf. also Fig.7). After removal of osteosynthesis material (bottom) the condylar head left hand side is restored to normal configuration and function. Please also note osteomyelitis sicca and bone loss in the area of tooth 46 (first molar right hand side), which was in direct contact with the multifragmented fracture.

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However, hook pull induced deficits in the facial nerve are quite frequently also reported for an intraoral approach. Rare instances of Frey's syndrome and more so postoperative sensory disturbances following osteosynthesis in the condylar process region, which, to a varying extent, are reported in up to 40% of patients, also have to be taken into consideration. Other relevant sequelae are persistent occlusal disturbances, especially following conservative treatment, and immobilization-induced restrictions of mandibular mobility, whereby it is translation capacity that is usually affected. This is also reported following unstable surgical fracture management because only if there is capacity for exercise can mobilization of condylar process fractures take place as early as possible. The aim of efficient physiotherapy is therefore to minimize immobilization-induced scarring, which can have a detrimental effect on postoperative articular function. Compliance on the part of the patient then remains one of the other factors that are crucial for restoration of physiological range of motion.

SUMMARY

By tradition, the management of condylar process fractures is discussed controversially but over the last two decades it has undergone crucial further developments. While conservative fracture management was clearly dominant well into the 1990s, this place is increasingly being occupied by surgical treatment, which is now well confirmed by appropriate evidence. Nowadays the chief objective of successful treatment is no longer primarily muscle-guided adaptation while keeping the occlusal relationship as correct as possible, whereby fracture healing in misalignment is usually accepted. On the contrary, according to the current standard, comprehensive functional, skeletal, and esthetic restoration has to be achieved using preferably atraumatic procedures without encumbering patients with long immobilization times. This development is based not only on increased expertise in the various surgical approaches to the condylar process region but also on crucial improvements in osteosynthesis methods and materials, the use of endoscopically assisted procedures, and improved biomechanical understanding of this fracture localization, which usually involves challenging surgery.

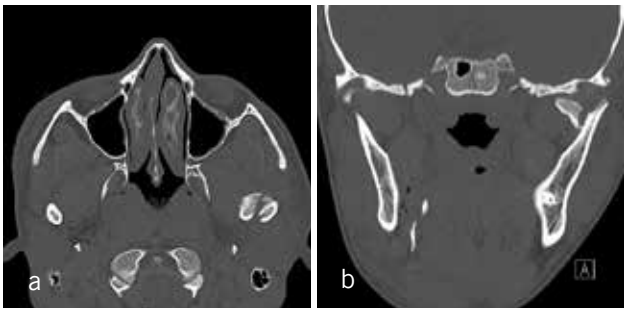

Fig.7a, b: Case series of figure 6 continued: preoperative situation left condylar head fracture type p with displacement and vertical loss , a) CT axial view; b) CT coronal view.

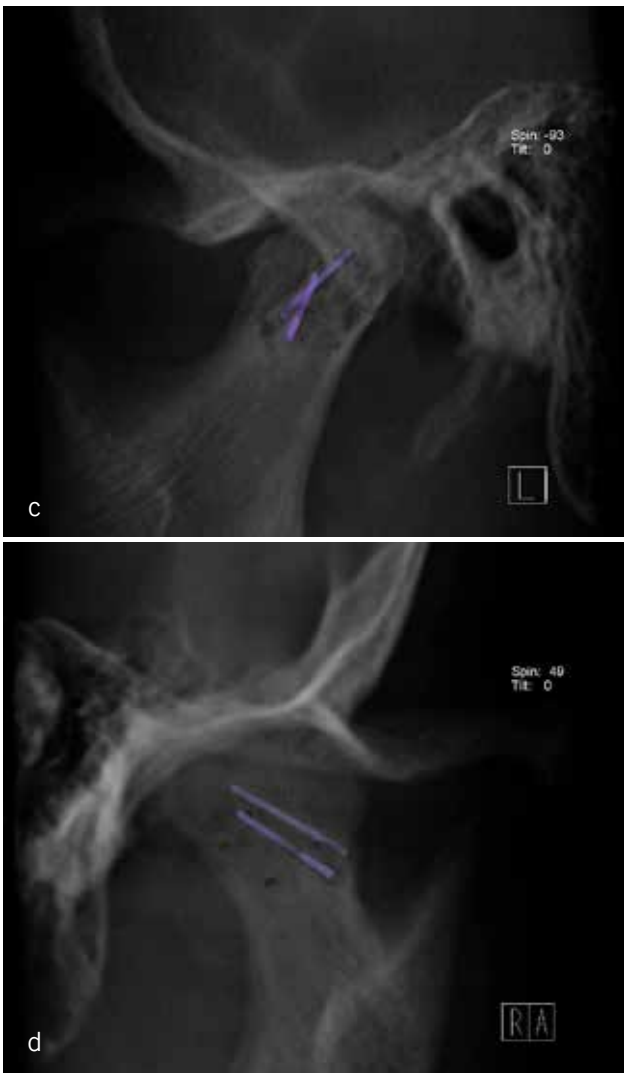

Fig.7c, d: Case series of figure 6 continued: postoperative control (3-D cone beam CT) of the positional screws and microplates c) ap-view d) lateral view shows good alignment and restoration of vertical height.

TABLES:

TAB. 1: CLASSIFICATION OF COLLUM FRACTURES BY SPIESSL AND SCHROLL

Typ	***Definition***
I	*"Collum fracture" without any major dislocation, deep or high*
II	*"Deep collum fracture" with dislocation*
III	*"High collum fracture" with dislocation*
IV	*"Deep collum fracture" with luxation*
V	*"High collum fracture" with luxation*
VI	*Capitulum fracture*

TAB. 2: SURGICAL APPROACHES TO THE CONDYLAR BASE AND TO THE JUXTA-BASAL CONDYLAR NECK

Approach	***Year***	***Author/Description***
Intraoral (transoral)	*1980, 2002*	*Pape et al., Mokros et al.,Schönet al.*
Submandibular	*1924, 1934*	*Perthes, Risdon*
Angular, high submandibular	*1993, 1999* *2006*	*Rasse, Eckelt* *Meyer et al.*
Retromandibular	*1995, 1996*	*Ellis III, Chossegros et al.,*
Retromandibular-transparotid	*2003, 2005,* *2005*	*Manisali et al.,* *Vogt et al., Vesnaver et al.*
Transmasseteric anteroparotid and transmasseteric transparotid	*2005* *2009*	*Wilson et al.* *Downie et al.*
Anteroparotid	*2009*	*Tang et al.*

TAB. 3: SURGICAL APPROACHES TO THE MANDIBULAR JOINT (CONDYLAR HEAD AND HIGH NECK)

Approach	***Year***	***Author/Description***
Preauricular	*1925, 1934,*	*Lindemann, Nieden,*
	1979	*Al-Kayat & Bramley*
Preauricular retrotrageal	*1944*	*Dingmann*
Endaural transtrageal	*1954, 1956*	*Rongetti, Davidson*
Auricular (temporally extended)	*1992*	*Rasse*
Retroauricular	*1920, 1931, 1987*	*Bockenheimer, Axhausen, Kreutziger*
Perimeatal (extended to retroauricular)	*1978*	*Eggleston*
Transparotid	*2015*	*Shi et al.*

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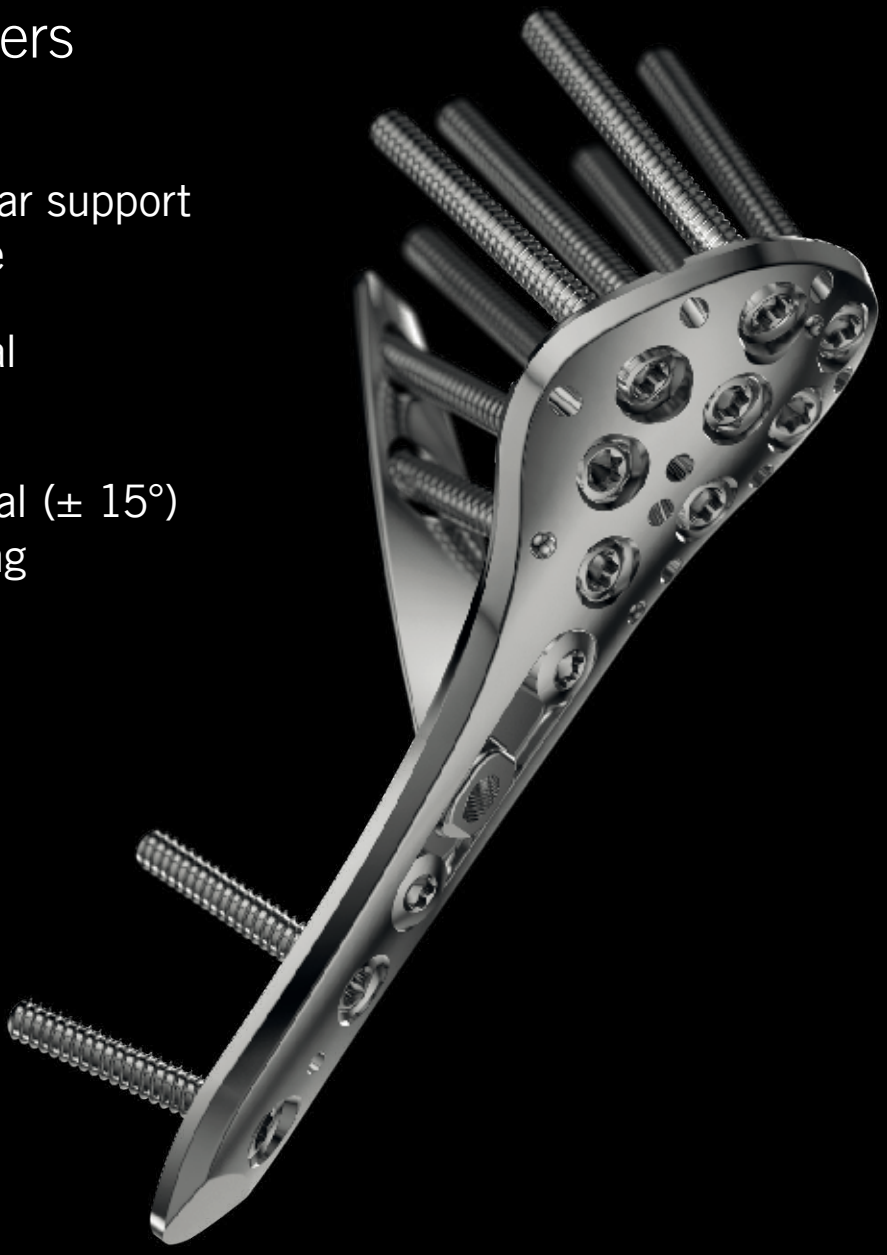

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